

*Second World Congress on
Safety of
Transportation*

18-20 February 1998

Prof. S. Hengst

Prof. K. Smit

Dr. J.A. Stoop

editors

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Second World Congress on
**Second World Congress on
Safety of Transportation**

Imbalance between Growth and Safety?

Edited by:

A. Bengt

K. Smith

J.A. Stoep



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Second World Congress on
Safety of Transportation

Imbalance between Growth and Safety

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J.A. Stoop



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Imbalance between Growth and Safety

Edited by

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Participants:

Steven de Vogel, *Editor-in-Chief Dutch Television*

Eric Nalder, *Chief Investigative Reporter*

Jan Dirk Blaauw, *Member of the Dutch Parliament*

Marcel Haegi, *Chairman European Federation of Road Traffic Victims*

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Preface

In transportation, safety is a key issue. Delft University of Technology understands the importance of the subject because four conferences, on Maritime Safety & Environment/Ship Production, on Aviation Safety and two on Safety of Transportation were organized during the last five years.

On 18 - 20 February 1998, the Second World Congress on Safety of Transportation was hosted by the Delft University of Technology. About 275 people from 29 countries and all modes of transportation listened to 18 keynotes, discussed over 70 papers, participated in 6 Round Tables and a closing plenary discussion. Participants were coming from industry, policy making, safety boards, research institutes and victim organisations.

Following the First World Congress on Safety of Transportation, the International Transportation Safety Association ITSA was founded. Simultaneously, an international non-governmental organisation was founded; the European Transport Safety Council ETSC. This network of experts participated in the organisation of the Second World Congress on Safety of Transportation.

We feel honoured that this second congress has had the support of prominent politicians from the USA and European countries. We are grateful to our sponsors who made this congress on Safety of Transportation a success. Their active substantive participation was encouraging and revealed market niches for knowledge development. Their financial support made it possible to realize this second congress on a world scale.

The theme of the congress 'Imbalance between growth and safety?' proved to be appealing to policy makers as well as transportation market partners. In his letter to the participants, Vice president Al Gore called the theme of the congress -improving safety as we forecast continuing transportation growth- right on target. European Commissioner Neil Kinnock mentioned many reasons for ensuring that safety and growth are made compatible.

Annemarie Jorritsma, the Dutch Minister of Transportation and Public Works rephrased the theme in a Shakespearean manner by stating: 'Imbalance between growth and safety... that is the question'. The congress showed also an increased involvement of societal parties such as national and international victims organisations. The Second World Congress has therefore given a further impulse to broaden the global network for cooperation in safety of transportation.

After the congress the chairman of ITSA, Pieter van Vollenhoven, requested the Delft University of Technology to take the lead in setting up a research centre for safety of transportation. Such a centre should be the beginning of a network of research institutes to cooperate with Transportation Safety Boards in various countries. The foundation of this centre will confirm the relations which are established between the Delft University of Technology and the international community of Transportation Safety Boards.

The scientific level of the contributions was high, participants came from all over the world, the number of participants grew, the theme was right on target, the societal participation increased. The Second World Congress on Safety of Transportation was successful. The next congress will even be better.

We trust to meet you again on that occasion.

Sjoerd Hengst
Chairman of the Organizing Committee

Editorial

During the congress the theme "Imbalance between growth and safety?" was elaborated in three phases to give the participants a modality orientation with a common learning knowledge.

The first day focussed on the international context in all modes of transportation. The key note speakers from ITSA, ETSC, IMO and ICAO highlighted institutional aspects, safety issues and concepts. Emphasis was on feedback systems for information and knowledge exchange between modes on the regulatory and supervisory systems levels. During parallel sessions issues in each of the modalities were discussed regarding regulatory and supervisory methods, social and economical aspects, enforcing regulations, data handling and accident investigation.

The second day, the needs and requirements within each modality, with an emphasis on an industrial view on safety issues were covered. Key note speakers defined issues as perceived from each modality. During specific parallel sessions for modalities, contributions on human and technical factors were presented. Parallel sessions covered new issues, technologies and design methods, evolution of safety boards and risk decision making from a user, manufacturer, institutional or social point of view. Each modality discussed its priorities and preferences during Round Table sessions. The common elements and notions between the modes were derived from the discussions and defined as lessons learned.

The third day focussed on learning, irrespective of modality, to investigate the potential of an international research agenda. Key note speakers elaborated on the feedback and feedforward loops in the transportation systems with an emphasis on accident and incident investigation experiences. In parallel sessions feedback and feedforward learning, building partnerships, knowledge infrastructure and future trends in technology were discussed. Politicians, journalists and victim organisations finally debated research topics and notions presented by policy makers, legislators, industry, researchers and the safety board community.

The issue of an imbalance between growth and safety was adressed again during the closing session. The need for a frog leap improvement of safety targets to keep in pace with new and major developments in transportation was noticed by professor Klaas Smit. Safety should be included in operational practice to prevent that cost-marginal operational conditions overrule other performance parameters. Quality must incorporate punctuality, efficiency, safety and environmental aspects to balance decision making in all phases of the transportation chain.

The transport of hazardous material by rail and shipping may serve as an example how to manage safety during distribution and transportation in an integrated chain concept, applying production safety as a reference. Investigation methods should be developed to improve transparancy of the systems performance. Accident analysis should be supplemented by incident reporting and analysis as early warnings of poor systems

performance. To deal with substandard performance, identification of risky carriers in aviation and substandard vessels in maritime transport should be stimulated, to improve safety performance. Human factors and ergonomic designs can be improved through simulator applications and operator training facilities as being used in aviation and shipping.

Last but not least, victim care and family support activities should be encouraged to deal with social aspects and safety perception of the public as well as users in all modes of transportation.

Five issues for further research and development emerged.

- Investigate a systems engineering approach to safety for each mode of transportation. This should include hardware, software as well as personnel. A system encompasses transport equipment, infrastructure as well as traffic control and deals with all life cycle phases of the system.
- Investigate safety assurance systems, facilitating accident and incident analysis. Technical, operational issues as well as tactical and strategic aspects should be considered to make safety an objective, elaborated into quality programmes, supported by management commitment.
- Investigate a structured and integrated "design for safety" approach to develop equipment and infrastructure, considering the characteristics of the different modes. Quantitative targets applying risk and safety models should be developed, based on numerical input from accident and incident data bases. Decision making may then be based on quantitative cost-benefit considerations.
- Investigate the possibility to build partnerships between stakeholders and actors. The role of independent Transportation Safety Boards may facilitate the collection of information and the exchange of experiences between national bodies, research institutes, universities and other centers of knowledge.
- Investigate the potential of intermodal approaches with respect to safety improvements. Which lessons can be learned from other industrial branches with high safety levels, e.g. process industry, power supply and offshore. Are their approaches more general applicable with respect to chain concepts, design methods, safety management systems and public perception.

New players appeared in the debate. At the Second World Congress a new international trend emerged in the development of victim organisations. In the USA the NTSB received additional legal mandate to organise family support for aviation crashes, in Scandinavia maritime accidents have led to self-organisation of victims and relatives, while in road safety the European Federation of Road Traffic Victims FEVR has been founded. These victim organisations represent a new category of stakeholders in the debate about safety of transportation. Their voice will be frequently heard in the future on international congresses. Their input is adding a new dimension to the interest of safety of transportation.

Sjoerd Hengst

Klaas Smit

John Stoop

Editors



THE VICE PRESIDENT
WASHINGTON

February 13, 1998

International Transportation Safety Participants
Second World Congress
Safety of Transportation Conference
Delft University of Technology
The Netherlands

Dear Conference Participants:

Although I cannot be with you today, I want to welcome you as you gather together to discuss new developments and challenges to make transportation safer worldwide. I am impressed by the stellar credentials of this conference's presenters and participants, and the depth of the agenda. Not only will you share information about technological advances in all modes of transportation, your discussion groups and panels will be essential to translating this knowledge into concrete safety advances; and that translates into saving lives throughout the world.

I am especially pleased that one of your keynote speakers is National Transportation Safety Board Chairman Jim Hall. Jim is a personal friend and has done an exemplary job of leading the NTSB during the past several challenging years.

As you know, many opportunities face us as we move toward the 21st Century. To take advantage of them, we must develop the technological and human factors expertise to implement safer solutions to our expanding and changing global transportation needs. That's why the theme of this Congress -- improving safety as we forecast continuing transportation growth -- is right on target.

We must further our knowledge and understanding so that all of us, no matter in what corner of the world we live, help make sure that innovative ideas and improvements are shared by everyone - including those in government, academia, industry and the private sector. Together we can reach our common goal of providing transportation to more and more people and, at the same time, improving the accident rate.

I encourage all of you to take full advantage of this occasion to implement positive change. Please accept my best wishes for a productive and enthusiastic conference.

Sincerely,

Al Gore

Opening Address

Neil Kinnock

European Commissioner for Transport and Transeuropean Networks

I regret that other work prevents me from joining you at this Second World Congress on the Safety of Transportation, but I'm grateful for this opportunity to speak to you, before you begin what I'm sure will be an interesting and challenging few days.

The title of your Congress directly addresses the issue of whether there's an imbalance between growth and safety and I note that it's phrased as a question. I don't intend to try to pre-empt your discussions, but it might be useful if I briefly outline the action which we are taking in the European Union to try to strengthen safety in transport against the background of the growing volume of movement.

Transport obviously is the lifeblood of modern economies and economic growth is both a cause and a result of the increasing transport activity. For all of the plain humane reasons and because of basic economic considerations therefore, transport safety has to be regarded as a pre-requisite of transport efficiency and sustainability. In the Commission and in conjunction with the Member States we consequently seek to make safety a central ingredient of all of the policy initiatives to which it could apply. Last year, for instance, I was pleased to launch a Europe-wide action program for promoting road safety which will run until 2001 and follow a triple strategy which involves first an up to date analysis and improving the gathering and dissemination of information and best practice on road safety. Secondly undertaking promotional measures to try and stop accidents happening and putting particular emphasis on the human factor, both to secure improvements in behaviour and to try to create circumstances which are likely to reduce errors and thirdly actively encouraging changes in road infrastructure and vehicle design, which will reduce the consequences of accidents.

Meanwhile there's a body of law being applied and in preparation to increase safety levels in road traffic with provisions that vary from higher standards of maintenance to the introduction of a digital tachograph. When 45,000 people are still dying in road accidents in the European Union every year, these and other developments are of course vital to reduce the number of tragedies and to reduce the huge direct costs of about 45 billion ECU, around 49 billion dollars, which they generate every year.

In civil aviation the European Union has a relatively good record with 30% of the world's air traffic movements and just 10% of total accidents. There is however no complacency. A Commission proposal for a law establishing safety assessment of Third Countries aircraft using community airports will probably be adopted by the Council of Ministers before the end of the year. Our proposals for the establishment of a European aviation safety authority have been published and are being considered by the Member States and other future initiatives will deal with the collection and exchange of information on incidents in order to help efforts to improve the prevention of accidents.

In shipping the Commission began to implement at common policy on safe seas in 1993 with the strategy that was due to last until 2001. I'm pleased to say, however, that good progress has been made and the program is almost completed. Compliance with international legislation on training and qualification of sea ferries, on the management of shipping companies and on many other aspects of improvement on safety are now in force. And we've also ensured the application of latest technology for a safer flow of traffic.

Of course there's still more to do in our efforts to try to achieve the highest level of safety for people vessels and the environment that the sea will allow. And that's why I recently launched the Europe-wide campaign to promote quality shipping with maritime safety as a central objective. Our purpose is the eventual elimination of substandard shipping which is a menace to everyone and of course a source of grossly unfair competition to the owners and the shippers who do fulfil safety requirements. In maritime transport as in every other mode, our view is that there really can be no justification for compromising on safety. The well-being of people, the security of the environment, the efficiency of movement and the considerations of real cost produce a mixture of substantive political, moral, economic and commercial reasons for ensuring that safety and growth are made compatible.

I'm sure that people attending this conference share that conviction and want to apply it in practice and I consequently wish you all a very fruitful meeting. Thank you for listening.

Opening of the Second World Congress on "Safety of Transportation"

Karel F. Wakker

Rector Magnificus, Delft University of Technology, The Netherlands

Ladies and gentlemen,

Good morning and welcome at the start of the Second World Congress on Safety of Transportation. In particular, I like to welcome Mr. Dubbeld, Director Transport Safety of the Ministry of Transport, Public Works and Water Management, Mr. van Vollenhoven, Chairman of the International Transportation Safety Organisation, and Mr. de Croo, Chairman of the European Transport Safety Council. Of course, I also welcome the other speakers of this congress; they will share with us their thoughts and experiences on various relevant topics, and they will inform us about the latest developments and ideas in the world of transportation. To all of you, I would like to say that we are proud that you have decided to attend this congress, which is organized by Delft University of Technology, in close cooperation with the Erasmus University Rotterdam, the International Transportation Safety Association and the Dutch TRAIL Research School for Transport, Infrastructure and Logistics. We are very happy to host so many foreign guests at Delft.

Ladies and gentlemen, human mobility and transportation in general are vital elements of our modern society and are of crucial importance to our economy. However, at the same time, we realize that transportation poses some dangers to our society. It contributes to the pollution of our environment and every year many accidents on the roads, in the rivers and in the air result in substantial material damage and a loss of many lives. As you all know, our country wants to position itself as a "distributing country" and "a gateway to Europe". To fulfill this mission, it is essential that all modes of transportation are safe and of high quality. As it may be assumed that transportation will expand significantly over the next decades in the growing Dutch economy, it becomes even more important to minimize the negative aspects of transportation: the threats to our environment and the safety issue. This brings us to the theme of this congress: "Is there an imbalance between growth and safety?"

Representatives of the various partners and stakeholders involved in the transportation business will address this question. Of course, they will have different perceptions of the topic of safety. Therefore, we think that it is very important to exchange information and experiences between all those involved, from the builders of various transportation vehicles to politicians and representatives of victim organizations. We think that we should exploit all information available, both to reach a better understanding of the various points of view and to be able to design, develop and operate safer transportation systems.

We all agree that safety is important. But we know that individuals perceive and discuss "safety" from various points of view. The man in the street does not like the factor "risk". He wants transportation systems which are one-hundred percent reliable and safe. However, technicians know that each system has a certain accepted inherent risk and that it sometimes fails. They also know that these failures may sometimes be catastrophic and may lead to casualties. As our transportation systems become larger and larger, the consequences of catastrophic failures become immense. Consider, for instance, the introduction of the new "super-jumbo" aircraft, designed to carry a thousand passengers or so. Obviously, new ways of dealing with the safety-issue have to be introduced. On the one hand, we have to learn to live with the factor "risk", and to accept that there is always a chance of failure. On the other hand, we have to implement new design procedures, which significantly increase the reliability of the transportation system and which limit the consequences of a failure as far as possible. However, we should realize that safety can suffer from a balancing of conflicting interests. A conflict between safety versus efficiency, costs, environment and growth. That balancing takes place in a rapidly changing world of globalization, growth, privatization and technological developments on the one hand, and of increased complexity in international legislation, policy making and spatial planning decision making on the other hand.

Given this context, it is clear that it is no longer sufficient to learn from "proven defects", but that we should take a pro-active approach in the development of safety of transportation. We should develop an integral approach to the issue of safety, in which notions such as "first time right", "zero defects" and "integral safety" are incorporated. In industrial sectors, such as the chemical process industry, the offshore industry, shipbuilding, aerospace engineering, car design, nuclear power supply and consumer products, this new approach has led to an increased focus on the design of products and their use in operational practice. The fact that we may welcome today speakers and guests from so many different groups concerned with the safety issue, shows that there is indeed a solid basis for a forum to discuss a pro-active approach in the development of safety of transportation.

Ladies and gentlemen, from its early days on, the transportation sector has learned its hard lessons from extensive and detailed accident investigation. Independent safety boards in aviation, shipping and railroads play a key role as a monitoring instrument. In the past, they have revealed the causes of accidents, aiming at the prevention of the repetition of similar accidents. Their investigations have led to major improvements in the technical components in all modes of transportation. Nowadays, safety boards also focus on organization, management and legislation aspects. Their recommendations are passed on for implementation to operators, legislators, manufacturers and other stakeholders of the transportation business. I am happy to report that, in accordance with the international developments, an intermodal Transportation Safety Board for The Netherlands is presently under discussion in the Dutch Parliament. This board will also focus on the prevention of accidents by the early warning of system deficiencies through incident analysis.

Delft University of Technology has a long and strong heritage in many modes of transportation. For more than 40 years, the National Railroad Accident Investigation Council was staffed by Delft professors. Also, the Dutch Road Safety Council developed its model for road accident analysis in close cooperation with our university. We believe that

modern technology will play a key role in improving the safety of transportation, and our university wants to contribute to the development of safer transportation systems and procedures. Recently, our university has selected ten themes on which we will concentrate a significant part of our research activities. One of these themes is: "Mobility of persons and transportation of goods". As a result, last year two interdisciplinary research programs, one on "Seamless multi-modal mobility" and one on "Freight transport automation", have started. In addition, we have already for some years the Dutch "TRAIL Research School for Transport, Infrastructure and Logistics", which is one of the organizing partners of this congress. We hope that our researchers may contribute substantially to the solution of a number of critical problems in large-scale advanced transportation systems and to the analysis of safety issues.

Ladies and gentlemen, our university is proud that we host a congress that addresses issues which are very relevant to our society. I wish you a successful congress and many stimulating and fruitful discussions. But I also hope that the program allows you to have many social contacts, making new friends and intensifying old friendships, and that you will find some time to stroll along the inner-city of Delft, a very special historical city that offers a lot to our foreign guests.

Plenary Keynote

Annemarie Jorritsma-Lebbink
Minister of Transport and Public Works

(The Minister was replaced by G.A. Dubbeld, M.Sc., Director of Transport Safety of the Directory General for Goods Transport)

As a Shakespearean Minister of Transport might put it: "Imbalance between growth and safety... that is the question." For the next three days, you, as experts from all over the world, will delve into this subject. By listening to speakers, holding discussions and finally, by contemplating various matters - that is, if you can find the time. And I have the honour of kicking off the entire programme instead of Minister Jorritsma, who regretfully could not be present due to urgent Parliament business.

Ladies and gentlemen, we find ourselves in a period of tremendous growth. Not only is the earth becoming more and more populated, but prosperity is growing steadily in many parts of the world as well. More people and more prosperity - that inevitably means more transport. And it looks as though this trend will continue. It is expected that some modes will even experience growth of 50 percent in the coming decades. So it is very important to control this growth as much as possible and ensure safety. But we cannot adopt a wait-and-see attitude. We must anticipate developments in order to ensure the level of safety in the future as well. I call that "Sustainable Safe Transport".

Safety is not an absolute notion. The social context and cultural background determine which risks are deemed acceptable. The only thing that is certain is that every form of transport entails risks. Transport without any risk of injury to persons or damage to means of transport, load, infrastructure or environment is an illusion. But what is acceptable? What are the limits? This is the whole issue.

Safety policy boils down to obtaining and maintaining an acceptable level of safety which fits within the relevant social and cultural context. Here as well, the traditional costs and profit principle applies. The measures taken must be in balance with the sacrifices they necessitate. When much can be gained for a relatively small sacrifice, a higher level of safety is realised.

The transport sector is growing. The means of transport themselves are not only becoming larger - just look at the mammoth tankers and extra long freight trains - traffic is also becoming more intensive. We are seeing more and more lorries, ships and freight trains, all going faster and faster. And that, of course, has consequences for transport safety. Especially in a country such as the Netherlands, with its small surface area, high population density and important transit function, it is impossible to isolate yourself from those developments. So the Dutch Ministry of Transport and Public Works is working hard, despite growth in the transport sector, to further improve safety in transport where needed and where possible. And no matter what, we feel that the level of safety may not decline

under any circumstances.

This is quite a challenge. Fortunately, we have a whole arsenal of instruments at our disposal. But as you know, every measure has its price. Alternatives are weighed against each other using risk analyses and formal safety assessment technologies.

For the sake of legal security and sustainability, safety regulations are laid down in legislation, but I am fully aware that regulations alone can never be enough. The support of the sector makes or breaks the success of the measures. And you can only receive that support by discussing possible policy measures in broad consultation.

Not only on a national level, but definitely international as well. The transport of today is, after all, not limited to the borders of a country. In fact, it often involves a chain of different modes of transport. A policy on a purely national level is certainly not the obvious choice. To the contrary. A major part of safety policy will have to be designed on an international level. Transport by road, rail or inland waterways is a matter of regional international policy. But for aviation and ocean shipping, global policy is essential.

That policy is determined in all sorts of international forums and organizations. I should like to take advantage of this opportunity to express my appreciation for the excellent work done by those organizations. It is a good thing that the many facets of transport safety are being examined and studied so closely. This is also one of the many areas in which our host for today, the Technical University of Delft, has a reputation to maintain.

Ladies and gentlemen, we are familiar with a classic package of measures to improve the safety of transport. I can mention the technical requirements of the means of transport, proficiency requirements and traffic regulations. These are excellent measures that work well. But with a view to the safety standard already achieved, attention to safety management and human behaviour will become increasingly important.

While aviation is a relatively young branch of transport, policy in this domain has developed farther than in other modalities. But serious efforts are currently being made to catch up, which will benefit transport safety. A recent example is the establishment of the "International Safety Management Code" for ocean shipping.

As I've said: measures to increase safety in transport can only succeed if it receives broad support. And this means discussing all the aspects and possibilities of safety policy. Beyond the borders, with all interested parties. Only then can the rules be properly upheld.

But there is yet another track we can take to make proposed policy measures a success. And that is the mechanism of the market effect. Policy measures have more chance of success if different players in the transport sector have a common interest and recognize it as such. The conclusions of the MareForum '96 congress will serve as a reminder.

Ladies and gentlemen, growth in the transport sector has an indisputable influence on safety policy. But the scale may not tip, and I am convinced that that is not necessary. This congress will help to find the answers. I hope this congress will serve to inform and inspire you. A congress with concrete results, in the form of many useful recommendations which can safeguard the proper balance. I thank you for your attention.

Plenary Keynote

Pieter van Vollenhoven

Chairman ITSA, International Transportation Safety Association

May I, as chairman of the International Transportation Safety Association, begin by expressing my gratitude to Delft University of Technology for organizing this Second World Congress on Transportation Safety, and for again making such an effort to ensure its success. I can well imagine that some people here at the university were far from convinced of the need to organize another congress. For cost-savings are what matter these days. And the market economy. So why on earth should we put transportation safety in the spotlight? And if we have to have a conference on the subject, why not take a sector-by-sector approach? Focus on the shipping or the aviation sector, for instance?

But Mr. Chairman, I believe that it is precisely because the market is now at the wheel, and because the government is increasingly taking a back seat, that the spotlight should be put on safety - safety in general, and transportation safety in particular. For we have learned from the past that safety can very easily be overlooked when other interests, especially economic interests, are at stake. And this applies, of course, to the entire transport sector.

I am thinking here of the airlines on the FAA "black list". And the Challenger Space Shuttle crash - a crash that could have been avoided, for it had long been established that the O-rings were not up to standard. Indeed, according to the report on this accident, I quote: "We can lower our standards a little bit, because we got away with it last time.... you got away with it, but it should not be done over and over again like that."

I am thinking of the dangerously overloaded trucks on our roads and the outdated safety systems still used on the railways. What should be given priority? New lines for high-speed trains, or new safety systems on the existing network?

And what about the immense container ships that sail at high speed, in poor weather conditions, through the overcrowded Channel?

Though I am not implying that safety is no longer a concern, the need to maintain a competitive position often leads transport operators to "lower their standards a little bit" - if they can get away with it. What we should not forget is that most accidents, as well as the most serious accidents, occur in the transport sector. Indeed, natural disasters apart, the transport sector accounts for around sixty percent of the major disasters that occur in the world every year. Let me give you a few facts and figures for your consideration. Natural disasters, such as earthquakes and floods, claim the lives of 20 to 30 thousand people all over the world each year. Over the same period, the roads in the United States and the European Union claim about 90,000 lives, and nearly three million people are injured in road accidents. In other words, though transport has given the world much that is good, the coin also has a reverse side.

As for the intersectoral versus sectoral debate, many people working in transport regard the intersectoral approach as unnecessary. Indeed, there are those who are totally opposed to it. For what on earth can, say, aviation learn from road or rail transport, or from shipping? Fortunately, it has begun to dawn on people in the various sectors that they have much to learn from each other. Take injury prevention, for example. The aircraft industry has greatly benefited from the results of tests carried out in cars with, for instance, crash dummies and seat anchoring. The knowledge of the effects of alcohol consumption on human behaviour is another example.

The aviation sector itself has much to offer too, namely a wealth of experience with, for example, black boxes, medical tests, information processing and guidance systems. And now the research world is endorsing the need to exchange information and promote an intersectoral approach. We need no better evidence than this Second World Congress on Transportation Safety. But what, if anything, did the first congress achieve?

Mr. Chairman, this is a question I should very much like to answer. Let me assure you that I have witnessed at first hand the lasting impact of your first congress, both at home and abroad. For it laid the basis for the establishment of the International Transportation Safety Association, in which all multi-modal and some single modal Transportation Safety Boards work together. Indeed, it was as a direct result of your congress that the agreement setting up the ITSA was signed in October 1993.

Plans for a Dutch Transportation Safety Board are also progressing well. Though the establishment of such a board was already under discussion, it was in response to your congress that, in 1993, the Lower House of Parliament formally requested the government to "prepare a bill establishing a national Transportation Safety Board". Now, five years later, that bill is before the Lower House. If, as is expected, the Upper House also approves the proposals, this year will see the establishment of our own multi-modal Transportation Safety Board, the sixth body of its kind in the world.

These two initiatives represent an immense leap forward in improving the safety of transport systems. And both came about thanks to your first congress. That is what I call a real achievement.

Mr. Chairman, ladies and gentlemen, I should now like to turn my attention to the subject of safety in general. Regulation, monitoring and technological innovation - activities in these fields have long been the mainstays of our efforts to ensure greater safety. But now two new trends have emerged.

The first of these is what I would call the notion of "shared responsibility" for safety. That it is not only the government, but society too that is responsible for ensuring safety. The second is the growing trend for society to demand of the government truly independent investigations into the causes of accidents.

The notion of shared responsibility has its roots in crime prevention. For it is in this field in particular that the government has gradually come to realize that it can no longer bear the sole responsibility for guaranteeing people's safety. In the past, people thought - rightly or wrongly - that it was up to the government to keep us safe. Now, however, they are beginning to realise that everyone in society has a part to play. Safety, in other words is a shared responsibility. And this leads to one very important question. When it comes to safety, what can we expect of, first, the government, and, second, society?

In the Netherlands, the government and the commercial sector work together in the National Crime Prevention Platform to make concrete agreements on ways of dealing with crime. These agreements sometimes take the form of a public-private partnership. They may, however, lead to legislation, such as the Disclosure of Unusual Transactions Act, under which banks and other financial institutions work together with government agencies to stamp out money laundering.

I firmly believe that this new approach to safety will be adopted in other fields too. In fact, I have already come across an example - in the report of the White House Commission on Aviation Safety and Security. This Commission was set up by President Clinton in the aftermath of the fatal TWA-800 crash near New York on 17 July 1996. Chaired by the Vice-President, Al Gore, it was asked, according to the final report of February 1997: "...for an initial report on aviation security in 45 days, focusing on detecting sophisticated explosives." One of its recommendations was, I quote: "We are proposing that government and industry come together in a new partnership... This partnership is in fact our first recommendation." It was for this reason that I, as chairman of the ITSA, asked Vice-President Gore to inform this congress how the United States plans to carry out this recommendation.

I am convinced that public-private partnerships of this kind are set to play a very important role in efforts to ensure greater safety in the future. We should, however, act with caution. For too many agreements and regulations might give rise to confusion. Indeed, we might find that we are no longer sure who was responsible for what. This makes the need for independent investigations even more urgent.

Serious accidents invariably lead to the cry for an independent investigation into the causes - from the media, the general public, the victims and their families, members of parliament and the government. In other words, no one would question the need for independent investigations. But how "independent" are they in practice?

Fortunately, disasters do not occur very frequently. As a result, however, few countries have a permanent committee solely responsible for investigating their causes. To establish such a body has long been considered a waste of time, since the members would soon lose their expertise through lack of work. In many countries therefore, committees of investigation are set up - if at all - on an ad hoc basis. They usually comprise people from the sector concerned who are involved, for example, in drafting regulations or monitoring compliance. They are mainly chaired by an independent person, such as a judge.

Experience has shown, however, that much is at stake for the members of these committees. Conflicts of interest are often inevitable. Appointing an independent chair has proved, in many cases, to be no guarantee that the investigation itself will be independent. As a result, society is often left with the uneasy feeling that not every stone has been turned, and that the full truth has not been revealed - even where this is not the case. The mere suggestion that the committee is not impartial, or that there is a conflict of interests, is enough to raise doubts about the outcome of the investigation. The resulting recommendations will be met with scepticism from the outset, even if they are excellent.

For many years, the sole exception was the National Transportation Safety Board, established in the United States in 1967 to conduct investigations into all transport accidents. Whether an accident occurs in aviation or shipping, on the roads or the railways,

or involving a pipeline, it is up to the Board to investigate its causes. The origins of the NTSB lie in the aviation provisions of the Chicago Convention of 1944. Under the provisions of Annex 13, which was added in 1951, investigations into the causes of accidents should be held independently of investigations to establish which party was at fault. The purpose of these investigations was to identify the lessons to be learned for the future. For the record, the Chicago Convention merely specified that "an investigation" should be conducted. It was not until 1981 that Annex 13 was amended to specify that the investigation should be "independent".

In 1994, the European Union took matters a step further. A directive was issued, providing for the establishment of a permanent, independent organization to conduct investigations into aviation accidents. But the NTSB was the pioneer. From the start, independent investigations were guaranteed, since the Board was to be a permanent, autonomous organization. It was also unique, since its remit covered not only aviation, but accidents throughout the transport sector, including pipelines. It was the aim of the American Congress to ensure a higher profile for the issue of safety than could have been gained by establishing separate organizations for each transport sector. And, since the organization was independent, conflicts of interest could be avoided.

We have learned many useful lessons from the American experience. Firstly, because the NTSB is an independent organization, its findings are recognized as impartial. And, as a direct result, its recommendations carry considerable weight. Indeed, 80 percent of these recommendations are carried out. Secondly, American experience has shown that the same procedures apply, whatever the accident. These two factors led to the establishment, in Sweden and Finland, of Accident Investigation Boards, responsible for investigations into all major accidents, also outside the transport sector. A third very useful lesson was the cross-sectoral approach adopted by the Americans. Its success led to the establishment of multi-modal Transportation Safety Boards in Canada, New Zealand, and now the Netherlands.

But a permanent, independent organization not only guaranteed independent investigations. It also proved vital in a number of other ways too, namely in monitoring the follow-up to its recommendations, and in carrying out studies of incidents, on the principle that prevention is better than cure.

If no one keeps an eye on what happens to recommendations, there is always a chance that they will disappear into a drawer, never to be seen again. The American answer to this problem was to compile a "Most Wanted" list. This list contains the major recommendations, not or not yet complied with. Fortunately, there is a growing awareness that measures should be taken before, and not after, the next accident happens. It is highly regrettable that the public tends only to be interested in safety after a disaster has occurred. The Safety Boards firmly believe, however, that prevention is the key, and that safety-related studies can prevent accidents occurring. Only if Safety Boards are permanent they can act, by means of these studies, as early warning systems. Only then they can alert us to possible threats to safety in our transport systems. America's National Transportation Safety Board, has, in brief, taught us many valuable lessons.

The ITSA

As I pointed out earlier, the ITSA is an organization in which multi-modal and single-modal Safety Boards work together. It not only provides a broad range of services for its members, but is also making a concerted effort to promote independent investigations into serious accidents, wherever they occur.

The members of the ITSA can well understand the dissatisfaction and sense of helplessness felt by the victims of accidents and their families on finding that investigations which were supposed to be independent were, in fact, nothing of the sort. We should of course realize that government authorities are very closely involved in drafting safety regulations and monitoring compliance with them. And this means that the same authorities are not always too keen on truly independent investigations. Indeed, most Safety Boards were set up only after Parliament had intervened. There has, however, been something of a breakthrough in the aviation world, with the new ICAO and EU regulations.

For my part, I urged the European Transport-Commissioner Mr. Neil Kinnock to extend the new EU directive to cover all transport accidents. Why, I argued, should independent investigations only apply to aircraft accidents? Aren't the frequency and consequences of accidents at sea and on our roads and railways reason enough to warrant the same treatment? It was Mr. Kinnock's view that unfortunately there would be too little support for such a course of action in the short term. But, by mobilizing members of parliament, victim support associations and journalists, the ITSA hopes to rally the support needed in the not-too-distant future.

Now that shipping, with the latest IMO proposals, is moving in the direction of independent investigations; now that the European Union, in its multi-year road safety programme, has not discounted the possibility of independent investigations into road accidents; now surely is the time for members of the European Parliament to summon up the political courage to call for the provisions of the aviation directive to apply to all transport accidents.

Mr. Chairman, ladies and gentlemen, as chairman of the ITSA, and as co-founder of the European Transport Safety Council, I sincerely hope that this congress will result in a new European directive - one that provides for independent investigations throughout the transport sector.

Founding members of the ITSA:

NTSB (U.S.A.)

TSB (Canada)

SHK (Sweden)

RVV (The Netherlands)

SOR (The Netherlands)

Plenary Keynote

Herman De Croo

*Chairman, Board of Directors, European Transport Safety Council
Former Transport Minister for Belgium*

The transport of goods and people is an international industry and efforts to remove trade barriers in the interests of competition open up both opportunities as well as serious challenges for safety. Consumer demand for safety in transport is growing, especially amongst the car buying public who, according to surveys, regard safety as an increasingly important part of buying decisions. Safety is rapidly becoming a marketable item. It is a growth industry. At the same time, growth in travel brings with it new and increased exposure to risk of accident and injury necessitating new safety measures by those who are responsible for the traffic system.

Of all the transport modes, the greatest risks are faced by road users. Road accidents represent the highest societal cost of road transport - more than either congestion or pollution - estimated at twice the EU budget for all of its activity. For the other modes, passenger transport tragedies continue to be a matter of public concern. In the European Union, the free, safe and sustainable movement of goods and people is at the heart of the European Community and the need to secure an appropriate balance between the mobility, safety and environmental aspects of transport policy is a key objective. The EU has Treaty obligations to take action on transport safety wherever appropriate and to secure a high level of protection in the standardisation process. The European Union has a key role to play in seeking the highest practicable standards of safety at international level, both in the Single Market and further afield.

Many people have a view about what measures would improve transport safety, but ETSC's starting point is that we should approach the subject in a systematic manner on the basis of the substantial scientific research and experience accumulated over the last thirty years. The use of scarce public resource to address the enormous costs of transport accidents demand that any expenditure is allocated as effectively as possible. In ETSC's view, only a data-led approach to transport safety is capable of delivering this. For the developing EU Common Transport Policy this means:

- establishing EU accident, casualty and exposure databases for all of the transport modes to allow monitoring of transport policy developments and to identify key future safety actions;
- defining target levels of safety for each transport mode and to adopt a systems approach in defining demonstrably effective safety strategies;
- building core information systems to encourage the dissemination of best practice from the wealth of international research and experience at EU level, so avoiding duplication and re-invention of the wheel.

Common action on transport safety at international level has very large potential to reduce risks for EU citizens at home and abroad. Vigorous action is now needed to develop these building block initiatives to ensure that this can be as effective as possible.

IMO's Role in Setting Standards for Safe and Environmentally Sound Marine Transportation

Pieter Bergmeyer

Former Chairman of IMO's Marine Environment Protection Committee

Ladies and Gentlemen,

1 Ref. to unfortunate absence of Admiral Matsopoulos of IMO

2 Ref to my MEPL Chairmanship vis ‡ vis dr. Pattofatto the Chairman of the Maritime Safety Committee

I feel privileged and honoured that I may address this important Second World Congress on Safety of Transportation, and it gives me real pleasure that I may inform you about an Organisation I worked with for some 25 years, the International Maritime Organisation, and in particular that I may inform you about the efforts of this Organisation in fulfilling its mission, which is often quoted as "Safer ships on Cleaner Seas".

The International Maritime Organisation, known as IMO, is a specialised agency of the United Nations having unique responsibility and competence in the field of ensuring safe and environmentally sound marine transport. At present the Organisation has 155 Member States and 55 non-governmental international organisations having consultative status.

At IMO's headquarters in London, the Secretary General, Mr. William A. O'Neil and his staff of about 300 men and women of all world nationalities provide a really outstanding service for this Organisation and its Member States.

Fifty years ago, in 1948, the IMO convention was established and ten years thereafter, in 1958, this convention entered into force and IMO started its work.

IMO has been successful over the years, in the past decades despite the large growth of marine transport and traffic density of shipping accidents still happen, and marine pollution still takes place safety in shipping has improved tremendously and marine pollution from ships has been reduced drastically. If you compare fig. '80 or '40's. Despite these facts, I must say, I still hear criticism from various sides on what IMO is doing.

Some say IMO is too slow and should do more, make safety and pollution prevention rules more stringent, apply the precautionary approach and IMO fails to ensure full implementation of its standards, rules and regulations.

Others say IMO is too fast, too many changes in too many complex regulations, which are difficult to understand and it is impossible to cope with these changes timely, impossible to implement them fully.

For a better understanding of what I am about to say, it is just as well to clarify the issue on what IMO can do and, in particular, what it cannot do. To illustrate that point we should be clear as to what IMO is and how it works.

Depending on one's point of view, one can regard IMO either as Convention or as a Forum of Nations. Both views are correct, although those who have a legal inclination would prefer the former. One obtains membership of IMO by becoming party to the Convention and is subsequently bound by its provisions.

However, the second view that IMO is a Forum in which nations meet to discuss maritime matters of concern, proves to be more practical. If the concern is shared by a sufficient number of members, it is likely that speedy action will follow. If there is no sufficient support, either a compromise is found or the proposal is not carried.

Over the years many proposals have been supported, resulting in more than thirty Conventions and hundreds of Resolutions that IMO has adopted and that spell out the details of those Conventions in order to make them more user friendly to nations that are parties to those Conventions.

In doing that IMO did, what in accordance with its own constitution, it undertook to do: "to provide a machinery for co-operation among governments in the field of governmental regulations and practices relating to technical matters of all kinds affecting shipping engaged in international trade; to encourage and facilitate the general adoption of the highest practicable standards in matters concerning maritime safety, efficiency of navigation and prevention of marine pollution from ships".

A friend of mine once explained to me that the keywords here are the first quoted words "to provide that machinery" because the comparison with machinery builders in the technical sense of its meaning is extremely appropriate.

Engine or machinery builders built their product on the basis of science and practical experience, adjusting that product as the client wishes. First by enhancing the existing, and if this is no longer feasible, by providing a new product. If experience with the product shows a weakness, prone to failure, measures are put in hand to overcome these weaknesses in design. A thing to bear in mind here is that if an engine is installed, it is there for better or worse. Should it at a later stage appear that there are better engines on the market it is not an easy thing then to re-engine.

An other thing to be borne in mind is that the engine builder will provide guidance on how to treat, lubricate, fuel and maintain the machinery but he will leave it to the purchaser to implement this guidance. The machine builder will also, if it is a large manufacturer, provide service facilities or experts world-wide to back-up his sales.

However, what the machine builder will not do as a matter of routine, is enforce his advice. If the buyer chooses to abuse his purchase, this is in essence the buyer's prerogative.

Comparison with IMO's work is striking!! Like the machine builder IMO bases its work on a judicious mixture of scientific facts and experience, always prepared to adjust the rules where experience has shown that change is necessary. Providing a vast array of guidelines on the implementation of the rules in terms of codes, recommendations, specifications and explanations where ambiguities occur.

It is important to note that ships are built and operated under those rules. Should there be reason to improve the rules or make them more stringent, it is not easy or

practicable to change ships accordingly. Therefore one will frequently see in IMO that a distinction is made between "new" ships, being built after the new requirements enter into force, and "existing" ships, being those that existed before that date.

In the comparison the clients of IMO are the governments that allow ships to sail under their flags. It is necessary to be clear about this. The clients are not shipowners, seafarers, shippers, charterers, managers or other individuals dealing with ships, but governments. It is those governments that are responsible for ensuring compliance with the many rules emanating from the meeting of IMO. Rules that they as IMO Member States conceive and adopt in the first place. If IMO is accused of being "slow", it is in actual fact those governments that are slow. If ships, their operators, personnel or cargoes are found not to be in compliance with IMO provisions, it is the governments that for one reason or another are not getting the message through to the ships under their flags.

All I am saying with this is that, contrary to what is often believed, IMO has no executive power. It is a mis-conception to think that IMO as such has the power to enforce its rules and regulations. IMO's Conventions put the onus of compliance with their provisions on the flag States, Parties to those Conventions. Let me say here that port State Control, the power given to port States under IMO's Conventions to exercise control on foreign flag ships entering their ports so as to ensure that these ships will receive no more favourable treatment and are also up to the international standards in force for safety and pollution persecution, that this port State Control is a secondary barrier to enforce compliance with the rules in force. The primary obligation to ensure this is with the flag State. It is particularly unfortunate that many flag States nowadays show a lack of direct involvement and are unable to fulfil their obligations under the IMO Convention.

These problems are exacerbated due to the long lasting low shipping market and the financial constraints under which the shipowners have to operate. In their efforts to minimise their costs it is understandable that they seek a solution in finding the cheapest crews and the cheapest registry. In addition they are shied away from ordering new ships due to the poor returns on the investments caused by over-tonnage. This in turn leads to the ageing of the world fleet, which in itself is reason for serious concern, as casualty statistics clearly indicate that older ships are more prone to accidents than younger ones.

Fortunately, Member States within IMO are increasingly aware of these problems and wheels are set in motion to rectify the situation. Action has been taken for coming to more pro-active measures rather than reactive measures triggered pressure, to improve the rule-making process and to improve implementation of IMO's standards, rules and regulations.

As a regard the latter, a special Sub-Committee on Flag State Implementation has been established. Guidelines for assisting flag States in fulfilling their obligations have been developed. It has also been made mandatory under the SOLAS Convention (Safety Of Lives At Sea) that organisations, such as Classification Societies, which are entrusted by flag State Administrations with the responsibility for carrying out surveys and inspections, shall comply with Guidelines adopted by IMO (Resolution A.739 (18)). Also "Enhanced Programmes" for survey and inspection of oil tankers and bulk carriers are made mandatory.

New measures for improving the safety of Ro-Ro ferries have been adopted and very recently, in November last year, a SOLAS Conference under auspices of IMO adopted

new measures for improving the safety of bulk carriers in the form of a new Chapter of the Convention.

But maybe more important, is IMO's shift in emphasis from efforts to improve ships hardware to efforts for improving the so called "human element issues" in safety and pollution prevention.

In this regard, firstly I would mention the recently revised Convention on Standards for Training Certification and Watch keeping of ships personnel, in which Convention a positive rule is assigned to IMO in the implementation process. I admit, not an easy nut to crack, but a necessity on which we work very hard.

In addition, so as to promote the responsible management of ships, and thus ensuring a better implementation of safety and environmental standards, the "International Management Code for the Safe Operation of Ships and for Pollution Prevention", the so-called ISM Code, has been made mandatory under the SOLAS Convention. Unfortunately, I must say here that time runs out to meet the 1 July 1998 compliance deadline for many "Phase 1" ships, being all passenger ships, oil, chemical and gas tankers and bulk carriers over 500 gross tons. Under the ISM Code, these ships must have their "Safety Management Certificate" and their companies the "Documents of Compliance". Ships that fail to have these certificates, run the risk of detention by Port States.

I shall refrain from going into any detail on these important issues, but I noticed in your programme for the Parallel Sessions this afternoon that interesting lectures will be given for shipping, both on an integrated management system as meant under the ISM Code, as well as on the integration of economics and safety policy. At present there are economic reasons to invest in quality shipping.

But let me turn now to IMO's products, the rules and regulations.

Is the adequacy of these regulations queried? Yes it is! I have to say.

Is IMO considering to change them? Yes we are!

Is this hastily done without carefully scrutinising the need for and the effect of any changes? No, it is not! Surely, it is acknowledged that there are inevitable weaknesses in the rule-making system of IMO. The rules are of necessity the end result of compromises reached between Member States. These Member States can have divergent objectives depending on the various interests they may have in shipping and on the extend to which they would be effected as typical maritime, port or coastal State.

It is also realised that reactive measures, triggered by disaster and taken under political pressure, this has been done in the past, are usually not the optimum for preventing a repetition of the disaster. Unfortunately tanker accidents often attract disproportional attention of the mass-media. We all know that "shipping is no news unless it is bad news"!!

One should however resist political pressure for hasty decisions and one should carefully balance the quality and effectiveness of an anticipated measure, against haste. And that is what we in IMO are bound to do now.

We also know that international rules and regulations aimed at safety in shipping and the protection of the marine environment must, if ever to fulfil their purpose, meet at least the following criteria, before being promulgated.

- the necessity for having a rule should be acknowledged and the need, the technical feasibility and economical viability should be demonstrated;

- environmental rules should solve and not just shift a problem; and, most important,
- rules should be understood by the operator and be controllable in an objective way by a third party.

Let me confess: a number of the current rules and regulations do not meet these criteria in all respect. So what are the remedial actions we took in IMO and in which direction are we going to meet future challenges?

Firstly, we changed the method of work of IMO's parent bodies, the Maritime Safety Committee (MSC) and the Marine Environment Protection Committee (MEPC), we reorganised the structure of their Sub-committees and adopted new "Guidelines on the Organisation and Method of Work of the Committees and their Subsidiary Bodies".

A very important element in these Guidelines, which apply in full since last year and which are strictly adhered to, is that "when new subjects for inclusion in the work programmes or amendments to existing IMO-instruments are proposed, the need for such measures and their relation to the objectives of IMO are to be demonstrated and substantiated in a document. In determining the scope of the measure and when analysing the issues involved, due regard shall be given to the costs to the maritime industry, to the legislative and administrative burdens involved and to the benefits which would accrue from the measure, so as to provide a very clear perception of the entire scope of the measure, thus enabling the Committee to make a well informed decision".

We felt the rule-making process can only be qualified as being "well informed", when all necessary data are made available to IMO and a full appraisal has been made. Only then "well balanced compromises" can be found!! An other instrument for improving IMO's rule-making process is called: "Formal Safety Assessment". Let me explain this.

In the Maritime industry, we have long been assessing risk associated with safety. For the most part, though, our assessments have been implicit, hidden within our decision-making processes. But as the complexity and rate of technological growth of our industry increases, we need to recognise, adopt and adapt many of the tools that have been developed to manage risk in a more formal and structured way.

Both MSC and MEPC are considering the development of a new approach to regulating safety and pollution prevention. This approach is known as "Formal Safety Assessment", referred to as "FSA". In essence, FSA is meant to be a formal, structured and systematic methodology, aimed at considering the ship's safety in its entirety, including protection of human health and life, protection of property and the marine environment, all this by use of risk assessment techniques.

A complete FSA application should comprise 5 main steps, i.e. (1) the identification of hazards, (2) the assessment of risks associated with those hazards, (3) ways of managing the risks identified, (4) a cost benefit assessment of the options identified in the third step, and (5) decisions on which options to select.

Last year both Committees adopted "Interim Guidelines" for the application of FSA. And although much is still to be done by the Joint MSC/MEPC Working Group on FSA, I am mentioning this now since I am convinced that the application of FSA in IMO's rule-making process will have a significant impact on future IMO legislation.

In conclusion let me say this. It is essential that IMO's rule-making process is clear,

well structured and based on facts and data derived from sound research. We should come to a holistic approach to marine safety and environmental protection, in which all risks are properly analysed. Shipping, being truly international by nature, needs internationally agreed rules and standards.

It is most important that any actions taken are taken by IMO, because only this ensures that everything done meets with international approval. One should bear in mind that the alternative to orderly internationally agreed rules would be a chaotic web of various national or regional requirements, creating mass inefficiency and commercial distortion, and that is detrimental to both, the safety of shipping and the protection of the marine environment.

In short: the best way to enhance safety and protection of the environment against pollution from ships, is through measures adopted in IMO, and although we have not yet reached our ultimate goals, IMO is on the right track and deserves full support.

Thank you for your kind attention.

Aviation Safety

Victor M. Aguado

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1. Introduction

I wish to extend my congratulations to the organizing committee of this Second Congress on "Safety of Transportation". In my view, it is very timely to address the dialectics of growth versus safety, as we find ourselves at the threshold of the 21st century and, in a period when our economies are expanding.

I therefore wish to extend my congratulations for the initiative and gratitude for the hospitality to the Delft University of Technology that is hosting these meetings, as well as to the Erasmus University of Rotterdam, the International Transportation Safety Association and the TRAIL Research School for Transport, Infrastructure and Logistics.

At the same time, this Second Congress on Safety of Transportation is undoubtedly a great way to mark the 155th anniversary of the University, to whom, on behalf of the Air Navigation Commission of ICAO, I wish a brilliant future. The gathering of this outstanding cast of participants, qualified and committed, will ensure that this Congress will have a major impact on the quality of life of our societies.

2. An industry with a recent history

As we are about to close out the 20th century, the world appears to us to be smaller and smaller, not only because of the explosion of the television networks and teleinformation industry, but also because of the everyday nature of our intercontinental travel today. We must not lose sight of the fact that, only a few years ago, in 1935, the DC-3 flew for the first time, an aeroplane with 21 passengers on board and a cruising speed of 300 km/h, thus taking the first steps in international commercial aviation.

In the 50's, the appearance of jet aircraft made a giant leap, making it possible to travel on aircraft with a cruising speed higher than 800 km/h and a capacity of more than 100 passengers. The next important step came in the 70's with wide-body aircraft.

Each of these landmarks contributed to the expansion of air transport, which it had, at all times, to address growing demand and maintain, if not improve, the safety numbers. In a very brief period of time, that from 1950 to the present day the industry has multiplied:

- the number of passengers by 50;
- the number of passenger-kilometers by 90.

3. Size and growth of the industry

With recent data corresponding to airlines registered in the 185 Member States of ICAO:

- we are approaching to 1.5 billion passengers transported by the world's airlines in 1997;
- and 25 million tons of freight.

We must be aware that other high-speed means of transport will find a niche in the market, will undoubtedly compete with aviation and will capture part of the demand. On the other hand, the new communications technologies that are increasingly more efficient and less expensive will make it possible through teleconferencing to do away with long journeys and business meetings making some of the travel unnecessary.

But in an economy that is more and more globalized, the exchange of goods is essential. We can take decisions by videoconferencing, but goods have to be transported. We can admire a tourist destination in the Internet or on a CD-ROM, but tourism is a living experience, not a virtual one. The tourism industry is today the largest world-wide industry that generates the largest number of jobs and one of the largest export activities, behind only the oil and the car manufacturing industries. According to the World Tourism Organization the total volume of international tourists for the year 2020 will reach three times the volume reached in 1995 with a five-fold increase in their economic impact.

Today with some preliminary data for 1997, in terms of "revenue passenger-miles", the world scheduled international revenue traffic has grown at a rate of 8% and domestic traffic at 6%. With regard to freight, in "revenue ton-miles", the growth in 1997, compared to the 1996 data, was 10%. The pressure of the demand is perceived in the airports and air traffic control systems. The data for the European continent during the third quarter of 1997 indicate longer delays in take-off than in the same period of 1996. Certainly, the efforts of the European agencies are achieving increases in the capacity of the system, but is it enough?

If demand continues to grow, unless there are drastic changes in the airport and air traffic management infrastructures and their procedures, these delays could continue in the future if safety is not be compromised. The systematic insistence on the part of operators to obtain from airports and control centres a higher rate of operations must be rigorously validated with the safety standards, even in the understanding that applying rigour would result sometimes in undesirable delays. But this "boom" that we are experiencing at the end of this decade, it also extends to aeroplane manufacturers who are surpassing those sales records that were established in 1989, almost a decade ago.

The world's two main manufacturers of large commercial aircraft Airbus and Boeing, were announcing during 1997 "orders and commitments" amounting to more than 1200 aircraft. Their production capacity was limited to 570 aircraft. The need to increase the rate of production to meet demand, this is to double the production of previous years, is not proving to be a simple exercise. In this race to increase production, it is necessary to emphasize and ensure the quality of the aeronautical products and therefore the safety of flight. The increase in the quality and safety assurance activity by the aeronautical authorities in the operations of airlines, the control centres and airports, as well as in the aircraft manufacturing processes, must be welcomed at this critical time of growth.

4. But, are there threats to that growth?

On the one hand, with regard to the supply of air transport, route and airport congestion is undoubtedly a limitation. Europe's symptoms at the end of the 80's are starting to appear in other regions of the world. But let us look at the other side, that of the demand. A different type of limitation may appear: the growing concern of public opinion about the safety levels of aviation, especially after major accidents. We can say that air transport is one of the safest modes of transport in the world. The strong technical regulation of equipment, systems, licenses and operations has played a role of paramount importance. The accident rate of commercial aviation had a spectacular drop during the 60's and 70's, decreasing by a factor of 10. The concern lies in noting that in the last 20 years the accident rate, previously on the decrease, has asymptotically approached a kind of slow moving minimum limit. Using data, still preliminary, for the year 1997 and referring to world scheduled revenue traffic, there have been 26 accidents with fatal consequences for the passengers or the crew, as compared to 25 accidents in the previous two years. The number of fatalities in 1997 was of 850 victims as composed with 1256 fatalities in 1996.

Even though traffic has grown at the above-mentioned rates, the absolute number of fatal events retain almost constant levels. Therefore, the accident rates have decreased reaching values of 1.34 fatal events per million operations. When we look at the ratios of fatalities per passenger carried, or per passenger-kilometer performed, there is also a slight downward tendency, but with the exception of 1996 in which a series of major accidents involving large-capacity aircraft took place. Undoubtedly, 1997 was much better worldwide than 1996 (exception in the Asia-Pacific region), but I must clarify that, as I mentioned earlier, the small downward tendency that could be observed in very specific periods is very far from the drastic improvements in these ratios that were observed during the 60's and 70's when the accident rates were reduced by an order of magnitude. If it is true that accident rates are maintained constant and traffic continues to grow as forecast, the absolute number of accidents and victims of those accidents will have a tendency to increase.

Public opinion has accepted the very low accident rates of air transport and it concentrates its attention on the absolute number of such accidents and the number of victims resulting from each of them. The low aviation accident rate in relation to other modes is not a sufficient argument for the flying public. The mere idea of having a serious accident every 10 days in the year 2005 is not easy to accept. There is no choice, safety levels have to be increased.

On the other hand, when safety is analyzed from a geographical perspective in the different continents, the accident rates differ by orders of magnitude. But safety in civil aviation must be a global concept and not limited to states, regions or continents. The question comes: do we have a robust system by which we ensure global safety?

5. The system that ensures safety

The system that has ensured the safety of international civil aviation is based on the Chicago Convention. ICAO, as an international organization, is assigned the objective of developing

the principles and techniques of international air navigation. For this purpose, the Organization adopts international standards. It also approves Regional Air Navigation Plans where the infrastructure required is contemplated.

Each Contracting State undertakes to achieve the highest level of uniformity possible, notifying, where it considers compliance impossible, the differences with respect to the international Standards and Procedures. It is in Article 1 that it is recognized that every State has complete and exclusive sovereignty over the airspace above its territory. Basically, States, as regulatory entities and aeronautical authorities, undertake to follow the international standards or to notify their differences.

But a recent analysis indicates that in the last 10 years, only 25% of States have informed ICAO, on average, of compliance with or, as the case may be, of differences with respect to the Standards adopted in the 18 Annexes to the Convention. From these data, it is not possible to state with certainty what is the degree of implementation of and compliance with ICAO Standards in the respective Member States.

What happens in the case by which there is no compliance with the Standard and also no differences are notified? Simply, the international community is formally unaware of such a situation, even though it may be known by other means. But are we fulfilling our responsibility vis-à-vis our citizens, those who fly all over the world, if we were to maintain this situation?

6. The change of scene

In 1944, 52 States were able to reach a consensus defending each State's complete responsibility and dependability to be able to generate legislation and the corresponding regulations incorporating international standards and to oversee compliance therewith.

The same spirit is still valid today, although the scene has changed substantially.

- a) The number of Member States has increased from 52 to 185. Some of the States that joined during this period were recently created.
- b) The air operator, the airline is a globalized enterprise, is no longer a self-contained entity in a national context both in terms of ownership and its commercial strategies. Globalization has occurred.
- c) The progressive commercialization of both airport and ATC service providers has led to new players appearing in the system.
- d) The gradual implementation of the Communications Navigation Surveillance ATM systems based on satellites, may induce to change the role to be played by States but not their responsibilities.

In order to ensure the safety of the system continuously in the airspace above their territory (as laid down in Article 1 of the Convention), mechanisms should be developed at the global level that allow States to fulfill their responsibility. Regular safety audits of service provider entities and the publication of the results thereof should be a consideration for a future common practice. Basically, the system that ensures safety at different levels, from the State level to the smallest of the service providers level, should remain to be robust.

7. The Safety Oversight Programme

Following that line, in June 1995, the Council of ICAO approved the Safety Oversight Programme. The programme is aimed at ensuring the effective implementation by States of the safety-related Standards in the areas of personnel licensing and training, operation of aircraft and airworthiness. The present ICAO Safety Oversight Programme consists of assessments of States by ICAO, on a voluntary basis, with the objective of offering follow-up advice and technical assistance as necessary to enable States to implement international standards. As of 15 February 1998, the total number of States that had requested an assessment under the ICAO Safety Oversight Programme was eighty-two, of which fifty-nine had been assessed by an ICAO team. The essential characteristics of the current programme are voluntary, at the initiative of the State, confidential in its process, and addressing the responsibilities of the State to carry out the oversight functions.

The preliminary results cannot be considered as a random sample of the 185 States. Nevertheless, important lessons have already been learned: from those results, it can be concluded that a vast majority of States, assessed, in spite of their best intentions and efforts, are facing serious difficulties in fulfilling their safety oversight obligations.

8. DGCA's

As a further step, on 10-12 November 1997, the first-ever world conference of ICAO devoted exclusively to the issue of air safety brought together Directors General of Civil Aviation and Administrators of Civil Aviation Authorities from 148 out of 185 Contracting States and representatives of 14 international organizations. The discussions focused on the ICAO Safety Oversight Programme, and the ways and means to enhance it. The dynamics of the meeting went beyond all expectations, reaching what can be considered historic results. Many were the recommendations of the Conference. I do not pretend to cover all today, but three of them should be outlined:

- 1) Regular, mandatory, systematic and harmonized safety audits be introduced, which should include all Contracting States and which should be carried out by ICAO.
- 2) Greater transparency and increased disclosure of the results of the audits be implemented.
- 3) The ICAO Safety Oversight Programme be expanded, at the appropriate time, to all areas of civil aviation which have an impact on safety, initially to include air traffic services, aerodromes and support facilities and services.

As you see, we have important guidelines resulting from the unanimous support of 148 States posing a big challenge to the International Community. We know "what to do"; the problem rests now on "how to do it" and "how to pay for it".

9. Final remarks

As final remarks, let me share with you my reaction to important statements from different States and international organizations in which some apparently ambitious objectives are

identified to increase, even more, the safety of air transport, by reducing the accident rates by 50% by the year 2004 and 80% in a 10 year period.

Even though certainly these are ambitious statements, I must confess to you my optimistic perception and my conviction that the objectives can be achieved. I shall tell you why:

1. New aeroplanes and new engines will be introduced in the market that will strengthen the reliability of operations;
2. New navigation systems that provide more information and higher precision, such as the CNS/ATM Systems based on satellites, will be common;
3. Universal carriage of transponders that strengthen the identification and surveillance functions, will be required;
4. Universal carriage of ACAS and EGPWS that warn the pilot of an imminent emergency vis-à-vis other traffic or terrain is currently being analyzed;
5. Greater emphasis on human factors is being extended to all regulatory activities;

But at the same time, to reach the objectives we certainly need something else:

1. Greater commitment by States to discharge their Safety Oversight responsibilities;
 2. Extensive cooperation among States, so that those facing difficulties could be helped.
- Safety in aviation is a global issue

And above all:

3. A continuous desire to be shared by all stakeholders: States, airlines, pilots, manufacturers and service providers to have a global strategy and a common goal to keep the air transport even safer.

The Multi-Loop Safety Improvement Model

Klaas Smit

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1. Growing public safety awareness

Despite continuously improving relative safety records, expressed in number of fatalities per unit of production in various modalities of transportation and within industry, public consciousness on risk and safety is growing. It is caused by the fact that passenger capacity per transportation unit is increasing. The resulting weight and the growing speed of transportation units are causing much greater collision forces, resulting damages and casualties.

Due to globalisation in industry, production of goods and products are becoming more geographically concentrated, resulting in larger transportation volumes over longer distances. Dangerous goods also need transportation often via subsequent modalities and transferpoints. Calamities may therefore cause risk, not only to the transportunit operators, but also to the public.

Transportation demand in densely populated urbanised areas is high. As urbanised areas are showing a strong growth, public is exposed to greater effects as risk is involved. Feelings of unsafety or public unsafety perception, is exponentially increasing with the number of fatalities with a major accident and will not decrease during the course of time. Reducing the probability factor of risk is not anymore convincing enough, but nevertheless of utmost importance.

As the complexity of transportation units and its related infrastructure is increasing due to increased capacity, speed and frequency, the probability of events which may lead to an accident must be further reduced. In most of the transportation modalities the relative number of fatal accidents is not growing, however absolute number of fatalities are increasing. Therefore the inherent safetyimprovement cannot longer compensate for the continuous growth of the transportation volume.

2. Safety as a contributor to improved economic results

Traditional instruments to ensure necessary safetylevels so far, have been mainly governmental laws and rules, agreed upon via national or supra-national organisations. These instruments are necessary but not sufficient to ensure safety.

In chemical process industry for instance, after some severe disasters in the past, safety has become a strategic issue of first priority, because a major accident will jeopardise

the reputation and even continuation of the company, because of public opinion and pressure. After introduction of systematic safety-improvement programs, it was shown that not only safety records were improving, but also production performance, leading even to costreduction on the longer term. It means that systematic attention to ensure and improve safetylevels, will also pay off in improvements in other areas, resulting in increased performance and costreduction.

These effects however, are not only resulting from the introduction of safety programs. The same effects are, to a lesser extent, observed by introduction of systematic environmental protection and quality assurance programs. This systematic attention for safety, supported by structured programs, are characterised by attention for the causal chain of accidents and incidents and elimination of the root causes during the system lifecycle. This will be discussed into some more detail.

3. Prevention of accidents by eliminating incidentcauses

Korenromp [1] presented a grouping of safety measures, to increase safety by decreasing risk, of five different categories:

1. Survivability of a disaster
2. Escape from a disaster
3. Fighting developing hazards
4. Suppression of hazards
5. Pure prevention.

This range shows from 1 to 5 decreasing effects and less cost to reduce risk and probability of potential hazardous event. An accident occurs when the fight against a hazard is not succesfull. An incident is defined as an event, which may result into a hazard, or eventually into a disaster. Such incidents happen within the grouping above, between pure prevention and suppression of hazards or between suppression of hazards en fighting developing hazards.

Accidents are analysed carefully, in order to identify the primary causes. In some modes of transportation systematic accidentinvestigation methods have been developed and accident databases are maintained in order to feed back the lessons learned to amandments of (inter) national laws, rules and regulations. This is a very long term feedback loop. As accidentrates are low, accidentcauses are of a multitude character and sometimes primary causes cannot be established unambiguously, the feed back loop is of course of great value, but not very effective in overall accident prevention.

Incidents as potential hazards, are obviously happening much more frequently as compared to accidents, reflecting much more the multitude character of potential accidentcauses. The chain: incident-recording, -reporting, -evaluation, -analysis and -improvementactions is therefore a powerful instrument in accident prevention.

Incidentanalysis and resulting improvementactions can be treated in the first instance confidentially within a department of the organisation of an transportoperator (e.g. operations- or maintenance department), or within a company. In anonimous form, these incidentreports may be fed back to the engineering and manufacturing companies of the

transport system, or may be collected in databases and disseminated between national and international organisations.

The feedback loop, established this way, is user-driven instead of a government-driven approach, is short term and broad-based in terms of potential accident causes. It however requires first of all a particular management attitude and -commitment to introduce an incident-elimination program and a cultural change of a company organisation, in order to record and report incidents and to analyse these for root causes.

The next step is to report anonymously the incident reports to manufacturing- and engineering companies. Reporting to national or international organisations is even a step further. However in some branches, these short term incident feedback loops have only been partially established. The anonymity must be ensured by safeguarding the admittance for enquiries into the database. A very important aspect is an adequate database structure and an unambiguous definition of the data-elements.

4. Ensuring safety by systems engineering approach

Ensuring system-safety levels and continuously improving safety by reducing risks, requires a systems approach.

This already starts with the transportation system definition and -specification for a system to be designed. A system is not only to be considered as the final transportation mean, but also includes its manufacturing system and its future maintenance or product-support system. It also embraces the safety of the passengers and containment of goods to be transported and includes its transfer of loads from and into other means of transportation. System safety is also to be considered with its relation to the infrastructure it is depending on, e.g. traffic guidance systems, harbours or airports. During the system definition stage, an initial risk analysis may already be conducted and possibly approved, leading to amendment of particular specifications. During this phase use might be made of above described accident- and incident databases.

In the design- and engineering phase, at various stages risk- and safety analysis and the application of proven techniques like: hazard-, fault tree-, accident prevention-, failure mode effect and criticality-, reliability- and maintainability analyses are required and conducted and the results considered during design reviews. In some branches, system design is subject to certification as part of a design certification program. Also the design and engineering organisation may require a quality certification in order to comply with quality assurance requirements which also satisfies quite a number of safety assurance elements. During this phase, use might be made of accident- and incident databases.

In the manufacturing stage inherent system safety levels need to be ensured by a quality assurance program, for those system aspects which are critical to realise inherent system safety. This also may require certification of the manufacturing organisation. In some branches, like aircraft industry, the resulting products may be subject to type certification, by proving its inherent reliability and safety under (severe) operating conditions and each unit is certified before entering service.

In the operations phase, the operational organisation may be certified in order to

the reputation and even continuation of the company, because of public opinion and pressure. After introduction of systematic safety-improvement programs, it was shown that not only safety records were improving, but also production performance, leading even to cost reduction on the longer term. It means that systematic attention to ensure and improve safety levels, will also pay off in improvements in other areas, resulting in increased performance and cost reduction.

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4. Ensuring safety by systems engineering approach

Ensuring system-safety levels and continuously improving safety by reducing risks, requires a systems approach.

This already starts with the transportation system definition and specification for a system to be designed. A system is not only to be considered as the final transportation mean, but also includes its manufacturing system and its future maintenance or product-support system. It also embraces the safety of the passengers and containment of goods to be transported and includes its transfer of loads from and into other means of transportation. System safety is also to be considered with its relation to the infrastructure it is depending on, e.g. traffic guidance systems, harbours or airports. During the system definition stage, an initial risk analysis may already be conducted and possibly approved, leading to amendment of particular specifications. During this phase use might be made of above described accident- and incident databases.

In the design- and engineering phase, at various stages risk- and safety analysis and the application of proven techniques like: hazard-, fault tree-, accident prevention-, failure mode effect on criticality-, reliability- and maintainability analyses are required and conducted and the results considered during design reviews. In some branches, system design is subject to certification as part of a design certification program. Also the design and engineering organisation may require a quality certification in order to comply with quality assurance requirements which also satisfies quite a number of safety assurance elements. During this phase, use might be made of accident- and incident databases.

In the manufacturing stage inherent system safety levels need to be ensured by a quality assurance program, for those system aspects which are critical to realise inherent system safety. This also may require certification of the manufacturing organisation. In some branches, like aircraft industry, the resulting products may be subject to type certification, by proving its inherent reliability and safety under (severe) operating conditions and each unit is certified before entering service.

In the operations phase, the operational organisation may be certified in order to

ensure operational safety and also the individual system operators, by certifying their capability to operate a system or even a particular system type or -model. Especially the ability of an individual operator being capable to practice emergency procedures, in order to act adequately during hazardous situations, need to be ensured by periodic training and checks.

Also infrastructural systems, organisations and personnel to support operations or operators, like traffic control and facilities like harbours and airports, might be subject to certification against quality and therefore inherent safety requirements.

This also applies to maintenance organisations, influencing the inherent safety of primary transportation- and its supporting systems. It is essential to ensure inherent system safety by satisfying requirements with respect to the maintenance organisation, procedures, processes, instructions, tooling, facilities, spare parts, documentation, personnel and training.

Maintenance plays a vital role in ensuring safety, because the level of (preventive) maintenance and inherent systemsafety shows a distant, but essential relation. As maintenance budgets are continuously subject to reduction, is not considered a core-activity and therefore gradually contracted out, special care is required in ensuring the required maintenance quality.

Also shippers and integrators have to comply to requirements for containment of dangerous goods. These goods often will be routed through a transportation chain consisting of: the manufacturer of the goods, via road to air, or via road or rail to ship, from air via road to a distributor or consumer, respectively from ship via rail or road, to the distributor or consumer of the goods. The complete chain of transportation and transfer of dangerous goods should be monitored by telematics, its safe functioning to be demonstrated, all incidents to be recorded and its causes need to be traceable.

It means that requirements and rules may be applied to all involved parties in a transportation system, applicable to all system lifecycle phases, in order to ensure systemsafety requirements. It also shows that safety and quality assurance are strongly related, if these requirements are applied to process- and organisational conditions.

5. Assurance systems

Companies are, depending on the kind of operation and the possible effects on the public and society, subject to regulations for safety, health and environment. For ensuring product quality, companies have introduced, for competitive reasons, quality assurance systems. These assurance systems are referred to as Quality, Health, Safety and Environment (QHSE) systems.

Also Korenromp [1] draws attention to the parallel between safety and quality assurance. For each insurance system following common characteristics or development phases can be distinguished:

- identification of deviations in the final product or service (incidents or calamities), this concerns product inspection or service review
- identification of deviations in the processes providing the product or service

(process-parameter deviations), which have led to systems like statistical process control (SPC), thus avoiding incidents or calamities

- identification of deviations of organisation and procedures controlling the above mentioned processes, thus avoiding process-parameter deviations, to be verified by regular audits
- total assurance management systems (like Total Quality Management, TQM), where responsibilities to realise the required QHSE targets, are integrated into the lines of responsibility and ownership is developed from shopfloor to management levels within an organisation.

These systems have also in common that deviations (including incidents and calamities) are recorded, reported, evaluated against the standards and requirements, analysed for root causes and improvement actions developed, implemented. Subsequently, the effects are evaluated again.

This calls for a more integrated approach for QHSE requirements and assurance systems in organisations. It can be considered as a user-driven approach. It also supports recording and analysis of incidents, assigns responsibilities for QHSE aspects to everybody in the organisation, and it covers all system lifecycle phases. It also contributes to increased operational performance and costreduction, as a result of elimination of disturbances caused by deviations, incidents and calamities.

6. Feedback loops

It is relevant to consider the establishment of short feed back loops within the organisation of operators, maintainers and infrastructure providers by recording, reporting, evaluation, analysis and implementing improvementactions of incidents and deviations. These feed back loops may be called "intra-user feed back loops".

The results of these intra-user feed back loops within companies, may be exchanged by meetings within branch organisations of operators, maintainers and infrastructure providers. This may be referred to as "inter-user feed back loops". In this context, databases for collection and exchange of incidents may be considered.

In transportation of dangerous goods, shippers and integrators are required to registrate the identity of these goods and have to record and report incidents and calamities of the containment for these goods. For this purpose, use will be made of the developments in telematics for tracing goods throughout the transportation-transfer chain. Causes of incidents and calamities will therefore become better traceable. This requires "mutimodal exchange of incidents and calamities" within multimodal transportchains of dangerous goods. The development of a database for incidents and calamities is of importance.

The next loop is the feed back of incidents and calamities from various users to system manufacturers. This concerns mainly the design of the system, as designed and assembled by the prime manufacturer, respectively his vendors and subcontractors. The manufacturer may consider all incidents and accidents and provide the users with mandatory (in case of safety) or optional modifications in order to increase the inherent safety of the system. This loop is called the "user-manufacturer loop". In aviation, also the national

authorities from the country of the manufacturer are involved in this loop as far as safety aspects of the transportsystems are involved.

The traditional loop is the "long term accident loop", comprising of extension of laws and rules issued by governments and regulatory bodies, resulting from recommendations of accident investigation boards, sometimes supported by research organisations. This loop may sometimes be enforced by societal pressure groups or even by politics and parliaments.

The characteristics of this valuable and proven loop are the long term of actions taken from accident causes to laws and rules and the relatively limited basis of accidents which primary causes often cannot be determined unambiguously.

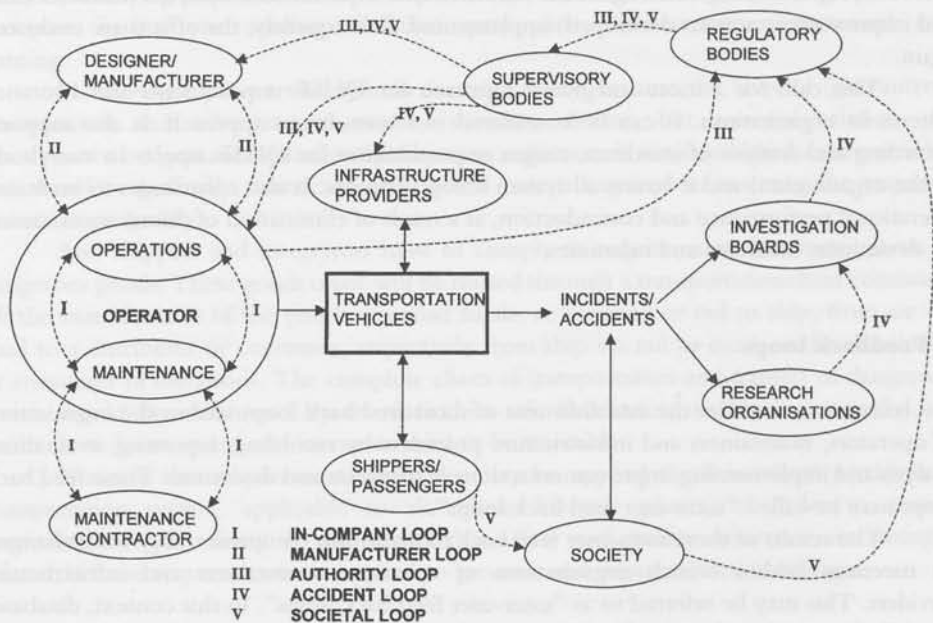


Figure 1. The loop model.

7. Conclusions

The proven long term safety improvement loop, consisting of enforcing safety and reducing risks by laws and rules, is characterised by its long term, its limited basis of elimination hazardous events out of a multitude of possible events which may lead to accidents and its limitations to identify primary causes of accidents.

Due to growing number of fatalities by single accidents, resulting from higher capacities, speeds and weight of transportation units, increased exposure of the public in urbanised areas and therefore a greater public attention, ensuring safety is considered more and more as a primary company objective of transport operators.

Experience in industry shows, that attention for safety improvement results in increased performance and productivity; it contributes to economic results.

As incidents as potential hazardous events, which may have lead to accidents, are happening much more frequently as compared to accidents, they reflect much more the multitude character of potential accidentcauses. The chain: incident-recording, -reporting, -evaluation, -analysis and -improvementactions therefore need to be established. This requires management commitment and a change in company culture.

Introduction of such a system may be derived from, combined or integrated with other assurance systems, like quality-, health- and environmental assurance systems, thus reinforcing each other.

Introduction of incident analyses and the resulting safety improvements means establishing short term feed back loops, within and through transportation company departments, between companies within a branch and between operating companies and the transportation system and supporting infrastructure manufacturers.

In this way, these short term loops may reinforce the traditional long term feed backloop of accident analysis and resulting amandments of laws and rules.

References

- [1] Korenromp, W. The ICAO Safety Oversight Programma, a Quality Assurance approach to Safety. Proceedings of the ISAC '97 Conference, 27-29 August 1997, Rotterdam, page 283-295.

Facts and Figures across the Modes

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1. Introduction

The main aim of the European Transport Safety Council (ETSC) is to identify and promote, from an impartial point of view, effective countermeasures to transport accidents with due consideration to practicality, public acceptability and cost. ETSC brings together 27 international and national organisations and a large network of independent transport safety experts from across the EU in pursuit of this objective. The organisation was set up in response to the increasing number of decisions being taken on transport safety as a result of the establishment of the Single European Market. The key concern was that increasing mobility as a result of EU liberalisation policies should not be at the expense of safety and that harmonisation efforts to remove barriers to trade should not lead to low safety standards.

Travel is so much a part of modern life that virtually everybody has an opinion about how to improve its safety, but ETSC's starting point is to approach the subject in a systematic manner on the basis of the substantial scientific research and experience accumulated over the last 30 years. In the five years since it formed, ETSC has demonstrated to policymakers that a substantial international consensus exists amongst professional experts about priorities for effective activity to reduce transport deaths and injuries in the EU.

My purpose in this presentation is to highlight areas where the greatest opportunities lie for reducing transport accident casualties and their socio-economic cost. I will outline briefly the type of approach which ETSC believes offers the best hope of keeping safety policies focused on the most important and most promising lines of action. To illustrate this I will use mainly European information from ETSC studies carried out during the last five years.

2. Risk of death in transport accidents

Considerable effort is being made at international level to produce accident and casualty databases, which should eventually allow more sophisticated international comparisons of risks of death and injury than are possible at present across the modes, than are possible at present. ETSC has made rough and ready estimates of the some of the risks associated with transport at EU level, to which I will refer later, but it is often more useful to look at national accident analysis for certain types of comparison.

An analysis of accidental deaths in Britain over a ten year period indicates that transport is the leading cause contributing 40 per cent of the total (Evans, 1997).

Table 1. Accidental deaths Great Britain 1982-1992.

Accident type	Average deaths per year	Percent
Transport	5508	40%
Home	4991	36%
Work	447	3%
Elsewhere	2902	21%
TOTAL	134848	100%

Source: Evans, 1997

Measured by deaths per 100 million hours of exposure to the activity, passenger travel has a higher death rate than either occupational activity or being at home.

Table 2. Death rate per 100 million hours in Great Britain by type of activity.

PASSENGER TRAVEL	Type of activity	Deaths per 100 m hours
	Bus or coach	0.10
	Train	4.80
	Ship	12.00
	Air	15.00
	Car	15.00
	Pedestrian	20.00
	Pedal cycle	60.00
	Two wheeled motor vehicle	300.00
EMPLOYMENT	All work	0.84
	Banking and finance	0.17
	Chemical industry	1.01
	Construction work	4.70
	All railway work	5.50
	Extraction of ores	12.30
HOME	All ages	2.60
	Under 75 years old	1.30
	Over 75 years	21.00

Source: Evans, 1997

In EU countries private car transport accounts for over 80 percent of passenger kilometres travelled and 45,000 road deaths represent over 90 percent of all transport deaths. ETSC estimated, in a recent study, that the socio-economic cost of transport accidents amounted to around 166 billion ecu in 1995 (ETSC, 1997a).

Table 3. Socio-economic costs of transport accidents in the European Union in 1995.

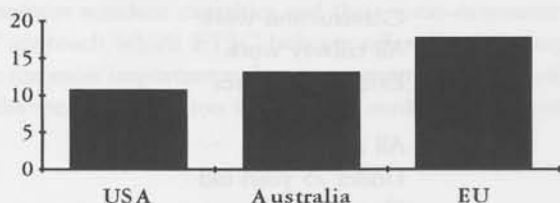
MODE	Total socio-economic costs per fatality x million ECU	Estimated number of fatalities in 1995	Total socio-economic costs x billion ECU
Road	3.6	45,000	162.00
Rail	2.1	1,300	2.74
Air	2.7	186	0.50
Water	9.8	180	1.78

Source: ETSC 1997a

Road accidents represented 97 per cent of the total costs of accidents occurring in all the transport modes. Road accidents represent the highest societal cost of road transport estimated at around 162 billion which is about twice the EU budget for all of its activity.

Table 4. EU death rates per billion vehicle kms in 1994.

Source: FERSI, 1996

Table 5. Fatality rates per billion vehicle kilometre in different continents in 1994.

Source: FERSI, 1996

Within the European Union, there is a sevenfold difference in the risk of road death amongst the best and worst performing Member States and many citizens face much higher and unfamiliar levels of risk when travelling abroad as part of their work or leisure activity than they would at home. Increases in EU traffic resulting from the recovery of national economies and cross-border Single Market activity which will shortly include new EU participants, will only exacerbate these problems for all Member States. Table 5 shows that there are also large differences in the safety of traffic systems in different continents which have similar levels of motorisation.

Many countries have still to reach peak levels of motorisation and the World Health Organisation has forecast that road accidents will be the sixth largest killer in 2020 and the third largest cause of years of life lost (WHO, 1996).

Table 6. Change in rank order of road accidents globally as a leading cause of death.

Road accidents	1990	2020
Number of deaths (millions)	1	2.350
Rank order of leading causes of death	9th	6th
Rank order of years of life lost	9th	3rd

Source: WHO, 1996

3. Most important transport safety problems

The international best practice reviews which ETSC has carried out during the last four years indicate that despite differences in levels of motorisation, climate and so on, the same key road safety problems occur in most European countries, differing only in extent. The key problems are as follows:

- Excess and inappropriate speed is widespread

The lack of compliance with speed limits is widespread across the EU. Surveys in various Member States show that around two thirds of drivers exceed the speed limit on urban 50 km/h roads and half exceed the limit on single rural roads (ETSC, 1995a). In urban and residential areas, the safety of high risk groups such as pedestrians, older road users and children is too often given much lower priority than the mobility of vehicle users.

Various Member States have demonstrated, with dramatic results, how drivers' choice of speeds can be influenced by the way in which roads and their surroundings are engineered, by imposing and enforcing speed limits and by educating and informing drivers. For example, recent work in Denmark and Germany shows that between 15 and 80 per cent reductions in casualties are possible through area-wide engineering treatment in residential areas. The U.K. has also reported recently over 70 per cent savings in casualties in some localities through use of speed camera equipment, but such activity does not seem to be widespread yet in any one Member State.

ETSC estimates that managing speed to produce a reduction in average speeds of just 5 km/h could prevent over 11,000 deaths and 180,000 injury accidents annually across the EU.

- Many accidents result from excess alcohol

Despite the significant reductions experienced by different countries over the last 10 years, many accidents still result from drinking and driving.

While less than 5 per cent of drivers drive with excess alcohol, they are responsible for at least 20 per cent of the serious and fatal traffic injuries. In the EU this means some 9,000 fatalities per year (ETSC, 1995b). A minor reduction in drinking and driving would make a large contribution to the improvement of road safety.

Most EU countries still have a blood alcohol limit of .80 pro mille in spite of the accident and behavioural research that indicate this limit is far too high. Germany and the U.K. still require reasonable cause for suspicion before breath-testing. Denmark, Ireland and Germany do not accept the results of evidentiary breath-testing in the courts, although this is to change in Germany shortly. All of this creates difficulties for the police and leads to limited enforcement activity, and to drivers' perceptions that the risk of detection is low. It is interesting to note that 78 per cent of EU drivers would support a low EU-wide limit .50 pro mille (SARTRE 1993).

- The accident risk of young novice drivers is too high

Road accidents are the main cause of death of young people. Most of the 15,000 15-24 year olds killed in EU traffic die in the first year after obtaining a driving licence (ETSC 1996d). It is difficult to avoid the conclusion that training regimes have failed the young driver. There has been a general tendency to think that training will solve the problem, but until such time as a scientific base is established for the development of training and testing countermeasures, we should look to demonstrably effective strategies to reduce this tragic waste of young life.

- Non-use of protective equipment such as seat belts and crash helmets

Despite legislation on seat belt use in most countries usage rates vary considerably. Reported front seat wearing rates in EU countries vary between 20 per cent (Greece) and 92 per cent (Germany), but several countries do not monitor usage, and the lower end of the range may be lower still. Rear seat wearing rates across the EU vary between 9 per cent (Greece) and 80 per cent (Sweden). Wearing rates in accidents are generally much lower than those observed from the roadside in normal traffic.

ETSC has estimated that if the lower wearing rates were brought up to the best rate which has been achieved internationally at any one time, then around 7,000 lives could be saved annually in EU countries (ETSC 1996b).

Eighty per cent of the 7000 motorcyclists and moped riders killed annually in the EU sustain fatal head injuries. Crash helmets have the potential to reduce the incidence of fatal head injuries by 50 per cent. This area is not yet the subject of any EU Directive on safety standards.

- Untreated high risk accident sites where low-cost remedial measures could be implemented

Low cost road engineering measures (LCM) can be implemented quickly, and offer high ratios of benefit to cost, for example, small changes in junction operation, road lay-out, lighting, signs and markings. They can be applied at high risk single sites, along a section of route or over a whole area. They are currently being implemented widely and systematically to great effect in some Member States, but not sufficiently in others (ETSC, 1996c).

- Insufficient crash protection provided by vehicles and infrastructure

Accident analysis shows that if all cars were designed to give crash protection equal to the

best in their class then 50 per cent of fatal and disabling injuries could be avoided (ETSC, 1996a).

Over the last few years, the legislative process at EU level has become more sensitive to safety needs and Directives are set to introduce new front and side impact crash test procedures in new types of cars later this year. These legislative standards are world leaders, however, the potential for further improvements is very large. For example, a requirement to make front ends of cars safer for pedestrians and pedal cyclists could save some up to 27,000 deaths and severe injuries annually. A further example is provided by front underrun guard protection which if mandatorily fitted to all heavy commercial vehicles, could save over 1000 lives every year.

At the same time, market forces stimulated by objective, consumer information are leading to much faster improvements in crash protection. The development of EuroNCAP, the new car crash test programme for consumer information, is a major and exciting step forward in Europe, although NCAP programmes have been in existence in the United States and Australia for several years.

The design and siting of street furniture also has a key role to play in reducing injury in the event of a roadside collision.

ETSC believes that significant reductions in deaths and serious injuries are dependent on the extent to which these six problems, in particular, are adequately addressed. Our surveys over the last five years have found that many appropriate solutions exist but still too few are being implemented, even when measures are highly cost-effective and publicly acceptable. So how can the gap between what is known to work and what is actually practised be narrowed?

4. Transport safety strategies with numerical targets

There is increasing recognition, at least amongst safety professionals, that the traffic system has to adapt to the needs, mistakes and vulnerabilities of users rather than depending upon the individual to get it right. Thirty years of research and experience have shown the limitations of over-reliance on the latter approach and have pointed to the need for a range of strategies to address the safety of the whole traffic system. Such strategies include:

Table 7. Strategies to address traffic system safety.

- Establishing data systems
- Identifying accident and casualty problems
- Establishing numerical targets
- Managing exposure to risk

by starting to make the safest modes the most attractive to the traveller
by land use planning

- Preventing accidents
by modifying user behaviour through: -interventions for all users in the form of attitude formation, education, training and enforcement;

- modification of the layout and appearance of roads to influence behaviour for the benefit of all users
- modification of the vehicle to assist drivers in adopting safer behaviour
- modification of the vehicle and infrastructure to reduce the risk of engineering failure or user error
- Reducing injury by improving the design of vehicles in terms both of occupant protection and their propensity to injure the more vulnerable road users they strike, and by adapting the roads and the roadsides so that collisions with roadside obstacles are less likely and less injurious.
- Reducing the consequences of injury by the development and implementation of improved trauma care systems.
- Research and monitoring

ETSC, 1997b

Since the late 1980s, several countries in Europe, the United States and Australia have recognised that strategic safety plans with numerical targets are a useful tool to increase the political priority and resource given to casualty reduction. Targets lead to better programmes and to better use of scarce public funds because they bring about the ranking of measures according to casualty reduction value and provide a focus for the efforts of all agencies involved in casualty reduction. It is unlikely to be a coincidence that the five EU countries with the lowest fatal casualty rates have all had targeted programmes since the 1980s, some since the 1970s whereas those with the highest rates have not.

This data-led, whole-system approach is being used increasingly in road transport and is equally applicable to the transport modes. At international level, ETSC has proposed that the European Union sets numerical targets to provide the focus for all its action programmes.

Table 8. ETSC's suggestion for target levels of safety for each of the modes.

ROAD:	To reduce annual deaths from 45,000 to at least 25,000 by the year 2010 (ETSC,1997b)
SEA:	Achieve an annual average of no more than 140 deaths in European waters between now and the year 2010 (ETSC, 1997c).
AIR:	Achieve an annual average of no more 150 deaths across the EU by the year 2010.

Road traffic and casualty trends indicate that a target of reducing annual deaths from the current level of 45,000 to 25,000 by the year 2010 would be challenging but achievable.

ETSC believes that a reasonable target for both air and sea travel is to maintain the current level of safety. Expressed numerically that means no more than an annual average of 140 maritime deaths at sea and 150 aviation deaths across the EU by the year 2010.

Substantial increases in traffic are forecast across the modes for the next twenty years bringing increased exposure to risk of accident and injury. New action is needed to address the key safety problems in all transport modes at national and international level to achieve safe mobility in the case of road transport and to maintain current levels of safety for all other modes.

References

- ECMT (1997) 43rd Annual Report European Conference of Ministers of Transport, Paris.
- ETSC (1995a) Reducing traffic injuries resulting from excess and inappropriate speed, European Transport Safety Council, Brussels.
- ETSC (1995b) Reducing traffic injuries from alcohol impairment, European Transport Safety Council, Brussels.
- ETSC (1996a) Consumer information on the crash performance of cars: the role of the EU, European Transport Safety Council, Brussels.
- ETSC (1996b) Seat belts and child restraints: Increasing use and optimising performance, European Transport Safety Council, Brussels.
- ETSC (1996c) Low-cost road and traffic engineering measures for casualty reduction. European Transport Safety Council, Brussels.
- ETSC (1996d) Driver training and testing - the need for improvement, European Transport Safety Council, Brussels.
- ETSC (1997a) Transport accident costs and the value of safety, European Transport Safety Council, Brussels.
- ETSC (1997b) A strategic road safety plan for the European Union, Brussels: European Transport Safety Council, 1997.
- ETSC (1997c) Priority measures for maritime accident reduction, European Transport Safety Council, Brussels.
- EVANS (1997) Risk Assessment by Transport Organisations, Andrew Evans, Centre for Transport Studies, University College London, Transport Reviews 1997, Vol. 17, No. 2, 445-163.
- FERSI (1996) Road Safety Research and Policy in Europe, Mission Paper of FERSI, Forum of European Road Safety Research Institutes, Leidschendam.
- SARTRE (1993) Social attitudes to road traffic risk in Europe. Report on principal matters. INRETS, Paris.
- WHO (1996) The global burden of disease: a comprehensive assessment of mortality and disabilities from diseases, injuries and risk factors in 1990 and projected to 2020, C.J.L. Murray, A.D. Lopez, World Health Organisation.

Safety Board Methodology

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Abstract. Transportation safety boards are bodies charged with investigating transportation accidents and incidents and making recommendations to improve transportation safety. The methods of safety boards can be characterised by five processes: initiation, fact-finding, safety deficiency identification, recommendation, and feedback. Tracing the history of safety boards reveals an evolution of their development, where specific stages can be identified which: give the board an independent status to assure the objectivity of its findings, change the focus of the board's investigations from finding fault to determining causation, extend the remit of boards from modality-specific to multi-modality, separate safety deficiency identification as a specific process and major board objective, and look to safety studies of multiple events instead of investigations of single events as the major source of recommendations. A new stage in this evolution appears to be emerging, as some safety boards are expanding their roles to assume responsibility for communication with the public (media, victim groups) as co-ordinators of information and guarantors of due attention to public needs.

1. Introduction

The transportation of persons and goods is an inherently risky business; fortunately, it becomes less risky as time progresses. Accidents have and will continue to occur. When accidents occur, there is a swell of a need to know what happened. This need can be motivated by many factors, including wanting to identify and correct the causes of accidents, deter and punish behaviour that contributes to accidents, or provide closure to a painful event. Over the years, boards of experts have taken on the task of studying accidents and - later - near-accidents or other events that could lead to accidents. Such boards have variously been called accident investigation boards, oversight boards, or - more recently and as is termed here - safety boards. To assist the Dutch government [1] in considering the informational needs and organisational design of a potential multi-modal national safety board (called the TOR from the acronym of its Dutch name *Transportongevallenraad*), RAND Europe, together with Faculty of Systems Engineering, Policy Analysis and Management of the Delft University of Technology examined the development of transportation safety and looked in detail at present-day Dutch and other national safety boards.

From our analysis emerged a generic safety board model, or template of the working processes of a board, by which all of the boards we examined can be characterized [2,3]. This model identifies and links five processes: initiation, fact-finding, safety deficiency identification, recommendation, and feedback. When we applied this template to the development of safety boards, a pattern emerged, as boards grew from arms of the

government charged with identifying the parties responsible for (typically aviation) accidents to independent entities charged with the missions of assuring and improving the safety of transportation and communicating such assurance to the public.

2. Five processes

The five processes of a safety board move the board from the decision to undertake an investigation of one or more accidents or incidents (near-accidents), through the formulation of recommendations to prevent or mitigate future accidents, to assessing the effects of those recommendations. Accompanying these actions are ongoing communications with the involved parties. Not all boards exercise all five of the processes; as we shall see below, part of the evolution of boards is to consistently and explicitly employ all five.

The initiation process is the mechanism used by a board to decide when to take action. A board obtains information about specific transportation accidents and incidents, as well summary statistical information on transportation conditions and events, the results of research relevant to transportation safety, and information about public concerns about safety. For specific events, boards set guidelines to help to determine which events merit an intensive investigation. In the case of aviation accidents and incidents, the International Civil Aviation Organization (ICAO) guidelines are a world standard; similarly, the International Maritime Organization (IMO) has supplied guidelines for maritime investigations. By contrast, there are no uniform international standards for investigating road, rail, or pipeline transportation accidents. When there is a series of similar events or a belief that there may be a general threat to transportation safety, a board may decide to conduct a (proactive or retrospective) safety study of that series or threat. To date, only the United States National Transportation Safety Board (NTSB) and the Canadian TSB have systematic programmes of safety studies.

The fact-finding process is the traditionally thought-of task of safety boards. Expert investigators assemble all the relevant data bearing on an event or events, in order to reconstruct the antecedents of accidents or incidents. The fact-finding is comprehensive in that expertise ranging from metallurgy to human factors are brought into play - no stone is left unturned (at least statistically if not literally) in a major investigation. Fact-finding investigations may be categorised into one of three main types:

- A *reactive event investigation* of an accident or incident. This is the more traditional task of accident investigation boards, and still constitutes the major proportion of effort of most boards. Event investigations, first in shipping and later in aviation, were the starting point of virtually all current multi-modal safety boards.
- A *retrospective safety study* to attempt to determine the common factors in a series of events. This can be an investigation of a set of individual events, a statistically-based study, or some combination of the two. Retrospective safety studies have been used to identify flaws in man-machine systems, technical defects in machinery, unsafe sites and risky carriers. On a more positive note, retrospective safety studies have established the worth of safety improvement devices and policies.

- A *proactive safety study*, in which a board plans a research study that includes primary data collection of events as they occur. Such a study may feature the collection of data not ordinarily obtained in an event, or an intensive scrutiny of a sampling of numerous (e.g. road accident) events, where that sample is based on predetermined characteristics of the situation that might be systemically related. For example, proactive safety studies have examined the role of driver fatigue in road and rail accidents. While there have been relatively few proactive safety studies to date, there is an increasing tendency to consider them.

The safety deficiency identification process takes the facts at hand - be they from single events or from safety studies - and determines systemic threats to transport safety. This process - only recently recognised in the safety literature as separate from fact-finding - is still as much of an art as a science, employing a variety of methods ranging from modern scientific tools such as pattern recognition, multivariate regression, or modelling to qualitative drawing on the experience and judgement of experts in the field [4]. The current frontier of knowledge in safety science is the development of improved safety deficiency identification methods and techniques. Central in this development is the "borrowing" of investigative methods from one transportation mode (e.g. air) by another (e.g. rail).

The recommendation process formulates effective steps to prevent the occurrence or mitigate the harms of accidents. While the need to implement some recommendations follows directly from the facts of an accident (e.g. make sure that the hatch doors of a DC-10 or a ferry boat cannot open once underway), others - especially those which impose large economic costs or might discriminate against some carriers - might not readily be accepted even though they would increase safety [5]. Therefore, many boards carefully frame their recommendations so that they are economically and politically acceptable. The recommendation process can - depending on the relationship of the board to the other stakeholders - include considerations of how the proposed actions might best be implemented.

The feedback process maintains contact between the work of the board and the external public world, including government, carriers, site operators, passengers and freight owners, accident victims and their families, and the general public. The most expansive feedback process is the one maintained by the United States NTSB, which consists a systematic monitoring of all of its recommendations, both in terms of the actions taken in response to the recommendations and the effects of these actions on transportation safety. Other parts of a feedback process can be in the form of an outreach program of public awareness, not only of the work of the board but of progress in transportation safety. The Canadian TSB publishes quarterly magazines for aviation, rail, water, and pipeline transportation to increase public awareness of its work. Again, the U.S. NTSB is famous is its ongoing list of the "dirty dozen" threats to transportation safety which would be ameliorated were its recommendations implemented. The feedback process often leads to new information for the board which can generate further safety studies. Because of the central role of safety boards in supervising the information gathering after an accident, there is a movement towards giving such boards the role of central information source immediately after an accident - in particular co-ordinating assistance for victims and information and care provision for families of victims [6].

Figure 1 displays a schematic of the five processes as they are performed in a contemporary safety board. Before a board comes into action, it is informed by different sources in the outside world, including accidents and incidents reported to it, statistical reporting of accidents and other safety-related data, safety and other research, and public opinion. Each of these inputs plays a potential role in the initiation process of the board. Although the model is presented as a logical flow from initiation through feedback, the real world is not so linear. A fact-finding investigation can lead to a perceived possible need for the study of more events, which necessitates a return to the initiation process. In looking for systemic safety deficiencies or effective recommendations, knowledge gaps in the facts at hand may be detected, leading to further work within the fact-finding process. The feedback process, especially as it involves communicating with the different stakeholders, can occur in parallel with all of the other processes.

3. The evolution of safety boards

Viewing the history of safety boards in the light of this five-process model reveals an evolution of safety boards. The original accident investigation boards were modality-specific (first maritime, then aviation) quasi-judicial arms of the transportation ministry or corresponding governmental agency charged with conducting investigations to determine responsibility for accidents. In terms of Figure 1, they only initiated investigations after an accident and reported the results of their fact-finding. There was no safety deficiency analysis, few recommendations for safety improvement, and little public visibility. A contemporary safety board is an independent, often multi-modal organisation charged with maintaining public confidence in transportation safety through the introduction and promulgation of empirically-based recommendations that address systemic deficiencies in transportation safety. Between these two contrasting pictures of a safety board, we have observed boards at different stages on this evolutionary path, responding to the needs of the times and the experiences of their predecessors.

Independence. Most transportation safety boards began as arms of the government (or possibly as agents of the transportation industry), charged with determining responsibility for accidents. This was rapidly realised to be problematic when the board's "owner" was one of the responsible parties. That is, nonindependence introduced an inherent potential conflict of interest that all too often was realised. The response was to give the board an independent status in order to assure the objectivity of its findings. In other words, boards were separated from their parent ministries or owners so that they could investigate with equal impartiality any actor contributing to an accident. While governments have from time to time painfully felt the consequences of this independence, its necessity is almost universally recognised.

While all boards have some form of independence, this can differ from country to country. The U.S. NTSB and Canadian TSB find their independence in their legislative mandate; they do not answer to any ministry or department, but directly to Congress/Parliament (with administrative oversight but no control from the executive

branch of government). The Finnish board is supervised by the Ministry of Justice; in this way it is free from the influence of the Ministry of Transportation. Other multi-modal boards find their freedom in the legislation establishing the board; still others, although nominally responsible to a Ministry of Transportation, have a tradition sufficiently well-established so that effective independence is maintained.

No fault. The next step in the evolutionary path comes from the recognition that an investigation into responsibility for an accident will produce evasive behaviour on the part of actors who believe that they might (rightly or wrongly) be found at fault. If a board wants to find out how an accident occurred, it needs to abandon the goal punishing the actors contributing to its occurrence. That is, if the objective of the investigation is to fully understand what happened, then there must be some form of "protection" that will allow parties to contribute knowledge to that understanding even if that knowledge is self-damaging. The move away from finding fault is sometimes accomplished by legislation assuring that information obtained by the board cannot be used as evidence in a fault-finding proceeding. Full recognition of the need of a safety board to avoid fault-finding was perhaps first signalled by the formal mission statement of ICAO [7] to determine the most probable cause of an accident. To this date, most but not all safety boards have fully moved away from fault-finding and the sanctioning of guilty parties; there remain groups who believe that the investigative power of safety boards should be used to resolve issues of punishment and restitution for losses, as well as providing a deterrent force against unsafe behaviours. However, almost all boards inaugurated in the past fifty years have had some form of ability to protect information sources from self-incrimination.

Multi-modality. An important stage in the evolutionary path is the establishment of a transportation safety board whose remit is across modes of transport. Presently, independent multi-modal boards exist in the United States, Canada, New Zealand, Sweden, Finland, and Russia; the Netherlands is likely to inaugurate its board soon. Most of these multi-modal boards can trace their heritage to aviation safety boards, with other modalities added in at this stage. The Dutch TOR - which will combine previously separate single-mode boards to create the multi-modal board - is unique. Interestingly, although there were maritime and inland waterway boards before the invention of the aeroplane, these boards did not form the basis of either aviation accident investigation boards or multi-modal boards. The move to multi-modality was typically triggered by the recognition that the improvements in aviation safety needed to be extended to other modalities, not by any notion of economies of scale of investigating different modalities. More recently, there is overt recognition of the additional benefit of cross-modality and common-modality conceptualisations of accident prevention. Multi-modal boards do not necessarily cover all modes of transportation and are not limited to transportation. For example, the Canadian TSB and Finnish boards do not investigate road accidents; the Swedish board has the power to do so, but has not yet conducted a road accident investigation. The U.S. and Canadian boards investigate pipeline accidents, but the Dutch TOR - as presently structured - will not. The Swedish board also investigates major accidents at certain fixed sites (primarily dealing with infrastructure) as well as transportation.

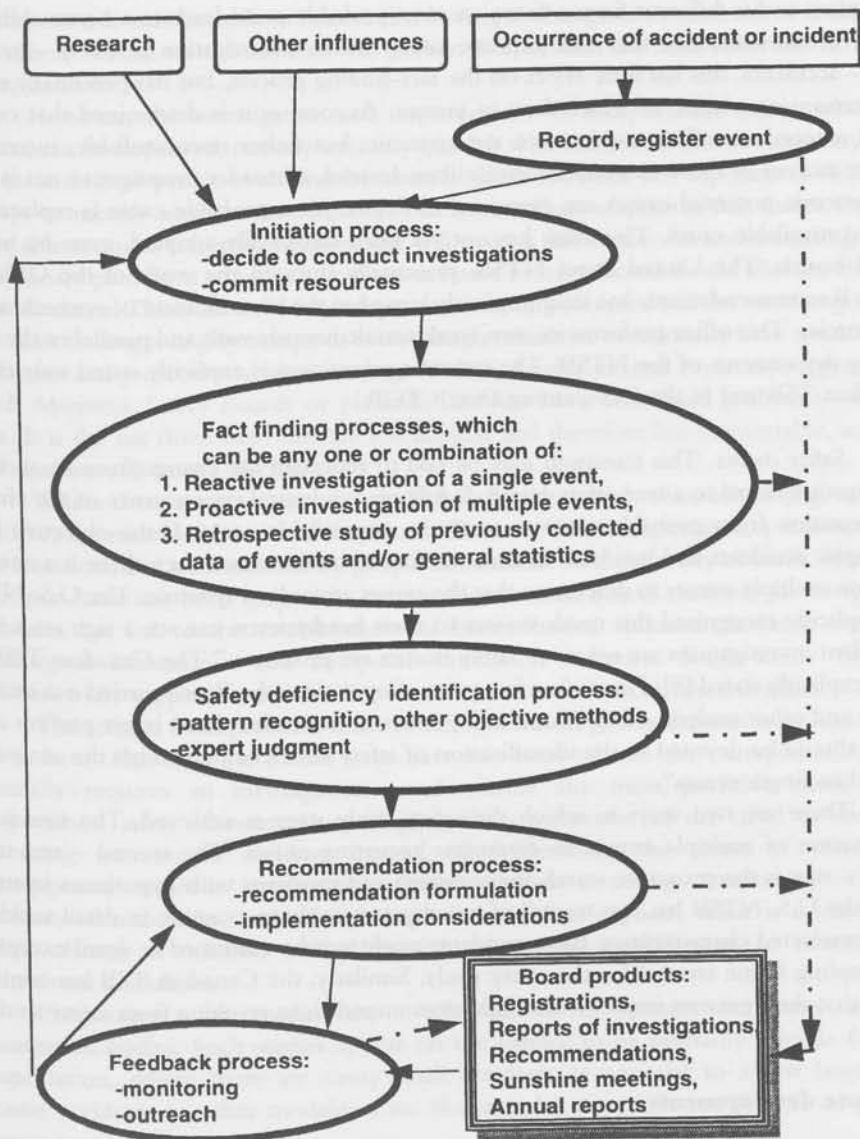


Figure 1. Processes in a contemporary Transportation Safety Board.

A systemic perspective. This evolutionary step is a crucial conceptual change of focus from identifying the most probable cause of an accident to identifying systemic safety deficiencies. That is, the purpose of an investigation is changed, so that the orientation of fact finding is towards finding factors that might produce future accidents rather than detecting the cause of the accident under investigation. While all transportation accident investigation boards look for systemic safety deficiencies, the realisation that the focus must

be explicit and is different from a focus on most probable cause leads to a better ability to make recommendations that will improve safety. In the investigation of many - perhaps most - accidents, this has little effect on the fact-finding process, but has potentially major implications on choice of which facts to pursue. As soon as it is determined that certain causal antecedents of an accident are not systemic, but rather uncontrollable, interest in deeper analysis of those antecedents diminishes. Instead, a broader investigative net is cast, and systemic potential causes are examined in depth. Most probable cause is replaced by most controllable cause. This stage has not yet been universally adopted, even by multi-modal boards. The United States NTSB, principally through the work of the Office of Safety Recommendations, has long implicitly aimed at the identification of systemic safety deficiencies. This office performs its own work simultaneously with and parallel to the fact-finding departments of the NTSB. The systemic orientation is explicitly stated only in the Canadian TSB and in the forthcoming Dutch TOR.

Safety studies. This transition may be said to represent the change from an accident investigation board to a true safety board. It follows as a logical consequence of the change in orientation from probable cause to systemic, controllable cause. If the objective is to investigate accidents and incidents in order to find systemic causes, then there is a need to examine multiple events to determine that the causes are indeed systemic. The U.S. NTSB has implicitly recognised this need; visitors to their headquarters can see a sign on a wall, "Accident investigations are reactive. Safety studies are proactive." The Canadian TSB has more explicitly stated [8]: "In its first five years of operation, the Board carried out enough studies and other analyses of significant safety issues to determine that a larger portion of its efforts should be devoted to the identification of safety deficiencies through the analysis of other than single events".

There are two ways in which the safety study stage is achieved. The first is the examination of multiple events to determine recurring causes. The second - and more radical - step is the proactive search for accidents and incidents with hypotheses in mind. Thus, the U.S. NTSB has "go teams" of investigators ready to examine in detail accidents with preselected characteristics; these accidents might not be examined in detail except for the sampling frame created for the safety study. Similarly, the Canadian TSB has come to realise that their greatest impact is through recommendations resulting from safety studies.

4. Future developments

Solidifying recent progress. The evolutionary path of safety boards is not inevitable, but it does seem to be a good prognosis of the future. Each step in the evolution represents a potential improvement in transportation safety, as the independence, availability of information, and scope of investigation are broadened while the focus of the investigation is narrowed to systemic safety deficiencies which may be controlled. However, each step in the evolutionary path represents a break from established tradition, and there are always those who perceive threats to their "rice bowl" (to put it negatively) or proven effective work processes (to put it positively). This is perhaps particularly true for agencies with good

records; it is not unreasonable to believe that having to change one's methods to correspond with others' whose records are less-well proven will weaken the field. After all, "if it ain't broke, don't fix it."

However, the investigation and improvement of transportation safety, while not broken, can be improved; nobody seriously quarrels with this point. The evolutionary path, like its analogical parent evolution by natural selection, does not represent a deliberate attempt to modify accident investigation, but is instead an adaptation that makes the field better able to make recommendations that will make a difference. An understanding of the evolutionary path from accident investigation board to safety board should alleviate the fears of the doubters. Thus, the need for independence is fully accepted and the need to get away from fault finding is largely accepted, even though ministries occasionally have trouble with the former and prosecutorial agencies (e.g. the U.S. Environmental Protection Agency, the Dutch Maritime Safety Board) or plaintiffs' lawyers have occasional problems with the latter. It is the last three steps that are less familiar and therefore less comfortable, and it is these that we will briefly discuss.

Where there are not yet multi-modal boards, the modal communities (e.g. aviation, maritime) are mistrustful, because they fear a dilution of their importance, a diminution of their resources, and a domination by people not familiar with their way of work. However, these fears have not been realised in current multi-modal boards. Indeed, the merging of modalities has led to the establishment of better-funded technical facilities, including metallurgical laboratories and computer simulation software. Single-mode expertise continues to be supported, and can draw on these extra resources when needed.

The refocus from probable cause to safety deficiency identification is an idea whose time is here. Although the formal steps have not been taken - for example, ICAO still nominally requires an investigation to determine the most probable cause - the transportation safety literature increasingly reflects awareness of the need to focus on preventing tomorrow's accident instead of determining the cause of yesterday's. Contemporary accident investigation reports include a strong component of safety deficiency identification, even if it is implicit instead of explicit. What is needed is an explicit change of mission, ratified by the appropriate modifications to national and international guidelines.

Prospective safety studies are a relatively novel concept for many accident investigation bodies. Such studies appear on the surface to be primarily suitable for road transportation, where there are many small accidents as opposed to a few large ones. Because accidents in other modalities are (fortunately) rare, it is not feasible to plan in advance to study them.

But proactive lessons can be learned if phenomena other than accidents are used to form the basis of the sampling frame. In aviation, for example, ICAO guidelines require some investigation of virtually all aviation events; these events could be the basis of a prospective investigation.

The next evolutionary step. It is interesting to conjecture that the next step in the evolution of safety boards will be towards the role of public safety assessor. Safety boards already function as central gatherers of information, and it is a short step to transform them

into central information disseminators as well. As mentioned above, the U.S. study following the TWA 800 disaster strongly urged the U.S. NTSB to take on a role as a clearinghouse for informing the public and victims' relatives following a disaster, as well as seeing that the appropriate ameliorative steps are taken to reduce the tragic consequences of any accident. It is not difficult to see safety boards as transportation ombudsmen, the principal advocate for the safety of transportation and the appropriate care of victims of accidents. As with the previous evolutionary steps, there will be opponents to this change, but if this new role for safety boards fills a public need, it will most likely evolve into being.

References

- [1] Tweede Kamer der Staten-Generaal Vergaderjaar 1994-1995, 23674, Instelling van een Raad voor de Transportveiligheid [Installation of a Board for Transportation Safety], 's-Gravenhage, 1995.
- [2] J.P. Kahan, J.A. Stoop, L. van Dorp, E.J. Frinking, E.M. van der Horst, and K.M. Malone. An Inventory of Transport Safety Information In the Netherlands, Santa Monica, California: RAND Report MR-776-EAC/VW, 1996.
- [3] J.P. Kahan, L. van Dorp, E.J. Frinking, J.A. Stoop, and E.M. van der Horst. Modellen voor een TOR [Models for a Transportation Safety Board], Delft, the Netherlands: RAND Europe, Report RE-97.05, 1997.
- [4] J.L. de Kroes and J.A. Stoop, eds., 1st World Congress On Safety of Transportation 26-27 November 1993 proceedings, Delft, the Netherlands: Delft University Press, 1993.
- [5] R. Hillestad, K. Solomon, B. Chow, J.P. Kahan, B. Hoffman, S. Brady, J.A. Stoop, J. Hodges, H. Kloosterhuis, E.J. Frinking, and M. Carillo. Airport growth and safety: A study of the external risks of Schiphol airport and possible safety enhancement measures. Santa Monica, California: RAND, Report MR-288-EAC/VW, 1993.
- [6] White House Commission on Aviation Safety and Security, Final Report to President Clinton, Washington, D.C.: Department of Transportation, 12 February 1997 (available on the internet at <http://www.aviationcommission.dot.gov/212fin-1.html>).
- [7] International Civil Aviation Organization, Aircraft Accident and Incident Investigation, Eighth Edition, Montréal, Québec, Canada: July 1994.
- [8] Transportation Safety Board of Canada, TSB occurrence classification policy, Hull, Québec, Canada: no date.

Safety Board Operational Experiences

Benoît Bouchard

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I am pleased to be here and participate in a congress on transportation safety. Interest in the subject is obviously high when so many individuals have come here from all over Europe and overseas. I believe that we are particularly fortunate in having the continuity that comes from returning to Delft where so much important safety information was exchanged at the First Congress in 1992.

It is well known that Canada has a particular geography - 10 million kms² - with a widely distributed population of 30 million people who expect and desire a very extended but safe transportation system. For more than 100 years transportation has defined Canada. Those expectations and concerns led to the Canadian Transportation Accident Investigation and Safety Board which began operations in 1990. It is commonly known by its shorter applied title, the Transportation Safety Board of Canada or simply the Transportation Safety Board.

The TSB was not the result of a sudden inspiration. Canada first recognized the need for some kind of transportation accident investigation agency well over twenty years ago. However, public acceptance of the idea came slowly. Acceptance of the notion developed first in aviation where the public demand for information following major accidents is generally most vigorously stated.

In the time between the general recognition that a transportation accident investigation agency was needed and the time when specific proposals were put forward to Parliament, there was a great deal of discussion and study. Many issues were considered and it quickly became apparent that there was no clearly superior concept and that many interests would have to be considered and balanced. Among the questions that we considered were: Should the agency be court-like? Should it have the authority to order changes? Should there be privilege attached to some of the information that it would obtain? What modes of transportation would its mandate cover? Should it be independent, and so on. Over time three factors came to dominate Canadian thinking. First, that the body should be as independent as possible. Second, that it should be structured to gather information quickly so that safety problems could be addressed and risks to the public could be identified in the shortest possible time. Third that the mandate should extend beyond individual accidents where that would help identify systemic safety problems.

The first Parliamentary initiative was when a member of Parliament introduced the concept of a transportation accident investigation authority separate from the regulator. Then there was a proposal for a Commissioner of Transport Accident Investigation but that didn't become law. A short time later, in 1978, there was a major aircraft accident in western Canada that raised public concerns about both the safety of air travel in Canada and the objectivity of the government's accident investigation practices. A formal commission

of inquiry was established to look at air transportation and accident investigation. Many of the issues that had been under consideration for several years were examined publicly by the Commission.

The Commissioner recommended the creation of an independent safety board to investigate aviation accidents and incidents. It proposed the provision of privilege to certain types of information to encourage people to come forward quickly, freely and without fear of any form of penalty. It accepted the notion of identifying safety deficiencies which would tend to be systemic and which need not relate to cause. The Canadian Aviation Safety Board came into being in 1984 and began its work to the satisfaction of Canadians.

Not long after the government, in which I was a Minister, decided to apply the principles of the Canadian Aviation Safety Board to other modes of transportation. The intent was to have a measured and rational analysis to produce legislation for a new transportation safety board with a wider mandate. The investigation principles of the aviation safety board were believed to be sound. However, plans for a calm debate were swept aside by controversy. A DC-8 registered in the United States, which was bringing 248 peacekeepers home from the middle east for Christmas 1985 crashed on take-off after a stop for fuel at Gander, Newfoundland. The investigation began normally and the Board held a short public inquiry. All was proceeding as expected when disagreement developed among the Board Members. There were ten members and one faction became dissatisfied with the leadership of the Chairman and began to distrust the staff. What followed was a power struggle within the Board that spilled over into public view. Seeds of doubt were sown to discredit the Chairman and investigators. Arguments that could have taken place rationally within the Board were exposed to the media who took full advantage of the opportunity to expose the allegations of sloppiness, dishonesty, cover-up, conspiracy and anything else that seemed of interest to Canadians.

In the midst of all this I was appointed as Minister of Transport. I remember that it was a difficult time. Public confidence in the safety of the transportation was being eroded by the endless stream of allegations. There was a need to verify that the principles in the Aviation Safety Board legislation were still applicable to a multi-modal transportation safety board. There was a need for rational debate in an emotionally charged climate. With a great deal of concentration and very little time we confirmed that the principles for investigation were sound. We found that the Board of ten members was too large. We found that the Chairman needed more authority to direct the work of the agency without compromising the independence of the Board Members in their making of findings and recommendations.

I gave a great deal of my attention to the development of the legislation. It dealt with creation of a small agency to investigate transportation accidents and incidents, but it had the potential to disrupt much of the commercial and political activity of the country unless we got it right. We saw that with the DC-8 accident at Gander, Newfoundland, which I have just described. The "Gander" debate was laid at the feet of the government ministers responsible and consumed considerable time in Parliament. It produced no useful outcome and caused an unwarranted loss of public confidence in the safety of the national transportation system. The new legislation passed Parliament and the TSB began its job of investigating transportation accidents and incidents and it gave the public reason to restore its faith in the transportation accident investigation process. I moved on to be the Minister

for other Departments and eventually chose to leave active politics. A short time later I was asked to go to Paris for three years as the Canadian Ambassador to France. The new legislation had been in place for six years by the time I returned to Canada. I had mixed feelings of surprise and pleasure when I was asked if I would become Chairman of the Transportation Safety Board as soon as I returned to Canada. I was also pleased that I had taken so much care in the formulation of the principles that would be put into the legislation of the Board.

With the experience of almost eight years of operation we are pleased with the Board and its work. There are some amendments to the Board's legislation before our Parliament right now, but they are minor and are to respond to some government initiatives, to tidy up some administrative matters, and to enhance operating practices and independence. Nevertheless, the time has come to bring some carefully thought through change to the Board's operating style.

The Board has steadily earned its reputation with Canadians and the time has come to make it better known. First, because the findings and recommendations of the Board will be more quickly accepted and have more credibility if the agency is better understood. Second, because Canada has made major changes to its transportation system in the past few years. These changes bring new opportunities of commercial development but they also bring new management and financing arrangements and possibly new areas of risk. As an idea of the magnitude of the changes. Air Canada, which is the nation's largest air carrier has been sold by the government to private ownership. The Canadian National Railway, the nation's largest railway has moved from government to private ownership. Most of the country's airports have passed from the Department of Transport to local operating authorities. All the air navigation aids and the operation of the air traffic control system have been sold to a non-government and not-for-profit corporation. Ports and harbours are being passed to local operation. The degree of economic regulation has been significantly reduced. The point is that there have been many profound changes to the system. They were looked at by the government and assessed for safety before the changes were made. In the work of the TSB we have not seen anything inherently unsafe in the new arrangements. However, if there are major accidents the new arrangements will be questioned by the public and by well organized interest groups. The TSB will be expected to conduct a quick and objective analysis of such accidents. It will need the full support of the public to have its recommendations accepted. It will need to be somewhat better known and understood to be sure of such support.

I have referred to the TSB as a multi-modal accident investigation and safety organization. But while we consider all modes of transport of equal importance, over half of our investigations are in the air mode. We also have the mandate for maritime investigations. Finally, we investigate railway accidents and incidents, and we investigate oil and gas pipeline accident investigations. In North America, the United States and Canada both consider the movement of oil and gas as a form of transportation. There is one other obvious form of transportation that I have not mentioned, which is road transport. That is the mode in which over 90% of transportation fatalities occur. In the Canadian federation, most road transport is within the jurisdiction of the provinces and most of what is not within their jurisdiction has been delegated to them. The question of federal investigation

of at least some road accidents is often debated, but like other issues involving our constitution, it is not likely to be changed significantly in the near future.

Now, I would like to touch slightly on some technology issues. The transportation industry is evolving rapidly and investigators need to be able to analyse the latest applications of technology. New materials are being introduced and there is limited information about the life span, aging characteristics and failure modes of some of these materials. Computer hardware and software is being used more extensively in all modes of transport. Many new aircraft have no mechanical connection between the pilot and the control surfaces. Computer signals move the controls and much remains to be learned about how such systems fail and how the failures can be analysed. While many of these systems are complex and difficult to analyse, there is also a bright side. First, these new systems and materials tend to be more reliable than their predecessors. Second, much of the new technology is available to investigators. Such things as laser theodolites, infra-red photography, and data recorders are regularly used tools of investigators. In Canada, we have done some pioneering work in the analysis of flight data recorder information. We can analyse information by computer in a few days when just a few years ago the same process would have taken months. Now, that information can be transformed into animations that make the analysis much easier to understand. While we did the original work on the computer analysis of the recorders we now work on a cooperative basis with several countries to determine new requirements. We share the analytical software and we share the costs. We believe that recorder analysis is important for all modes of transport. We have developed a draft statement of requirements that lists the features to be recorded to give a similar level of confidence in the data, regardless of mode. We have done that from our own perspective and recognize that the same philosophy needs to be applied to road transport to make the package complete. We have started consultation on the paper and hope to have something to propose to the regulatory authorities in the coming months.

For Canada, the most privileged mechanism to share information with other countries is the International Transportation Safety Association or ITSA. The accident investigation agencies of several nations belong to the organization to promote the free sharing of safety information. It is one of the places where we can take test our ideas and compare our initiatives. We all believe in the importance of independence and objectivity. This congress is proceeding in the spirit of ITSA and all of us who are members hope that other nations who want to advance independent, objective transportation accident investigation will consider membership in the ITSA.

To conclude, safety in transportation remains, as I said at the beginning, one of the most sensitive issue for the Canadian population. We know in our country that we will travel frequently and for long periods. Therefore, safety remains unconditional and that explains why Canadians are so demanding for safety regulations and their strict application. That also explains why they want a very independent safety board to analyse objectively and quickly any safety failures in the transportation network.

Air Transport Session 1 Empirical Model

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Context and Policy

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Abstract. Whether passengers should be given freedom to choose whether to fly is a question that has been discussed since the early days of aviation. World War II and more evidence on the benefits regarding lower prices led to the deregulation of the airline industry by the Airline Deregulation Act of 1978. In the years that followed, there was a change in the economic nature of the industry. The main effect of this was a period of 11 years during the period 1980-1990, in which airlines were included plus some other international airports that will be used as a control group. This study examines the effects of the deregulation of the airline industry and is fully available for the whole period, while also including level of industry concentration and prices from 1980-1990 and 1991-1995. The study examines the effects of deregulation on the industry and on the level of industry concentration. The study also examines the effects of deregulation on the level of industry concentration and on the level of industry concentration. The study also examines the effects of deregulation on the level of industry concentration and on the level of industry concentration.

1. Introduction

When a passenger decides to use the air transport mode he does so because whether he is choosing it over a mode or a city centre. However, there might be some way of signal that would allow him to purchase information and enter the cost of service for his choice.

In this literature we may find several references on the price elasticity of air transport. The works by Rose make use of 1970s-1980s data and suggest the hypothesis that operating with greater flexibility would be able to allow airlines profits should be closely supervised by civil aviation authorities. Nevertheless, it might be possible that the price mechanism would be providing a similar signal, in such a case passengers would have another decision, certainly more available for them than airlines profits, which is how much to pay for the level of safety for its flights.

The purpose of this paper is to check whether the price signal is available and to confirm previous results of the literature regarding the price-safety link by using European airlines data.

Air Transport Safety: An Emperical Model

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Abstract. When a passenger boards a plane he does not know whether he is choosing a safe or a risky airline. However there might be some sort of signal. We can already find some evidence in the literature regarding how profits influence the level of safety, though the signal might be also found through the price mechanism. In this paper we try to test if cheaper or less profitable airlines means a greater risk of accident. The data utilised to that end is a panel of 31 airlines during the period 1970-1995. All AEA members are included plus some other international carriers that will be used as a control group. Data about accidents is collected from The World Directory of Airliner Crashes and is fully available for the whole period, while data regarding level of activities, costs and revenues come from AEA Yearbooks and IATA (WATS) and ICAO (Financial Data) publications, though for the period 1984-1995.

Preliminary results using Poisson estimates and controlling for different levels of exposure, suggest a negative and robust relationship between number of fatalities and profits. This implies that in a period characterised by tight controls, airlines have managed to escape the civil aviation controls on safety or that these have proved to be imperfect. With respect to prices results are not conclusive.

1. Introduction

When a passenger decides to use the air transport mode he does not know whether he is choosing a safe or a risky airline. However there might be some sort of signal that would allow him to get more information and infer the sort of carrier he has chosen.

In the literature we may find several references to the profit variable as an indicator of the level of safety with which air carriers operate (Golbe, 1986; Rose, 1989 and Rose, 1990). The works by Rose make use of US air carriers data and support the hypothesis that operators with greater profit margins would be safer, and hence airlines profits should be closely supervised by civil aviation authorities. Nevertheless, It might be possible that the price mechanism would be providing a similar signal. In such a case passengers would have another element, certainly more available for them than airlines profits, with which to form beliefs about the level of safety for an airline.

The purpose of this paper is to check whether the price signal is available and to confirm previous results of the literature regarding the profit-safety link by using European carriers data.

2. The data set

The data set utilised is integrated by a group of 31 airlines that includes all AEA members and 10 non European airlines that are utilised as a control group. Data on accidents come from the World Directory of Airlines Crashes (1996) and are incorporated to the data base for the 1970-95 period. Data regarding revenues and levels of activities for European airlines have been found on several Yearbooks and Statistical Appendices published by AEA and are available for the period 1984-1995. Information concerning non-European carriers has been obtained from the World Air Transport Statistics that IATA publishes yearly for the period 1985-1995. Finally costs data were collected from the publication Financial Data that ICAO edits also yearly.

Data on revenues and costs are found on original sources already converted to US dollars and are deflated by using the GDP deflator for the US economy [1]. Nevertheless and alternatively, we could deduce inflation by using national inflation indexes for each company, however the international nature of airline service and hence, the international nature of airline costs make us to chose the above mention deflator.

3. Descriptive analysis

A first approach to the data set is given by Figures 1 to 6, where we group European airlines on one side and non-European on the other. With respect to the European group and the number of accidents variable, it stands out THY (Turkish Airlines) followed very closely by the spanish, the french and the hungarian flag companies. In terms of number of fatalities it is again the turkish company which gets away from the others. It should be pointed out the very low number of fatalities that Air France experiences in spite of having suffered 10 accidents. It is also important to emphasise that there are four companies with zero accidents (Air Malta, Finnair, Icelandair and Luxair), and other cases with zero victims in spite of having experienced some accidents (Aer Lingus, Sabena and SAS).

With regards to non-European companies it is outstanding the situation of the australian company Qantas that has not had any accident on its recent history. By number of accidents TWA (Trans World Airlines) stands out, though the japanese flag company is the one with the highest number of fatalities. Nevertheless a more rigorous analysis that would take into account differential features of airlines is required in order to get a conclusion regarding the level of safety with which these operate.

The analysis of trends shows that for both groups of companies there is an stabilisation phenomenon on last years, however for AEA members there seems to be a more erratic behaviour. On the contrary non-Europeans rates move softer around its trend. Finally when one compare rates by groups it happens that Europeans seem to be riskier. Again a deeper analysis is required before reaching a final conclusion, such a task is performed on section 4.

4. Econometric analysis

Regarding estimation procedures we seek to analyze the nature of the relationship between safety and airlines fares and profits. Safety can be measured in different ways, among them we have chosen in this section number of fatalities. With respect to fares these are approximated by average revenues while profits are introduced as operating margins. To do this we use the panel data set described above and estimate several poisson models by pooling data [5], so the number of fatalities in a period are explained by several factors that are introduced as averages for the period considered.

For the econometric analysis we take the period in which all relevant variables are available, this is 1984-1995 (for non-European airlines the period starts on 1985). We have tested for the poisson distribution of number of fatalities and it happens that it actually behaves as a poisson variable. As we are interested in the effect of prices and profit margins on safety we have to estimate two types of models:

1. We estimate a model for the variable number of fatalities per company using the factor passengers-km as the exposure variable. As a first step and in order to analyse the impact of fares upon safety we make use of average revenues (yield) and total operating costs as the main regressors. Secondly, we search for the so called profit-safety link. Results from these estimations are reported on Table 1.
2. We repeat the same process but using the variable number of landings as the exposure factor. Estimates for these models are reported on Table 2.

Additionally for both types of models we make the estimation for the whole group of companies and then we separate for European and non-European in order to test for the robustness of results. Relevant variables for econometric modelling are presented on the following table:

NFPC	Number of fatalities per company*.
ARE	Average revenue in terms of passengers-km (\$ cents).
OCOST	Total operating costs (thousand dollars).
OPEMAR	Operating margin defined as $(p-c)/p$ (\$ cents).
AVEDIS	Average distance by flight.
TYPEDUM	Dummy variable that takes value one for European companies and zero otherwise.
PASKM	Passengers-Km (thousand).
NLAND	Number of landings (thousand).

* If the carrier has not had any accident it will appear as having also no fatalities.

Results from Tables 1 and 2 are capturing a negative and robust relationship between profits and number of fatalities. This means that less profitable airlines are, for all groups, always riskier. However variable ARE is not behaving as expected. Only for European airlines we have found that those carriers with lower yields are experiencing more fatalities. This result

should be interpreted in the sense that having controlled by total costs and other factors, cheaper European airlines would be riskier. However this can not be considered as a signal by passengers as they are not able to discern, as econometrics does, if lower prices are due to improvements on efficiency or safety costs cuts.

Table 1. Parameter estimates for the rate of fatalities per passenger-km (thousands).

Variables	All companies		European companies		Non-european companies	
	ARE	0.345*	-	-0.077*	-	0.863*
OCOST	-0.085*	-	-0.781*	-	0.137*	-
OPEMAR	-	-1.408*	-	-2.285*	-	-11.491*
AVEDIS	0.001*	0.001*	8.5e-04*	5.6e-04*	8.5e-05	0.002*
TYPEDUM	-0.680*	-0.174*	-	-	-	-
CONSTANT	-17.697*	-15.576*	-12.249*	-15.076*	-20.011*	-20.175*
Goodness of fit	Chi ² (19) = 1994.5	Chi ² (20) = 2249.5	Chi ² (12) = 744.2	Chi ² (13) = 1058.3	Chi ² (4) = 372.9	Chi ² (5) = 900.7

*:Significant at 5%

Table 2. Parameter estimates for the rates of fatalities per landing.

Variables	All companies		European companies		Non-european companies	
	ARE	0.354*	-	-0.164*	-	0.910*
OCOST	-0.023**	-	-0.634*	-	0.160*	-
OPEMAR	-	-0.772*	-	-1.678*	-	-13.730*
AVEDIS	0.002*	0.002*	1.5e-04*	0.001*	0.001*	0.003*
TYPEDUM	-0.712*	-0.064	-	-	-	-
CONSTANT	-7.182*	-4.647*	-0.683	-3.973*	-9.858*	-10.414*
Goodness of fit	Chi ² (19) = 2005.3	Chi ² (20) = 2416.1	Chi ² (12) = 724.2	Chi ² (13) = 998.5	Chi ² (4) = 411.9	Chi ² (5) = 985.8

*:Significant at 5%

** : Significant at 10%

Another important variable is TYPEDUM that is capturing just an opposite effect to those captured by Figures 5 and 6. European airlines, once special differential features are considered, are not riskier than the group of non-European, having a similar or even better fatality rate than non-European.

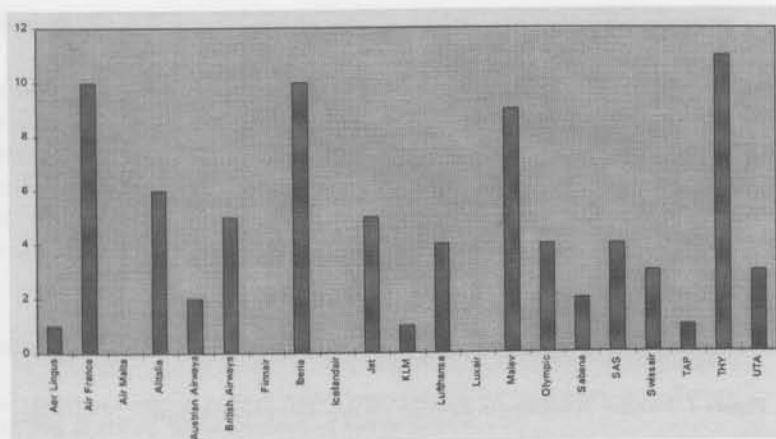


Figure 1. Number of accidents for European companies, 1970-1995

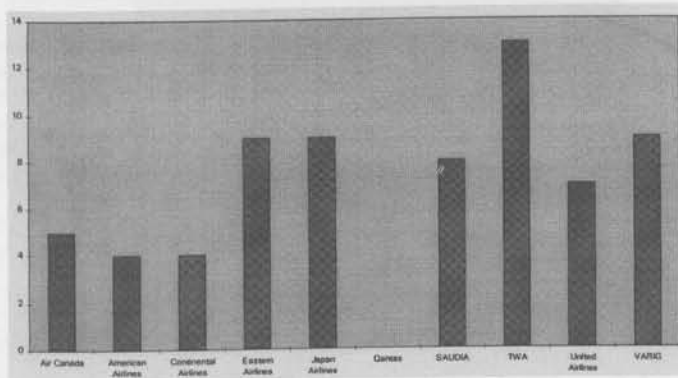


Figure 2. Number of accidents for non-European companies, 1970-1995

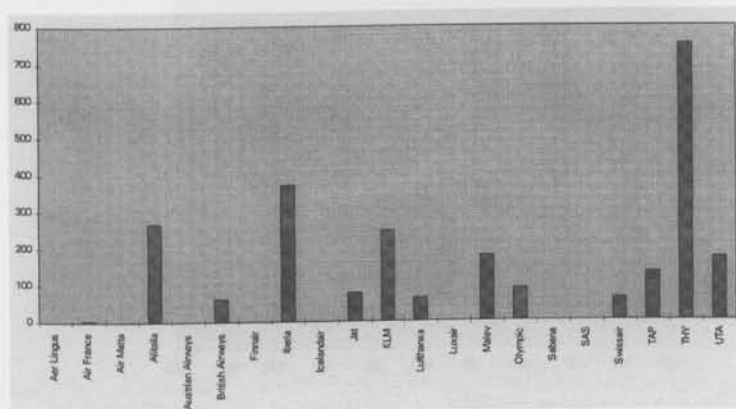


Figure 3. Number of fatalities in accidents for European companies, 1970-1995

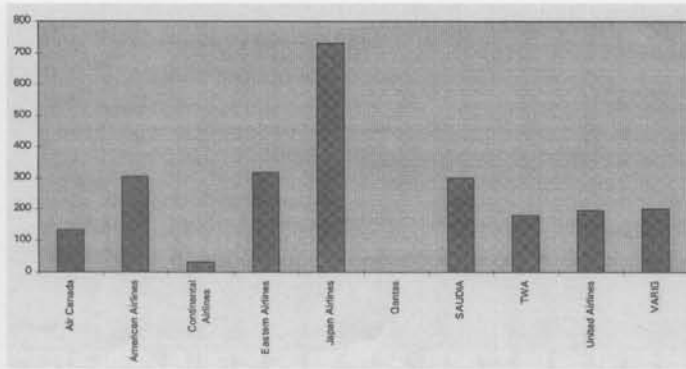


Figure 4. Number of fatalities in accidents for non-European companies, 1970-1995

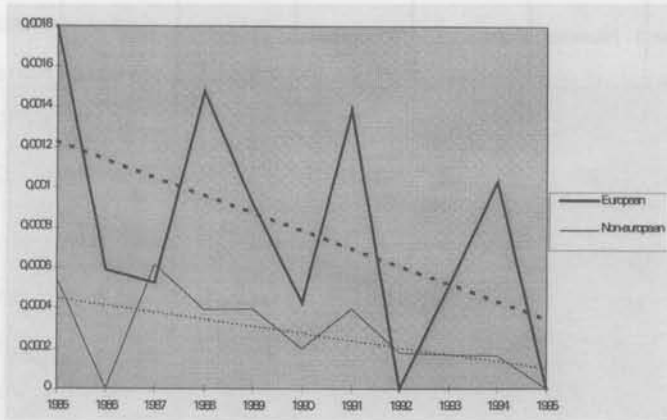


Figure 5. Comparison of accident rates per each 100 million passenger-km, 1985-1995

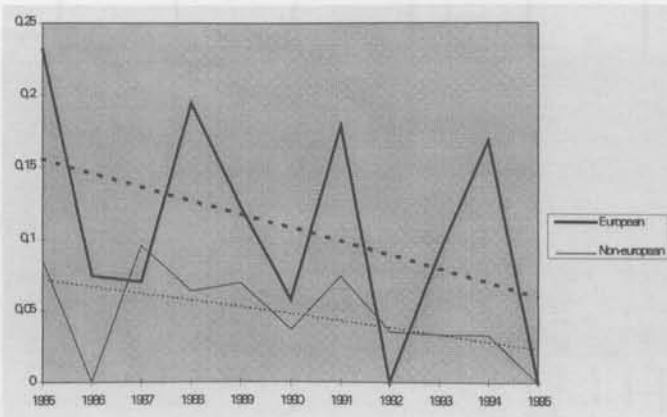


Figure 6. Comparison of accident rates per each 100 thousand landings, 1985-1995

5. Conclusion

This note improves with respect to previous works on airline safety in that it is making use of European data and exploring the existing link between safety outputs and prices (yield). Our empirical results give evidence as to support that profits but not prices might function as a signalling mechanism, and thus should be carefully monitored by civil aviation authorities. In a period of tight economic and safety regulations either airlines have managed to escape the civil aviation controls on safety or these have proved to be imperfect.

References

- [1] Association of European Airlines (AEA). Yearbooks and Statistical Appendices. Brussels.
- [2] Denham, T. (1996). World Directory of Airliner Crashes. PSL.
- [3] European Commission (1995). European Economy. Annual Economic Report. Brussels.
- [4] Golbe, D.L. (1986). "Safety and Profits in the airline industry". *The Journal of Industrial Economics*, vol. 34, no. 3, pp. 305-318.
- [5] Greene, W.H. (1993). *Econometric Analysis*. Macmillan. New York.
- [6] International Air Transport Association (IATA). World Air Transport Statistics. Geneva.
- [7] International Civil Aviation Organisation (ICAO). Financial Data. Montreal.
- [8] Rose, N.L. (1989). "Financial Influences on Airline Safety" en Moses, L.N. and Savage, I. (ed.) *Transportation Safety in an Age of Deregulation*, Oxford University Press.
- [9] Rose, N.L. (1990). "Profitability and Product Quality: Economic Determinants of Airline Safety Performance". *Journal of Political Economy*, vol. 98, no. 5, pp. 944-964.

New Approaches in Aviation Safety Oversight

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1. Early steps in international civil aviation cooperation

Over fifty years ago, international civil aviation fell into the category of a dream or an adventure. Few anticipated how it would shape and influence life in the latter part of this century. Probably no one believed it would become such a safe means of travel.

There was no consensus on how to structure commercial arrangements to provide air services across national borders. Certain things do not change. Today, these agreements still provide the headlines and really knotty issues diplomats address. There was also little agreement on common standards or operating procedures for international aviation. Each nation retained restrictive rights over its airspace. International air travel would require air crews to know a multiplicity of rules and procedures as they crossed each border. If an international aviation system was to emerge and flourish, it was necessary to solve all these regulatory and institutional matters effectively. Fortunately, the safety issues were left to the technicians.

The safety technicians did a wonderful job. In 1944 these technicians, representing 52 countries, met in Chicago to establish a common, minimum set of aviation regulations, standards, and operating procedures. Their work resulted in an aviation document known as the Chicago Convention and Annexes, and in the founding of an aviation organisation of global dimension, known as the International Civil Aviation Organisation (ICAO), to develop and oversee these aviation standards. ICAO, a part of the United Nations, serves as the coordinating body for international civil aviation, and the Chicago Convention and its now 18 Annexes, serves as the minimum international aviation safety standard that the 185 ICAO member countries have agreed to uphold. ICAO has no oversight capabilities but relies on its members to implement civil aviation regulations in compliance with the safety standards under which they have agreed to abide.

The Chicago Convention and its annexes remain the basis for promoting safety of flight throughout the world. These ICAO standards were not developed to be "stand alone" safety regulations. Many ICAO standards simply require member states to address various safety practices within their national regulations. Likewise, the Chicago Convention is not meant to be a self executing document. It requires each government to make a "contract" with the rest of the world: "if my country shares in the many benefits of international commercial air transportation, it will also share in the provision of safety oversight of these operations". Unfortunately it appears today that these obligations, were not met everywhere in the world or not devoted adequate resources to fulfilling them.

2. Absolute safety does not exist

Aviation safety is a sensitive issue in all countries. The biggest accident that ever occurred in aviation was in Tenerife in 1977. Speaking to this audience in the Netherlands, I will remind that one of the two aircraft that collided there was a Dutch registered KLM 747. More recently we also had the dramatic El Al accident in 1992, here in the Netherlands. Both of them are still in our memory.

To improve and to maintain safety is a very difficult exercise. 1996 was a bad year from the view point of aviation safety. Over 2 000 people were killed worldwide in aircraft accidents which in itself is very sad. It should be said however, that in the Netherlands in the same year, only about 1.300 people were killed in road accident. In the United States this figure was close to 50.000.

3. Where do accidents occur?

Worldwide statistics do show that in 1996 84% of air transport took place in developed countries; the U.S.A., Western Europe, Middle East, Far East and Australia. This 84% is related to 30% of all accidents. The remaining 16% of aviation, taking place in developing countries, was good for 70% of the accidents. From those statistics it is obvious where the prime problem is. If the safety in developing countries could be lifted to the same level as in the developed countries, the overall aviation safety statistics would improve dramatically.

The main question is how to handle this? Basically there are two approaches, an institutional approach and a technical approach. We will speak about the institutional approach: the institutional approach is mainly rule making, application of rules and surveillance.

4. The FAA approach: IASA (International Aviation Safety Assessment) Programme

Historically, oversight of foreign air carriers, including compliance with the Chicago Convention and ICAO Annexes was not questioned by the United States and was believed to be adequately addressed by the homeland government.

However, in recent years, FAA has taken a keen interest in the capabilities of foreign civil aviation authorities (CAA) to meet ICAO standards. Their concerns grew from a variety of safety related problems, including accidents and incidents, a growing number of operators flying into the United States, and the significant percentage of the US flying public using foreign air carriers on overseas flights. It heightened upon the recognition that some US operators were flying to and from the US under the flag of other countries without any apparent oversight. These are operators, whom we refer to as "loop-hole airlines", who were dry leasing US owned aircraft to foreign companies, and using US crews employed by brokers to operate commercial flights to the United States.

In mid-1991, FAA began to formulate a program to address these concerns. This

program included visits to twelve countries with airlines seeking authority to operate to and from the United States. After the trial period FAA findings convinced them of the need to formally establish the International Aviation Safety Assessment (IASA) Program. Notice of this new policy was published in mid-1992 (Federal Register, Vol. 57, No. 164, August 24, 1992). The purpose of the IASA is to ensure that all foreign air carriers that operate to or from the United States are properly licensed and with safety oversight provided by a competent CAA in accordance with ICAO standards.

The IASA process:

A foreign air carrier of a sovereign state desiring to conduct foreign air transportation operations into the United States files an application with the DOT for a foreign air carrier permit under the Federal Aviation Act.

Upon DOT notification of a pending foreign air carrier application, if the FAA has not made a positive assessment of that country's safety oversight capabilities, the FAA Flight Standards Service will direct its appropriate international field office to schedule an FAA assessment visit to the CAA of the applicant's country. This visit will usually be scheduled within ninety days of FAA receipt of the application.

The assessment program requires a team of FAA Flight Standards aviation safety inspectors to visit the CAA's of countries with airlines currently operating (DOT permits issued prior to FAA program implementation in 1992) or seeking to operate into the United States. The team gathers data on the international structure of each CAA to gain a better understanding of its laws, regulations, and methods of compliance with the Chicago Convention and its Annexes. The team may visit the applicant airline, or other airlines of that country, to verify CAA enforcement of the applicable ICAO Annexes. The assessment visits take approximately three to five days to complete.

Deficiencies found in FAA assessments typically fall into the following major categories:

- inadequate and in some cases non-existent regulatory legislation;
- lack of advisory documentation;
- shortage of experienced airworthiness staff;
- lack of control on important airworthiness related items such as issuance and enforcement of Airworthiness Directives, Minimum Equipment Lists, investigation of Service Difficulty Reports, etc...
- lack of adequate technical data;
- absence of Air Operator Certification (AOC) systems;
- non conformance to the requirements of the AOC System;
- lack or shortage of adequately trained flight operations inspectors including a lack of type ratings;
- lack of updated company manuals for the use by airmen;
- inadequate proficiency check procedures;
- inadequately trained cabin attendants.

If a CAA is found to be meeting its minimum safety obligations under the Chicago Convention, the FAA will forward a positive recommendation and the foreign carrier will be permitted to begin operations to or from the United States.

Carriers from countries that do not have an acceptable level of oversight from their CAA are not permitted to operate to and from the United States.

For some countries, FAA has no need to perform an on-site assessment of their safety oversight capabilities. In the cases of Australia, Canada, and New Zealand a long-standing cooperation in civil aviation gives them intimate knowledge of each other's systems and their mutual compliance with ICAO standards. In the case of the European nations who are full members of the Joint Aviation Authorities, they recognise the capability of the JAA to foster those countries' compliance with ICAO standards.

Also international "standardisation teams" have been created by JAA to provide such understanding and assurances.

5. ICAO and the SOP (Safety Oversight Programme)

ICAO is also conducting a very similar programme called SOP (Safety Oversight Programme) but on a voluntary basis. ICAO's oversight inspections, begun in June 1995, have required voluntary participation by states and have been limited to annexes for pilot licensing, aircraft operation and airworthiness. The more than 50 assessments conducted under the ICAO safety oversight program thus far revealed that many states, in spite of their best intentions and efforts, are facing serious difficulties in fulfilling their safety oversight obligations. ICAO led oversight teams have comprised three specialists, one each for licensing, aircraft operation and airworthiness. Team members are specialists seconded from aviation authorities. Annual oversight visits to national authorities are preceded usually by a questionnaire. Teams have made a practice of visiting at least one airline in each nation.

Oversight teams are organised under the Air Navigation Bureau of ICAO and use a manual written by the bureau. Inspections are co-ordinated through each of ICAO's seven regions, which the ICAO Secretariat expects to be the centres of future activity.

Results of the investigations remain confidential. More than 50 states have been reviewed so far.

However recent data did show that 60% of all ICAO members do not live up to ICAO standards.

No organisation can tolerate that the majority of its member states do not comply with its own rules and ICAO invites these countries to work hard to improve the situation in their country. We see that there could be disadvantages to this program however. First, it is a voluntary program and those countries who know that they are not meeting the ICAO standards may not request an evaluation; also, so far there is no organised follow-up, although it is needed.

6. ECAC and the SAFA (Safety Assessment of Foreign Aircraft) Programme

The European countries organised in ECAC, the European Civil Aviation conference, are working together in the SAFA programme, which means Safety Assessment of Foreign Aircraft. ECAC inspections under the Safety Assessment of Foreign Aircraft programme, begun in February 1996, have focused on ramp inspections of aircraft at European airports.

This programme, which is becoming mature quite rapidly, is primarily focused on

identifying risky carriers. Participating countries are carrying out ramp checks and report to the central databank in Hoofddorp at JAA headquarters. Also otherwise obtained information with safety aspects will enter into that databank. The information of the databank is available to all participating countries.

These programmes (IASA, SOP, SAFA) could however be perceived as a policeman's approach and this is not a healthy trend. Safety being an "attitude", cannot, rather should not, be forced down the throat as a bitter medicine.

7. The most recent developments

Directors general of civil aviation representing 145 nations have endorsed an expansion of the International Civil Aviation Organisation's Safety Oversight Program under which ICAO manages inspections of national aviation authorities across the globe.

At a three-day conference in November 1997, the civil aviation officials called for mandatory audits by ICAO-led teams of each national aviation authority among the 185 ICAO member states. They approved of an expanded base for inspections to include all safety-related ICAO annexes, adding those covering air traffic services, airports, support systems and facilities. Delegates also approved of increasing reporting and monitoring requirements that would reveal the level of a nation's compliance with ICAO safety standards and recommended practices.

ICAO's findings of serious deficiencies in safety oversight at dozens of unnamed nations spurred the delegates into expanding the ICAO program. The most serious shortcoming found was a lack of qualified personnel to carry out safety oversight of airlines and other aviation enterprises. During the conference, ICAO's oversight role received a booster shot when the European Civil Aviation Conference (ECAC), representing 36 nations, joined with ICAO in a memorandum of understanding on oversight issues. The agreement aligns their inspection programmes and sets the stage for information exchanges arising from inspections.

The confidentiality of ICAO safety oversight reports provided the basis for lively debate among the 420 delegates who filled the Assembly Hall at the ICAO headquarters. Opponents to confidentiality said the release of audit information could be used as an incentive to persuade nations toward a program of corrective safety deficiencies. Though no voice vote was taken, delegate sentiment appeared to be weighted toward a programme of openness, constrained however within a carefully drawn scenario of nation-to-ICAO dealings.

Some representatives of Third World nations whose aviation offices have submitted to oversight inspections argued for continued confidentiality under the ICAO programme. Some also criticised current safety assessment programmes as lacking in uniformity in approach and in standards, and argued that there were no safeguards against abuses. A delegate promoted mandatory inspections of all aviation authorities, a proposal that won endorsement from Third World and developed nations alike. Following a summary of new directions for ICAO given by the Council president, the FAA Administrator, said that she was very committed to the idea of disclosure and the idea of periodical auditing and

checking. She also said that the US' inspection programme will remain in effect as long as FAA has any concerns over the issue of safety. But their long-term goal is to work with ICAO and to see that it moves much more into this area, so that they can minimise and reduce some of the work they do in this area.

The FAA administrator later added that strengthening the ICAO Safety Oversight Programme (SOP) will help raise the level of safety across the world and that's particularly important for the US as more Americans travel abroad and in areas where the US has no regulatory authority.

8. A proposal for remedies

Coming back to medicine, within the previously described programmes the ICAO assistance programme looks much more like a doctors' approach. Hopefully the emphasis will gradually shift from the policeman's approach to the doctors' approach and the manufacturing industry is strongly insistent on this. How this can be organised is still an open question. Organising everything via ICAO might be too massive. A combination of an international and a bilateral approach might be the most efficient way of handling this particular issue.

Anyway, governments and ICAO should pay a major role. In particular as those programmes are primarily focused on the aviation authorities in the developing countries. A new solution has been recently brought by three major European bodies with the advent of Air EuroSafe:

What is Air EuroSafe?

A European Economic Interest Grouping formed on 29th September 1997 and registered in Hoofddorp (the Netherlands). It is a non profit organisation.

Who are the members?

Air Eurosafe Germany GmbH was founded on 05 June 1997 on the initiative of the Federal ministry of transport with the following shareholders:

- Germanische Lloyd AG in Hamburg founded in 1867, today a technical expertise organisation with more than 1500 employees and agencies in 400 places in 120 countries.
- Braunschweig Aviation Academy in Braunschweig founded in 1997 on the initiative of Aerodata GmbH, Simtec GmbH, the German Research Institute for Aviation and Space Travel (DLR) and the Federal Aviation Authority (LBA).
- TÜV (German Technical Inspectorate) Rheinland in Köln founded in 1872, today a technical expertise organisation with more than 7000 employees, has agencies worldwide in over 30 countries. The aviation department at TÜV Rheinland has already been active in the area of aviation safety for more than 20 years.
- TÜV Southern Germany Holding AG in München emerged in 1997 via the merger of TÜV Bavaria and TÜV South West. TÜV Southern Germany is a technical expertise organisation with more than 9000 employees and has agencies worldwide in over 60 locations.

Bureau Veritas established in 1828 is a French inspection and consultancy company dealing with Quality and Safety in the following fields: Marine, Industry, Civil Engineering, Certification, International Trade and Aeronautics. With 9000 employees and offices in over 150 countries, it is an independent company. The Aerospace Division is active in three major fields:

- it has a joint venture (Economic Interest Grouping called GSAC) with the French DGAC to provide the majority of the airworthiness inspection and monitoring functions on behalf of the French government;
- it provides similar services worldwide, primarily in the french speaking countries. In several it also provides flight inspection services;
- it acts as a private consulting body for airlines, manufacturers, banks and leasing companies, repair shops as well as airports and Defence.

The United Kingdom Civil Aviation Authority (UK CAA) was established in 1972 by Act of Parliament to bring together in one body the various civil aviation functions which, from 1919 onwards, had been undertaken by various Government departments and public bodies. It therefore embraces a national civil aviation experience stretching back over 70 years.

The UK CAA is both a regulatory body and a public service enterprise.

UK CAA's International Services draws upon the Authority's extensive collective experience to provide advice and assistance to aviation administrations in all parts of the world on all aspects of civil aviation from airport and airspace infrastructure development to airworthiness requirements for the certification and maintenance of aircraft.

The Authority's advice, based fundamentally on ICAO Standards and Recommended Practices and its own extensive experience, is quite independent of any commercial influences.

What is the mission of Air EuroSafe?

To support, on a European basis, the work of ECAC and ICAO safety assessment programmes and to assist with the development of aviation safety world-wide by the provision of technical support services to states and organisations which seek to achieve and maintain compliance with the criteria set out in the Annexes to the Chicago Convention.

What are the services of Air EuroSafe?

- Assistance for any country or organisation to update their aviation system and/or to develop a national/local aviation safety system;
- Temporary national/local aviation safety service (i.e. provide oversight advisory services) until the local system is sufficiently developed to take over all functions;
- on the job training for persons or organisations to perform safety oversight functions and to apply and interpret rules for:
 - the industries of new JAA member states and candidate member states
 - the industries and authorities in non-member states
- Where appropriate, a mechanism for the employment of recently-retired persons from authorities, military and industry for part-time or short term contracts to make their knowledge available for assistance and training programmes;

- Contributions to the ECAC and ICAO Safety Assessment programmes by providing resources when personnel are not otherwise readily available or when specific knowledge is required;
- Assistance to countries which are proposing to lease aircraft which are owned, registered or manufactured in Europe;
- Assistance to other States to form regional groupings for safety oversight purposes.

9. Finally how to maintain safety?

As I indicated before, the aviation safety level in Europe in particular and in the developed world in general is quite satisfactory compared to other transportation means. Nevertheless there should be no reason for complacency. Safety is like a spring that has to be compressed constantly. If you relax something horrible will happen. If the situation changes, existing matters, might not suffice any more. Then you have to adapt the methodology. By now, in the developed world there are two main reasons for concern. The first one is globalisation, and the second one is outsourcing.

Right now the main responsibility for aviation safety oversight is with national authorities. By nature airlines should be internationally oriented, even more so now that worldwide mega carriers came into existence. This means that the way in which the national authorities are organised does not fit properly with the developments in aviation.

It will be quite a challenge for the national authorities to keep up with present developments. Fortunately in Europe the cooperation between the national authorities within JAA so far, is quite successful and within a couple of years the JAA could be transformed into EASA, the European Aviation Safety Authority, which will mean that the emphasis might shift from the national authorities to an international body. A second positive factor is that the JAA and the FAA are working together more and more efficiently. In particular in the areas of airworthiness and maintenance. Both the codes that are used and the way in which they are applied, are becoming much closer together compared to for instance 10 years ago. This might become the nucleus for further international cooperation.

Also a group of experts met during the 53rd general assembly of IATA and requested worldwide measures to reduce by half the accident rate of the air transport before 2004. This resolution was taken at the beginning of November in Amman, Jordan, where the general assembly of IATA met. Although the accident rate could appear rather low (1 accident for 1.06 million of flights for western airlines in 1996), the rate did not go down in the last ten years. If it does not go down in the next ten years there will be an aeronautical accident every week. While the ultimate goal is a complete disappearance of all accidents, the group of experts said that a 50% decrease in the accident rate until 2004 is an intermediate goal which is accessible in the short term. Contributing factor of this target will be the implementation of a tutoring system of small airlines by big airlines who will bring their experience and technical competency. The installation of GPWS (Ground Proximity Warning Systems) and TCAS (Traffic Collision Assistance Systems) could become mandatory. Flight reporting rules could also be improved and more attention

should be brought to human factors and cockpit environment. Finally, safety oversight know how has to be transferred from experienced countries to less experienced countries, this is the mission devoted to such initiatives as Air EuroSafe.

A European Organisation for Aviation Safety

Klaus Koplin

Secretary General Joint Aviation Authorities

1. What is JAA?

1.1 Introduction

The Joint Aviation Authorities (JAA) are representing the civil aviation regulatory authorities of a number of European States who have agreed to co-operate in developing and implementing common safety regulatory standards and procedures. This co-operation is intended to provide high and consistent standards of safety and a "level playing-field" for competition in Europe. Much emphasis is also placed on harmonising JAA regulations with those of the U.S.A.

JAA Membership is based on signing the "JAA Arrangements" document originally signed by the then current member States in Cyprus in 1990. Based on these Arrangements and related commitments, the JAA's objectives and functions may be summarised as follows:

1.2 Objectives

- To ensure, through co-operation, that its members achieve a high consistent level of safety
- To achieve a cost effective safety system so as to contribute to an efficient aviation industry
- To contribute, through the uniform applications of common standards, to fair and equal competition within the member states
- To promote, through international co-operation, the JAA standards and system to improve the safety of aviation world-wide

1.3 Functions

- To develop and adopt Joint Aviation Requirements (JARs) in the fields of aircraft design and manufacture, aircraft operations and maintenance, and the licensing of aviation personnel.
- To develop administrative and technical procedures for the implementation of JARs.
- To implement JARs and the related administrative and technical procedures in a co-ordinated and uniform manner.

- To adopt measures to ensure, whenever possible, that pursuance of the JAA safety objective does not unreasonably distort competition between the aviation industries of Member States or place companies of Member States at a competitive disadvantage with companies of non-Member States.
- To provide the principal centre of professional expertise in Europe on the harmonisation of aviation safety regulation.
- To establish procedures for joint certification of products and services and where it is considered appropriate to perform joint certification.
- To co-operate on the harmonisation of requirements and procedures with other safety regulatory authorities, especially the Federal Aviation Administration (FAA).
- Where feasible, to co-operate with foreign safety regulatory authorities especially FAA, on the certification of products and services.

JAA's work was started in 1970 (when it was known as the Joint Airworthiness Authorities). Originally its objectives were only to produce common certification codes for large aeroplanes and for engines. This was to meet the needs of European industry, particularly for products manufactured by international consortia (e.g. Airbus). Since 1987 its work has been extended to operations, maintenance, licensing and certification/design standards for all classes of aircraft. Common procedures and the approval of design, production and maintenance organisations are covered. A single Joint Certification team, working on behalf of all JAA countries, is used for certification of new aircraft and engines. After the successful completion of the evaluations Type Certificates are issued simultaneously, and on a common basis, by all States.

JAA originated as the Authorities' response to the technical and economic needs of the European Aviation Industry. However, since 1 January 1992 JAA codes, as they are completed, are referenced in the European Community Regulation on Harmonised Technical Standards¹ and become law in the EC States. Industry is fully represented in committees and working groups developing requirements and procedures and in a Joint Assembly and Joint Boards where policy issues are debated. The JAA, as presently constituted, carry out their tasks of approval, certifications and safety monitoring using the staff of the national authorities, who also retain the responsibility for the legal findings, granting of licences and certificates, etc. The JAA Headquarters are responsible for the process of rulemaking, harmonisation and standardisation, (using specialist staff from the national authorities), the decision-making system, the "infrastructure" and various related tasks.

2. General organisation of the JAA

2.1 Membership

(a) Membership is open to States who are members of the European Civil Aviation Conference (ECAC), which currently has 36 member countries, and JAA are an "associated

¹ Council Regulation (EEC) No 3922/91 of 16 December 1991 on the harmonisation of technical requirements and administrative procedures in the field of civil aviation.

body" of ECAC. Membership takes effect when the 1990 "Arrangements" are signed. Twenty-seven countries are members of the JAA today - see Figure 1.

(b) "Two-Phase" membership of JAA

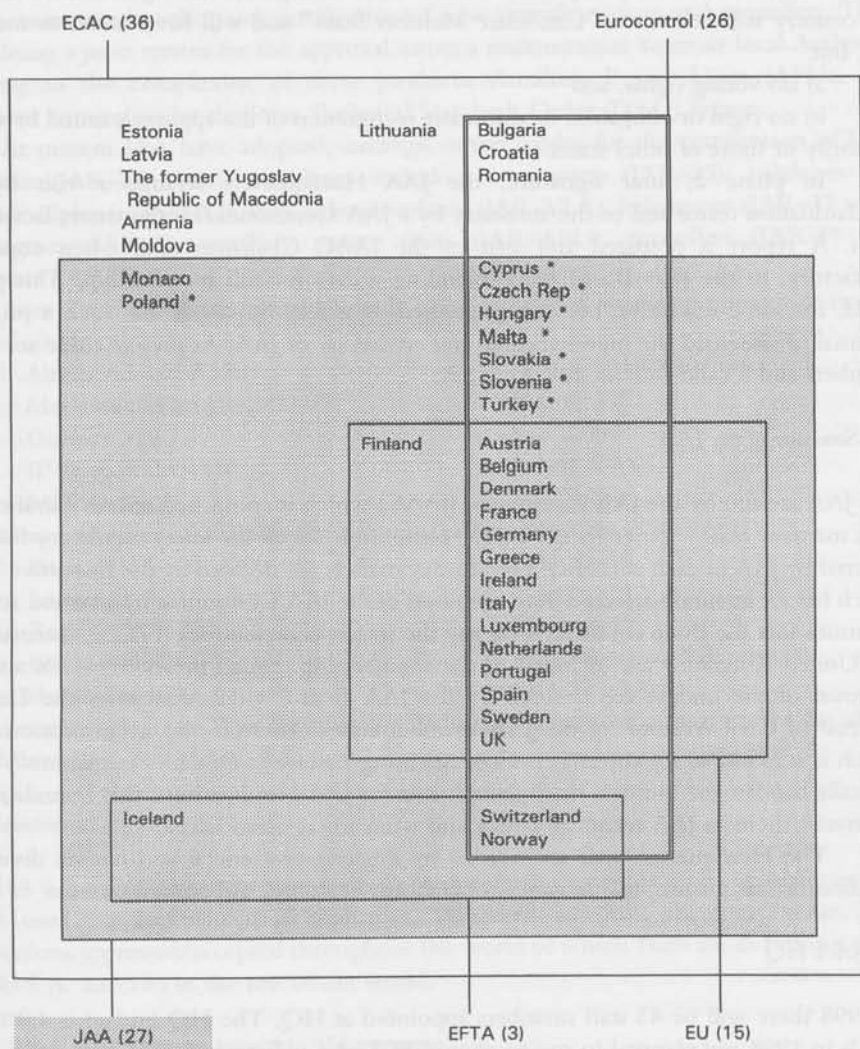


Figure 1. ECAC, EU, JAA, EFTA and Eurocontrol.

JAA have a two-phase membership system. The procedure starts with discussions with a "candidate" authority at JAA HQ leading, after a satisfactory conclusion, to a report to the

JAAC Chairman. The state can then formally apply to the Chairman of the JAA Board for membership, indicating its willingness to commit itself to the terms and commitments in the Arrangements. The JAA Committee also submits its report to the JAA Board and, subject to a two-thirds majority vote, the new State can sign the Arrangements. At this stage the country will become a "Candidate Member State" and will have access to meetings, etc., but:

- a) no voting rights, and
- b) no right or obligation to automatic recognition of the approvals issued by its own authority or those of other states.

In phase 2, after signature, the JAA Headquarters arrange a visit by JAA standardisation teams and to the authority by a JAA Committee/Headquarters fact-finding team. A report is prepared and sent to the JAAC Chairman and, when considered satisfactory, to the JAA Board recommending a date for full membership. This process could, for some countries, be very prolonged. It is felt, however, that such a process is essential to safeguard the high standards and credibility of JAA. At present there are 19 full members and 8 candidate members of JAA.

2.2 Structure of the JAA

The JAA are run by the JAA Committee (JAAC) which is comprised of one member from each member State - generally the person responsible for all the safety regulatory functions covered by JAA in each authority. Day-to-day matters are decided by the Executive Board, which has six members selected from members of the JAA Committee by a system arranged to ensure that the three countries who pay the largest contributions (France, Germany and the United Kingdom) are included in the membership. Broad policy decisions and final approval of the budget are decided by the JAA Board which comprises the Directors General of Civil Aviation of the JAA member states. There is also a Foundation Board which is responsible for the affairs of the Stichting Beheer (a Dutch "Foundation") which formally handles the business management role for JAA Headquarters; this Foundation has no involvement in JAA technical policy and work for aviation safety.

The Headquarters staff are headed by a Secretary-General and has six divisions - certification, regulation, maintenance, operations, licensing, and administration.

2.3 JAA HQ

In 1998 there will be 43 staff members appointed at HQ. The HQ budget is 4.0 million ECUs in 1998 and planned to rise to around ECU 4.4 million in 1999.

At present JAA are funded by national contributions (appr.80%), plus income from the sale of publications, training and some limited funds from EU (appr.20%). National contributions are based on indices related to the size of each country's aviation industry. The "largest" countries (France, Germany, the United Kingdom) pay around 20% and the smallest around 0.6% of the budget. All countries pay a minimum of 0.5% of the budget to cover "basic" costs of membership, plus their contribution to the remainder of the costs according to the formula.

3. Status and Implementation of JAA work

3.1 Certification

JAA are committed to the joint certification of new aircraft, engines and propellers. They are finalising a joint system for the approval, using a multinational Team or local Authority according to the complexity, of these products, Auxiliary Power Units (APUs) and equipment coming under the Joint Technical Standards Order (JTSO) system.

At present JAA have adopted, amongst others, codes for the certification of large aeroplanes (JAR-25), small aeroplanes including commuters (JAR-23), sailplanes and powered sailplanes (JAR-22), very light aeroplanes (JAR-VLA), helicopters (JAR-27 and -29), engines (JAR-E), auxiliary power units (JAR-APU), propellers (JAR-P) and equipment (JAR-TSO).

Joint Type Certifications have already been completed on a large number of aircraft some of which are:

Airbus A340 / A330	Airbus A319/320/321
McDonnell Douglas MD-11	Boeing 777
Dornier 328	Saab 2000
IPTN CN 235-110	Falcon 2000
MD 90-30	EMB145

In addition a number of aeroplane certification programmes are in progress:

Boeing 737-600, -700 and -800	MD-95-30
Learjet 45	Gulfstream V
Tupolev 204-200	Citation X
IPTN-M250	Canadair Global Express
Raytheon 4000	DO 328-300

On the engine side Joint Type Certification/Validation a number of projects for the above aircraft have been completed. Additional 20 engine programmes are in progress.

3.2 Maintenance

JAR-145 is a requirement to approve/accept maintenance organisations to maintain any aircraft used for commercial air transport. Published in 1991, there are some 2770 organisations approved/accepted throughout the world of which 1620 are in Europe, 1020 in the U.S.A. and 130 in the rest of the world.

JAR-OPS Parts 1 & 3, Subpart M: "Maintenance"

This is a section of JAR-OPS and covers the operator's responsibility for maintenance management and includes the aircraft maintenance programme and flight technical log. JAR-OPS was published May 1995, followed soon thereafter by the associated JAA-NAA procedures. Training of JAA-NAA staff and operators staff started in September 1995. Implementation of Sub-part M started early in 1996 and a small number of AOC maintenance arrangements have been accepted since.

JAR-66: "Certifying Staff"

JAR-66 is a requirement about qualifying maintenance personnel to issue certificates of release to service for JAR-145 organisations. JAR-66 envisages the issue of an aircraft maintenance basic licence in one of three categories following the successful completion of an examination process also specified in JAR-66. The licence will be issued by the JAA full member Authority but it is possible for JAR-145 organisations to prepare the licence. "Grandfather rights" for existing personnel is a key feature and it will only be necessary to qualify for the JAR-66 licence if either changing the scope of an existing NAA Authorities licence or moving to another JAA country. It should be noted that to issue an aircraft Certificate of Release to Service requires the release person to hold both the JAR-66 aircraft maintenance basic licence and a JAR-145 certification authorisation. JAR-66 was adopted 15 December 1997. Publication will occur mid 1998 with mandatory compliance by 2001.

JAR-147 Approved Maintenance Training

JAR-147 is a requirement for approved maintenance training to satisfy part of the JAR-66 requirements including in particular the conduct of basic and type examinations to be accepted by the JAA-NAA as a basis for issue of the proposed JAR-66 Licence. JAR-147 was adopted 15 December 1997. Publication will occur mid 1998 with mandatory compliance by 2001.

Maintenance Standardisation

The JAA concept for the approval of maintenance is that this is the responsibility of the national authorities; however, an important foundation for the mutual acceptance of maintenance is the use of Maintenance Standardisation Teams (MAST). Three such teams are operating and so far visits have been completed to all "full" JAA members and the fifth round of visits commenced Spring 1997, with the added task of looking at JAR-OPS M compliance. Organisations located in the U.S.A./Canada which have been accepted by JAA are subject to sample audits carried out by maintenance. International standardisation teams (MIST) operating in a similar manner to MAST teams. Canada and all regions of the U.S.A. have been audited twice and another round is in progress.

3.3 Operations

JAR-OPS Parts 1 and 3 (covering Commercial Air Transportation by aeroplanes and helicopters respectively) were adopted by the JAA Committee at the end of March 1995, the first issue being published on 22 May. At that time it was decided that JAR-OPS should, initially, be implemented under national legislation no later than 1 April 1998 with JAR-OPS 1 being subject to "phased implementation" such that the operators of large aeroplanes (those over 10 tonnes MTOM or with 20 or more passenger seats) and mixed fleets of large and small aeroplanes would be affected first, followed 1 year later (1 April 1999) by those AOC Holders operating small aeroplanes only. It was intended that JAR-OPS 3 should be implemented in toto on 1 April 1998.

As the Authorities and the industry have been working towards these implementation dates, it has become apparent that there will be a need to introduce a 6 month delay in implementation for JAR-OPS 3 (to 1 October 1998) and a corresponding delay for the operators of small aeroplanes only (to 1 October 1999). The primary reason for this short delay is that some amendments to JAR-OPS are being processed which will introduce some alleviations for certain sectors of the industry. Without a delay in implementation, those sectors of industry would, unreasonably, be required to comply with more stringent requirements.

The proposed Subparts of JAR-OPS Parts 1 and 3 on Flight and Duty Time Limitations and Rest Requirements (Subpart Q) have been the subject of particularly careful consideration, the JAR-OPS 1 material being sent out for consultation on three occasions to date. For a variety of reasons, these important elements of JAR-OPS have not yet been adopted.

The current situation in this area is that the European Commission has resolved to try and adopt a "new approach" with a view to progressing the issue. There has been considerable general discussion on the subject in the EU forum and the European Commission is now preparing draft proposals drawing upon these discussions. As a result of this activity, the JAA Committee has decided to await developments before considering the matter further.

Since the adoption and publication of JAR-OPS 1 and 3, the Operations Joint Implementation Procedures have been completed and published. These procedures must be followed by the authorities when implementing JAR-OPS in all JAA Member States. Included in this material is the mechanism under which Operations Standardisation Teams (OPST) (similar in function to the MAST system for maintenance) will operate. It is planned that OPSTs will begin operating in late 1997. In advance of the commencement of this standardisation activity, JAR-OPS training is being provided by the JAA Headquarters Operations Division for both Authorities and industry personnel.

Operational requirements covering General Aviation (including Aerial Work) activity by aeroplanes and helicopters will be contained in Parts 2 and 4 respectively. It had been intended to start this work in late 1996. However, it has been decided that work on the operational requirements for General Aviation will not now commence until JAR-OPS Parts 1 and 3 have been implemented.

In addition to the above-mentioned operational regulations, requirements have also been developed for Flight Simulators. All of the requirements concerning the evaluation and qualification of the various types of synthetic training device used for training flight crew will be covered by a set of requirements to be known as JAR-STD (Synthetic Training Devices) which will be divided into separate Parts. The first of these (JAR-STD Part 1A) addresses Flight Simulators (Aeroplanes) and was published on 30 April 1997.

The implementation date of JAR-STD Part 1A coincides with JAR-OPS 1 implementation in April 1998. Additional Parts of JAR-STD will be developed to cover Flight Simulators (Helicopters), Flight Training Devices (type specific) and Flight and Navigation Procedures Trainers.

The intention behind JAR-STD is that there should be a single evaluation of a synthetic training device, the findings of which should be acceptable to all JAA Member

Authorities. Such processes should result in considerable savings in that repetitious evaluations by individual authorities will no longer be required.

3.4 Licensing

Licensing is all matters related to personnel training, testing and authorisation. Arrangements applicable to flight crews are currently being drafted with a distinction being made between regulatory licensing Requirements (known as JAR-FCL) and their accompanying implementation procedures (referred to as JIP).

JAR-FCL is divided into 5 Parts: Part 1 - Aeroplane, Part 2 - Helicopter, Part 3 - Medical, Part 4 - Flight Engineers and Part 5 - Gliders and Balloons. Parts 1 and 2 contain requirements, acceptable means of compliance and interpretative material for training, testing and licensing of Airline Transport Pilots, Commercial Pilots and Private Pilots for aeroplane and helicopter. This includes the training and testing for Instrument, Type, Class and Instructor ratings and for Examiners. Part 3 contains the requirements, acceptable means of compliance and interpretative material regarding the medical requirements for pilots and further comprises the Aviation Medical Manual providing guidance for Authorised Medical Examiners.

JAR-FCL 1 and 3 have been subject to a very comprehensive discussion and comment period. After agreement in the FCL Committee they were adopted by the JAAC on 8 October 1996. After a transition period of 2.5 years they become effective on 1 July 1999. JAR-FCL 3 (Helicopter) has been adopted on 19 June 1997 and implementation date is planned for 1 January 2000.

Work has started on Part 4 (Flight Engineers). Part 5 (Gliders and Balloons) will be dealt with in a later phase.

Implementation of JAR-FCL will be carried forward in a standardised manner with the assistance of standardisation teams (LIST- and MEST-teams) working along the same pattern as in the Maintenance area. The JIP document contains procedures regarding these teams. Training courses started in JAA HQ in May 1997 to familiarise authorities' staff and interested parties with the JAA structure and, in particular, JAR-FCL and the JIP.

4. Outlook

Appendix 1 and 2 summarise the present position on JAR's, both those already adopted and those yet to be adopted.

There is general agreement between the JAA members that we need a more formal and legally binding status for JAA. Therefore a special working group developed a possible text for a JAA Convention that got an agreement in principle from the JAA Board but was not further developed as some members felt that a co-ordination with the European Union was necessary.

Since early 1997 the EU is discussing a proposal from the European Commission for the establishment of a European organisation responsible for civil aviation safety. There are good prospects for a conclusion of these discussions in 1998 using the text of the draft

convention as a starting point.

This envisaged new organisation will give the present JAA a formal legal basis and will be a step towards a Single European Aviation Safety Authority. In the meantime JAA will continue its work with the aim to become the genesis of a European Aviation Authority.

Current Designation, Date and Date	Current and Title
Change 1, 1 April 1997, New Designation: JAA 1	Initial JAA 1
Change 2, 1 April 1997, New Designation: JAA 2	Initial JAA 2
Change 3, 1 April 1997, New Designation: JAA 3	Initial JAA 3
Change 4, 1 April 1997, New Designation: JAA 4	Initial JAA 4
Change 5, 1 April 1997, New Designation: JAA 5	Initial JAA 5
Change 6, 1 April 1997, New Designation: JAA 6	Initial JAA 6
Change 7, 1 April 1997, New Designation: JAA 7	Initial JAA 7
Change 8, 1 April 1997, New Designation: JAA 8	Initial JAA 8
Change 9, 1 April 1997, New Designation: JAA 9	Initial JAA 9
Change 10, 1 April 1997, New Designation: JAA 10	Initial JAA 10
Change 11, 1 April 1997, New Designation: JAA 11	Initial JAA 11
Change 12, 1 April 1997, New Designation: JAA 12	Initial JAA 12
Change 13, 1 April 1997, New Designation: JAA 13	Initial JAA 13
Change 14, 1 April 1997, New Designation: JAA 14	Initial JAA 14
Change 15, 1 April 1997, New Designation: JAA 15	Initial JAA 15
Change 16, 1 April 1997, New Designation: JAA 16	Initial JAA 16
Change 17, 1 April 1997, New Designation: JAA 17	Initial JAA 17
Change 18, 1 April 1997, New Designation: JAA 18	Initial JAA 18
Change 19, 1 April 1997, New Designation: JAA 19	Initial JAA 19
Change 20, 1 April 1997, New Designation: JAA 20	Initial JAA 20
Change 21, 1 April 1997, New Designation: JAA 21	Initial JAA 21
Change 22, 1 April 1997, New Designation: JAA 22	Initial JAA 22
Change 23, 1 April 1997, New Designation: JAA 23	Initial JAA 23
Change 24, 1 April 1997, New Designation: JAA 24	Initial JAA 24
Change 25, 1 April 1997, New Designation: JAA 25	Initial JAA 25
Change 26, 1 April 1997, New Designation: JAA 26	Initial JAA 26
Change 27, 1 April 1997, New Designation: JAA 27	Initial JAA 27
Change 28, 1 April 1997, New Designation: JAA 28	Initial JAA 28
Change 29, 1 April 1997, New Designation: JAA 29	Initial JAA 29
Change 30, 1 April 1997, New Designation: JAA 30	Initial JAA 30
Change 31, 1 April 1997, New Designation: JAA 31	Initial JAA 31
Change 32, 1 April 1997, New Designation: JAA 32	Initial JAA 32
Change 33, 1 April 1997, New Designation: JAA 33	Initial JAA 33
Change 34, 1 April 1997, New Designation: JAA 34	Initial JAA 34
Change 35, 1 April 1997, New Designation: JAA 35	Initial JAA 35
Change 36, 1 April 1997, New Designation: JAA 36	Initial JAA 36
Change 37, 1 April 1997, New Designation: JAA 37	Initial JAA 37
Change 38, 1 April 1997, New Designation: JAA 38	Initial JAA 38
Change 39, 1 April 1997, New Designation: JAA 39	Initial JAA 39
Change 40, 1 April 1997, New Designation: JAA 40	Initial JAA 40
Change 41, 1 April 1997, New Designation: JAA 41	Initial JAA 41
Change 42, 1 April 1997, New Designation: JAA 42	Initial JAA 42
Change 43, 1 April 1997, New Designation: JAA 43	Initial JAA 43
Change 44, 1 April 1997, New Designation: JAA 44	Initial JAA 44
Change 45, 1 April 1997, New Designation: JAA 45	Initial JAA 45
Change 46, 1 April 1997, New Designation: JAA 46	Initial JAA 46
Change 47, 1 April 1997, New Designation: JAA 47	Initial JAA 47
Change 48, 1 April 1997, New Designation: JAA 48	Initial JAA 48
Change 49, 1 April 1997, New Designation: JAA 49	Initial JAA 49
Change 50, 1 April 1997, New Designation: JAA 50	Initial JAA 50
Change 51, 1 April 1997, New Designation: JAA 51	Initial JAA 51
Change 52, 1 April 1997, New Designation: JAA 52	Initial JAA 52
Change 53, 1 April 1997, New Designation: JAA 53	Initial JAA 53
Change 54, 1 April 1997, New Designation: JAA 54	Initial JAA 54
Change 55, 1 April 1997, New Designation: JAA 55	Initial JAA 55
Change 56, 1 April 1997, New Designation: JAA 56	Initial JAA 56
Change 57, 1 April 1997, New Designation: JAA 57	Initial JAA 57
Change 58, 1 April 1997, New Designation: JAA 58	Initial JAA 58
Change 59, 1 April 1997, New Designation: JAA 59	Initial JAA 59
Change 60, 1 April 1997, New Designation: JAA 60	Initial JAA 60
Change 61, 1 April 1997, New Designation: JAA 61	Initial JAA 61
Change 62, 1 April 1997, New Designation: JAA 62	Initial JAA 62
Change 63, 1 April 1997, New Designation: JAA 63	Initial JAA 63
Change 64, 1 April 1997, New Designation: JAA 64	Initial JAA 64
Change 65, 1 April 1997, New Designation: JAA 65	Initial JAA 65
Change 66, 1 April 1997, New Designation: JAA 66	Initial JAA 66
Change 67, 1 April 1997, New Designation: JAA 67	Initial JAA 67
Change 68, 1 April 1997, New Designation: JAA 68	Initial JAA 68
Change 69, 1 April 1997, New Designation: JAA 69	Initial JAA 69
Change 70, 1 April 1997, New Designation: JAA 70	Initial JAA 70
Change 71, 1 April 1997, New Designation: JAA 71	Initial JAA 71
Change 72, 1 April 1997, New Designation: JAA 72	Initial JAA 72
Change 73, 1 April 1997, New Designation: JAA 73	Initial JAA 73
Change 74, 1 April 1997, New Designation: JAA 74	Initial JAA 74
Change 75, 1 April 1997, New Designation: JAA 75	Initial JAA 75
Change 76, 1 April 1997, New Designation: JAA 76	Initial JAA 76
Change 77, 1 April 1997, New Designation: JAA 77	Initial JAA 77
Change 78, 1 April 1997, New Designation: JAA 78	Initial JAA 78
Change 79, 1 April 1997, New Designation: JAA 79	Initial JAA 79
Change 80, 1 April 1997, New Designation: JAA 80	Initial JAA 80
Change 81, 1 April 1997, New Designation: JAA 81	Initial JAA 81
Change 82, 1 April 1997, New Designation: JAA 82	Initial JAA 82
Change 83, 1 April 1997, New Designation: JAA 83	Initial JAA 83
Change 84, 1 April 1997, New Designation: JAA 84	Initial JAA 84
Change 85, 1 April 1997, New Designation: JAA 85	Initial JAA 85
Change 86, 1 April 1997, New Designation: JAA 86	Initial JAA 86
Change 87, 1 April 1997, New Designation: JAA 87	Initial JAA 87
Change 88, 1 April 1997, New Designation: JAA 88	Initial JAA 88
Change 89, 1 April 1997, New Designation: JAA 89	Initial JAA 89
Change 90, 1 April 1997, New Designation: JAA 90	Initial JAA 90
Change 91, 1 April 1997, New Designation: JAA 91	Initial JAA 91
Change 92, 1 April 1997, New Designation: JAA 92	Initial JAA 92
Change 93, 1 April 1997, New Designation: JAA 93	Initial JAA 93
Change 94, 1 April 1997, New Designation: JAA 94	Initial JAA 94
Change 95, 1 April 1997, New Designation: JAA 95	Initial JAA 95
Change 96, 1 April 1997, New Designation: JAA 96	Initial JAA 96
Change 97, 1 April 1997, New Designation: JAA 97	Initial JAA 97
Change 98, 1 April 1997, New Designation: JAA 98	Initial JAA 98
Change 99, 1 April 1997, New Designation: JAA 99	Initial JAA 99
Change 100, 1 April 1997, New Designation: JAA 100	Initial JAA 100

Appendix 1

1. Amendment status of joint aviation requirements

The JARs currently adopted are at the following amendment status:

Document and Title	Current Amendment Status and Date
JAR-1 Definitions and Abbreviations	Change 4, 1 June 1987, plus Orange Paper 1/92/1, 1 January 1992
JAR-21 Certification Procedures for Aircraft, Products and Related Parts	1st issue, 3 June 1994, plus Orange Paper 1/95/1, 1 August 1995
JAR-22 Sailplanes & Powered Sailplanes	Change 5, 28 October 1995
JAR-23 Normal, Utility, Aerobatic and Commuter Category Aeroplanes	1st issue, 11 March 1994
JAR-25 Large Aeroplanes	Change 14, 27 May 1994
JAR-27 Small Rotorcraft	1st issue, 6 September 1993
JAR-29 Large Rotorcraft	1st issue, 5 November 1993
JAR-APU Auxiliary Power Units	Change 2, 26 September 1983, plus Orange Paper APU/92/1, 27 April 1992
JAR-E Engines	Change 9, 21 October 1994
JAR-P Propellers	Change 7, 22 October 1987
JAR-OPS Part 1 Commercial Air Transportation (Aeroplanes)	1st issue, 22 May 1995
JAR-OPS Part 3 Commercial Air Transportation (Helicopters)	1st issue, 22 May 1995
JAR-TSO Joint Technical Standard Orders	Change 2, 13 September 1995
JAR-AWO All Weather Operations	Change 1, 29 November 1985, plus Orange Paper AWO/91/1, 28 November 1991
JAR-VLA Very Light Aeroplanes	1st issue, 26 April 1990, plus Orange Papers VLA/91/1, 22 October 1991, and VLA/92/1, 1 January 1992
JAR-145 Approved Maintenance Organisations	Change 1, 4 August 1995
JAR-FCL Part 1 Flight Crew Licensing (Aeroplane)	1st issue, 14 February 1997
JAR-FCL Part 3 Flight Crew Licensing (Medical Requirements)	1st issue, 28 February 1997
JAR-STD 1A Aeroplane Flight Simulators	1st issue, 30 April 1997

Appendix 2

1. Amendment status of joint aviation requirements not yet published

The JARs currently not yet published are at the following amendment status:

Document and Title	Current Amendment Status
JAR-11 Rulemaking Procedures	WG draft
JAR-26 Retroactive Airworthiness Requirements	WG draft following NPA adoption late 1997
JAR-34 Aircraft Emissions	WG draft
JAR-36 Aircraft Noise	awaiting publication mid 1997
JAR-39 Airworthiness Directives	WG draft, NPA due 3rd quarter 1997
JAR-66 Certifying Staff	2nd NPA, 2nd quarter 1997
JAR-147 Maintenance Training Organisations	NPA, 2nd quarter 1997
JAR-FCL Part 2 Flight Crew Licensing (Helicopters)	adopted 2 June 1997

A Discontinuity in the Trend of Safety in Civil Aviation

How safety oversight by aviation authorities might contribute to a much needed breakthrough in the trend of safety

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1. Needed: a breakthrough in safety of civil aviation

The trend in the safety of civil aviation is very well known and alarming. A flattening out of the gradual improvement of the accident rate is anticipated not to keep pace with the rapid growth of air transportation. The problem that arises is how to break this trend and how to create a discontinuity in it, in order to achieve a situation which is more acceptable than having a new major aircraft accident every other week hitting the headlines. Several initiatives are developing, technical as well as organizational.

From the authorities' point of view, a major initiative has been taken by CAO in its Safety Oversight Programme, which addresses safety in a top-down approach by investigating the effectiveness of safety oversight activities of national Civil Aviation Authorities. The ECAC Safety Assessment of Foreign Aircraft (SAFA) program aims for the same target but uses a bottom-up approach by investigating safety deficiencies of aircraft and airlines.

Several other initiatives are being developed, by the authorities as well as by the aviation industry. However useful and necessary these initiatives may be; it is not expected that they can provide a major breakthrough. The total effort in aviation safety is so extensive already and the achieved level of safety so high, that only a gradual improvement can be expected by even stepping up this effort considerably.

All these initiatives and most of the current work on aviation safety issues approach safety in a traditional way in which safety is considered as some quantifiable concrete characteristic, for which the responsibilities are clearly defined with regard to liability and supervision. Safety means survivability, and this survivability must be provided by the operator and by the (aviation) industry in accordance with suitable legislation. The regulatory authorities have the obligation to ensure that this legislation is adequate and complied with. This approach stems from the past and is clearly reflected in the Convention on International Civil Aviation, ICAO's charter, which lies at the basis of all legislation for civil aviation in the world. This situation has been more than acceptable for over half a century, but now it might be time for a review of these principles to take place, in order to reach the breakthrough which we need so hard.

2. A review of the notion of safety in aviation

The concrete notion of safety which allows for measuring safety in convenient numbers, like that of the number of casualties or accidents per number of flights or per number of passenger kilometers, ignores the fact that safety might be much more than just survival; more than only being safe.

Being safe is taken care of in aviation to a very high extent. Although every casualty is one too many, the average number of casualties in international civil aviation is about 1000 per year; very low for such a large and global activity. However, apart from this limited number of casualties, there are millions of people who are frightened of aviation. They are frightened to fly themselves or have fear for all the aircraft that fly above their heads, which in the event of an accident might endanger them or their property. This is especially a characteristic situation in aviation, because flying takes place in an environment which is hostile to human life and because aviation has an extremely pronounced profile in publicity.

Apparently there is something missing in the traditional understanding that safety is a situation in which one is protected against threats to one's life.

The American psychologist Abraham Maslow in his analysis of human motivators, mentioned safety (security) as one of the few basic human needs like food, health and shelter. Quite clearly his notion of safety was much wider than only being safe and encompassed well-being as well. According to this wider view, safety is a situation in which one is protected against threats to one's life and well-being.

When this is true, the perception of safety is part of safety itself, because it has a profound influence on well-being.

In my opinion, it is necessary to add the abstract notion of well-being to the definition of safety, in order to be able to explain phenomena which otherwise are incomprehensible. For instance, it can explain why 100 little accidents in each of which there is one casualty, together, have not by far the same impact on society as one major accident in which 100 people die. It also explains the seemingly out of balance importance of that moderate number of casualties per year in civil aviation and it explains clearly why external safety needs so much attention, although in number of casualties it is much less important than internal safety.

3. Consequences: responsibility for confidence

The addition of the abstraction well-being, including feeling safe, the perception of safety, to the definition of safety itself, has significant consequences for the approach to safety. When in India an aircraft from Kazakstan collides with an aircraft from Saudi-Arabia, the impact on safety is not only limited to those three States, but the confidence in aviation safety, the factor of feeling safe, is compromised all over the world.

This leads to the logical conclusion, that maintaining and improving safety in civil aviation everywhere in the world is of great global interest, and especially important to the States where the majority of international civil aviation originates from. Therefore the

whole world should be involved and needs to bear responsibility for its oversight, and of course, contribute to it, in order to create and maintain confidence in the safety of international civil aviation.

Looking at the Chicago Convention, such an international responsibility is not mentioned anywhere. The responsibility for the oversight of aviation safety is burdened to explicitly mentioned States:

- The State of Design
- The State of Registry
- The State of the Operator
- The State in whose airspace the aviation activities take place.

It is however not at all in conflict with the Chicago Convention, when also this international responsibility should be recognized. The actors remain the same, existing responsibilities remain, but safety oversight would be improved considerably, when the global aviation community would take this additional responsibility for confidence in aviation safety seriously, for example by providing adequate resources to enable States to comply with their obligations, when these States themselves lack the means for it.

4. No economical disruption necessary

The present attention for safety oversight everywhere in the world, by means of the ICAO Safety Oversight Programme, the American IASA program (International Aviation Safety Assessment), the ECAC SAFA program etceteras, reveals that in many States of the world, safety oversight is below the required Standards. This does not mean that aviation safety is suddenly much worse than before this awareness. It does however explain, why there are such large differences in the aviation safety level in different regions of the world and it indicates that improving safety oversight is a powerful means to further improve safety in civil aviation.

The results also clearly indicate, that many States are not capable of performing an effective safety oversight, for which they bear responsibility according to the Chicago Convention.

- Strictly keeping to a rigid interpretation of the Chicago Convention, we now face a situation in which airlines from many small and poor States could now be excluded from participation in international civil aviation. Such a one sided approach by States who are convinced that they themselves are in compliance with the international Standards is dubious for several reasons.
- Safety oversight is not the same as safety itself: it is one powerful tool to reach a safe situation, but a safe situation can also be achieved in other ways.
- Barring a supposedly risky airline from a State's airspace, because the State of this operator is not in compliance with the requirement of a good safety oversight, might protect the citizens of the State which bans that airline against a slight external risk, but it does nothing against the internal risk that those same citizens run when they enter the airspace of the non complying State. Even when they travel with their own, trusted airlines, they still are subjected to a situation which, because of that

same lack of safety oversight, might be dangerous. That is a risk which might be much larger than the evaded external risk. A balanced measure would be not only to ban flights from airlines operated by the deficient State, but also prohibit all other airlines to enter the risky airspace of that State! (I do not promote such measures)

- Measures like closing a State's airspace can only be taken by States which are in a powerful position with respect to the involved non complying State. It is not surprising that such measures are interpreted as a 'patronizing and commercially influenced power play. Often they have damaging consequences like the deterioration of political, economical and social relations.

Therefore, instead of such indiscriminate measures, a more positive approach is to be preferred. In view of the above mentioned global nature of aviation safety and the international responsibility for confidence in it, States which are in need of support in order to achieve compliance with the requirement for an effective safety oversight should be aided. The results of the Safety Oversight Assessments performed by ICAO, provide guidance as to the needs and the type of support that is suitable. In many cases this support will have to be permanent or semi-permanent, because a satisfactory situation is not within reach in the foreseeable future without such support. In those cases a practical solution might be, that regional safety oversight centers are created, from which aviation experts are sent to the States in the region in which their services are needed. These centers should be heavily subsidized in order to keep their services allowable and attractive for all the involved States. In this way there is no matter of infringement of the sovereignty of the States, as there is always the possibility for States, to do the job themselves. Safety oversight assessments should be repetitive once in every few years and in such a situation, when there is no excuse for a State, to not comply with the international Standards related to an effective oversight, compliance could reasonably be enforced by any other State or by groups of States collectively.

In many other situations, States are capable and willing to perform their safety oversight duties themselves, provided that there is adequate support. This could be aid in training and education, but also material support in order to provide adequate working conditions needed for effective oversight. Often a major bottleneck is that the Civil Aviation Authority, being a State organization, is very limited in its resources because these are subject to the priorities in the national budget, which also does not allow for adequate remuneration of aviation specialists.

Who benefits? Certainly not everyone and not everybody equally. For internal safety the answer might be, that it is the passenger who benefits, but given the time of exposure to the risk, the crew of an aircraft benefits much more. Still it looks reasonable when the costs of internal safety are not charged to the crew, but only to the passengers.

For external safety the answer is more difficult. The beneficiaries are people on the ground, but who and to what extent, it is hard to say. In the immediate environment of a large airport, external risk accumulates, but everywhere else there is also some external risk of aviation. Who would expect something like the Lockerbie disaster? Certainly not the citizens of this small village! And although the beneficiaries of external aviation safety are the people on the ground it would be unreasonable to have them pay for a risk which is imposed upon them by activities from which they do not profit at all. Also for this risk it

looks reasonable to charge the cost to airline passengers.

The cost of safety oversight are moderate, but they are not the same everywhere. They depend very much on the scale of operations in a State. As the area in which oversight is necessary is a very wide area and covers a variety of disciplines, including for instance airworthiness, flight operations, Air Traffic Control and security, it is impossible to suffice with only one aviation specialist. Even when there is hardly any activity, you need at least some three to five individual specialists in a State in order to comply with the minimum requirements. The one hundred smallest aviation States in the world together would need some 400 aviation specialists when each of them separately would take care of its safety oversight obligations. Still they collectively generate no more than about 1% of the global international civil aviation. In comparison: The Netherlands alone generates more than 4% and according to a rough estimate there are less than 100 aviation specialists involved in the specific safety oversight tasks of the Dutch Civil Aviation Authority (RLD), even including national aviation. This means that safety oversight in small States is very inefficient and needs in proportion, more than ten times as much manpower than in the relatively large (aviation) States.

It emerges then for example that, when all the required safety oversight activity in the 100 smallest aviation States would be taken care of by regional safety oversight centers, a number of some 200 aviation specialists would be sufficient, taking into account that the efficiency could be doubled by this coordination of efforts.

Related to the global production of passenger-kilometers, which in 1996 amounted to 1363 billion for international operations, the cost of such a combined safety oversight would be no more than an additional 2 to 4 dollar cents per 1000 km journey.

These rule of thumb calculations are suggestive, and they are meant to be so. Instead of creating a lot of economical and political disruption by indiscriminate measures as banning airlines when their Civil Aviation Authority does not come up to its obligations, it is much better and certainly more effective to provide support in one way or another to improve safety oversight.

5. An outlook to the near future

Last November, in Montreal, an important conference took place, for which all Directors General of Civil Aviation of all the ICAO contracting States were invited. The purpose of this conference was to discuss the results and the future of the ICAO Safety Oversight Programme.

It was concluded that the safety oversight assessments, which until now were voluntary, should become mandatory and regularly repeated, like audits in a quality assurance system. ICAO's highest authority, the Assembly, still has to approve of this recommendation, but it may be expected that the Assembly will support this recommendation, because in principle the audience of the Directors General conference are basically the same authorities that constitute the Assembly.

This is a very important achievement, but it is not enough for a real breakthrough in aviation safety. Additionally to these regular, mandatory assessments in each State, there

must come the means to enable all States, no matter how poor or deficient, to comply with their obligations regarding safety oversight. I have suggested one possibility for such a much needed support, but there are of course many other solutions. Amongst them are certainly also bilateral aid-programs. Key-point is that the developed part of the world should recognize its interest in, and its responsibility for a global effective safety oversight everywhere and anywhere to the same Standards, as provided by the ICAO. Let's hope that this breakthrough may occur!

6. Conclusions

1. A break-through in the trend of safety in international civil aviation is necessary and is unlikely to be achieved without a major change in the approach to aviation safety.
2. The traditional understanding of safety as being a situation in which one's life is protected adequately, falls short in explaining the need for further improvement of the already very high level of safety in civil aviation.
3. Extending the definition of safety as being a situation in which also care is taken for human well-being, seems to be very appropriate, especially in civil aviation. This addition with an abstract notion as well-being, includes feeling safe, the perception of safety. It requires attention for the confidence in aviation safety as well as for safety itself.
4. The implications of such an extended notion of safety are significant, because it has as a consequence, that safety in aviation should not any more be considered as solely a matter of national concern for the directly involved States. All States in the world should share responsibility for the confidence in aviation safety, even more when they are more involved in international civil aviation and they should also contribute to it, collectively or individually.
5. Many mostly small or poor States turn out not to be capable to perform an adequate safety oversight related to their participation in international civil aviation. Instead of penalizing these deficient States by banning their airlines, it is a better and more effective approach to support such States in assisting them to comply with their obligations.
6. The cost of such support is moderate, but it needs the political will and courage to recognize the mentioned global responsibility for safety in civil aviation. This responsibility is not reflected in the Chicago Convention but neither is it in contravention with it.
7. The ICAO Safety Oversight Programme is ideally suited to be instrumental for monitoring the needs in the area of safety oversight and to establish what support is necessary and where.
8. The cost of international support, when considered as an effective safety measure, is very moderate and related to the total cost of transport by air, nearly negligible.

An Integration of Economic and Safety Policy

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Before starting I have to make a remark. When I am referring to governments I am mainly referring to governments of OECD member states. The OECD-flags are dwindling but the ship owners are their national citizens. And it is not the flag which is important but the ship owner as we all know. Therefore, OECD governments have a different role to play compared with, e.g. Belize, Vanuatu, Liberia.

There is a general feeling nowadays, we are moving in the right direction. IMO is very active with respect to STCW and ISM. Some parts of the industry are very active with vetting programmes like CDI and SIRE. The European Shippers Council is now developing rules of conduct for the selection of vessels to be chartered. IACS is tightening the grip on its members. Lots of laudable efforts, it cannot be denied. But are we really moving in the right direction? The general feeling isn't supported by statistics at this moment, hard to find as they maybe. The casualty rate of ships remains stable for over decades now. Remarkably stable compared with the progress made in other transport modes. The number of detentions of PSC is still raising. More than 14.000 seafarers are loosing their lives every year.

Despite the general feeling, these statistics and others are still making me somewhat hesitant. The poor quality of maritime statistics and the little attention they get is an omen already. Are we really moving in the right direction....fast enough? Or is, despite all the efforts, something more needed, a fundamental shake-up of the system.

For shipping, safety and economy are two sides of the same coin. One should expect therefore closely interrelated governmental policies for safety and economy. However, not only in shipping the left hand of government does not always know what the right hand is doing. To my opinion bringing the two together is vital for a sound development of the shipping industry.

Although the shipping market is very competitive, it is not a well-balanced efficient market. And these imbalances are a threat for the future. Governments must act only in case of market failure. No wonder we have seen for many years now substantial interventions of governments and multilateral organisations like IMO, ILO and the OECD. But after many decades of governmental policies the solution is still not within our hands.

Maybe there is a relation between this lack of results of governmental policies and the complexity of the shipping industry involving many players, each trying to optimize individual goals. The starting point is however very simple, a supply - demand relation. A ship owner wanting to make a profit with transporting goods and a cargo owner wanting transport services for the lowest price. But then it starts, a whole bunch of other market

players is introduced, e.g. insurers, classification societies, banks even flag states. They all bring their own interests to the market, interfering with our very simple starting position. All of these players, including many flag states, are trying to make a profit on the shipping market. In this respect all players show rational economic behaviour. It is what you can expect on an economic market. But, what about the effects on safety. In most parts of the market, especially on the spot market, the competition is cut-throat. And safety, e.g. in the form of well-trained seafarers or a well maintained ship, are seen as costs. And there are many ways for a ship owner to avoid costs.

What about the other players, like cargo owners, classification societies, etc.? Well, they are very worried of course. But above all, they are worrying about individual positions on the market. No wonder to find behind a substandard ship, not only a sunstandard ship owner, but also a substandard cargo owner, sometimes even a substandard classification society, insurer, etc.

If rational economic behaviour of market players does not let them pay for safety, who is? Well I can name some, the tax payer, the seafarer, sometimes with his life, the environment. The result of the shipping market is clearly sub-optimal on a societal level. Governments cannot be too happy with the shipping industry.

If market players are playing according to the rules and the result is not what was intended maybe we have to consider the possibility something is wrong with the rules of the game. By the way, who is creating the rules for the market. Isn't it government?

Maybe it is time to rethink the basics of governmental policies and strategies as the present ones are not very effective. Before developing new strategies what was wrong with the old ones.

As in other markets in shipping there is always a pressure on prices. Simply the result of competition on the market. That's the way we want it. And shipping is very competitive, therefore the pressure on prices is tremendous.

In normal efficient markets you would expect a focus on cost reduction by increased productivity, e.g. by innovation in process or product. Or in a focus on better quality of products and services. However, compared with other industries, shipping is not the innovative industry, we ourselves may think it is and you can have a big argument about the quality in services. Also the regulatory system creates heavy obstacles for innovation. And to make it even worse there is a structural overcapacity in the shipping industry with a devastating effect on prices. How do ship owners cope with the enormous pressure on prices?

Ship owners have developed a variety of cost reduction strategies, e.g.:

Flagging out: the search for cheap labour, simply reducing labour cost, but with what effect on the quality of labour? Nowadays about 85% of accidents is related to human errors. As long as ship owners have so much more interest in labour cost than in quality of labour, there is little reason to be optimistic.

Globalisation of ship management: the search for a tax-friendly environment or outsourcing management activities to cheaper places. One of the effects of globalisation was that shipping went to places in the world with other legal and moral standards with respect to safety. Globalisation gave ship owners ample opportunity for other strategies, like neglect of maintenance, unsafe operation and life-time extension. The average age of the world cargo

fleet was less than 10 years in 1970 and 1980, in 1993 it was 17 years. Many ship owners are now entirely relying on port state control as a periodic control on their vessel, while previously ship owners themselves were carrying out maintenance check-ups. The ISM-code should prevent this. However, the implementation depends on flag states, of which many are unwilling or unable to perform their obligations.

These strategies has brought cost-reduction, but at what price for safety. Substandard ships do have a competitive advantage, with a depressive effects on freight rates, making life of a quality ship owner difficult. Overcapacity, substandard shipping create a tremendous imbalance in demand-supply. The cargo owner lies above, making life for a quality ship owner even more difficult.

This emphasis on cost-reduction is killing for innovation. Why investing in innovation for increased productivity, if there is an never-ending source of cheap labour. Why investing in innovation for safety if there is no price for such quality on the market, if it is very simple to evade the rules.

The price of shipping is too cheap, real rates of return are too low, not permitting any real innovation. In the shipping industry innovation is clearly not playing the role it does in other industries. Cost-reduction did not and cannot bring ship owners the desired effects. Under present market conditions it only led to lower freight rates, not improving the position of the ship owner at all. Not improving the position of the cargo owner either. The logical result of this development is the present discussion about liabilities, e.g. in Brussels.

A tanker shipping market, mainly oriented on the spot market, with a low return on capital, without incentives for quality shipping is an endangered market. Under present market conditions I have serious doubts if it can guarantee in the future a provicient, safe and environmental service.

More money can be made out of buying and selling ships, than by operating them successfully. But what about the core business of the shipping industry? And if it is buying and selling what are then the implications for maintenance and crewing policies of companies? What are the effects on safety?

Because the market is not willing to pay for safety the emphasis on cost-reduction profoundly changed the entire industry. Governmental policies till now did not follow that change. The effects of cost-reduction show the fundamental relation between safety and economy and governments are ignoring it till now. That very fundamental relation can be shown by the following statement: "as freight rates go down, markets go down, ships go down".

All goodwillig governments are very busy fighting the symptoms, the ships going down, and are meanwhile neglecting the economic origins.

How did a government of a traditional maritime country react on the change in the industry? Flagging out, the use of tax havens inspired OECD-governments to develop two policies, one for safety and one for economy. Developed frequently within two separate branches of the same government. The problem is often starting with the lack of communication between maritime safety agencies and the economic policy makers within one government. No wonder the policies were not-related and imbalanced.

Safety policies were:

- rules, more rules,
- enforcement, more enforcement

In a situation with globally huge differences in levels of regulation and above all enforcement, more rules and more enforcement must lead to more economic benefits related to ducking the rules. In other words more safety rules, more safety enforcement does lead to more economic distortion of the shipping market. Safety policies became in this way an incentive for flagging-out.

Safety policies led also to a large abundance of prescriptive safety rules and regulations. Prescriptive rules do take away responsibility for safety from the industry towards government. Prescriptive rules are also killing for innovation of the industry. Prescriptive safety rules have become an obstacle for a sound development of the shipping industry.

Economic policy was about:

- subsidies for shipping

Flagging out, delocation of companies are economic losses for a national economy. Therefore, it was quite normal that governments were trying to stop the economic distortion of the market by foc's and tax havens. But how did they do it. By creating even more distortion.

Subsidies for shipping, shipbuilding subsidies, depreciation schemes, roll-over reliefs are diverting the focus of the company from the market to the fleshpots of governments. The result of these policies can only be inefficient companies and the building of more ships than the market is demanding, in other words subsidized overcapacity. In almost any state aid scheme the fleshpots of government can only be reached via the building of a ship. The inevitable result of these schemes is therefore increased overcapacity, more pressure on freight rates, more cost reduction by ship owners, more flagging out, etc. The history of the economic policies of the OECD countries show it all.

But what about the effects on safety? More distortion of the market by governmental policies has lead to even more emphasis on cost-reduction by ship owners. Instead of stopping the downward spiral, governmental policies can even have to a certain extent an accelerating effect.

Maybe it is time for a change, maybe it is time for a fundamental re-evaluation of governmental policies.

The result of the present rules of the shipping market is not what we intended as governments, nor as market players either I assume. Governments have to change to rules of the game to guarantee the desired effects.

At this moment IMO, flag states and port states are fighting the market instead of letting market players do the job. By doing it all alone governments took over responsibilities from market players. This cannot be the right way. Government is not primarily responsible for safety in shipping, market players are. End-of-the-pipeline-solutions, i.e. flag and port state control, is the best governments can do. Governments must see to it that the market is organised in such a way that it is able to solve the safety problems. Governments must therefore create a frame work for the market. This frame work is setting conditions for market players enabling them to solve the problem in an efficient, non-distortive way.

What can be said about these conditions. The problem must already be tackled at the source, which is the economic process in the market. Already when demand and supply are meeting, safety must be present because there is a price to pay for safety. The only problem is who is going to pay it. In an ideal situation of course the external costs of safety must be an integral part of the freight rate. When safety has a price, market forces will create a result optimal for safety as well. How can this be realized.

The result of all IMO regulation is the ship owner to be the only market player to blame when something went wrong. Only he is liable for safety in shipping. Under present market conditions the cargo owner is not paying for safety. He is not accountable for it. And when he is there can be seen attempts to escape liabilities, as the discussion on the Exxonvoy charterparty shows. Very alarming for a quality tanker operator I should say. Do classification societies have any realistic accountability or liability for their certificates? If not, what is the value of such a certificate. Are insurers applying quality rating, which can have an enormous impact on the quality of shipping? Insurers do not dare, because of fear for market share. The insurer is not having any accountability for prevention of accidents only for handling of financial claims after the accident did occur. And the banks, they are above all interested in repayment of debts and interest. They do not have a policy related to the quality of the ship owner. They are not accountable for funding questionable enterprises.

Despite all the efforts of IMO there still are no quality standards for and no quality control of flagstates themselves. Some flag states are only a legal excuse for ship owners for doing nothing with respect to enhancing safety. Flag states are maybe accountable but certainly not liable for their lack of inspection and control. And what can you expect on a market from accountability without any realistic liability.

Thus at the end we are still left with the ship owner, the only one facing realistic liability, while many others are unhampered in contributing to the overall safety problem.

No wonder, there are some ship owners who are hiding behind legal defence screens. A ship owner not to be found is simply the result of the present rules of the market, where only the ship owner is really facing liability. Of course there are segments of the market, like chemicals, where it is better organized. But in these segments the cargo owner has a vested interest in quality transport. Some time ago I would include the tanker market as well. But I am not so sure any more. Oil majors withdrawing from ship owning, oil majors attempting to make ship owners more liable for pollution prevention are very alarming signs.

Quality shipping will only be possible in the context of balanced demand-supply relations, stable relations between ship and cargo owner. For this a more long term approach towards the market is essential. However, present market conditions are not favourable for such an approach.

In the new set of rules for the game other market players, including flag states, must face liability as well. These shared liabilities will give market players an economic interest in paying their share of the safety related costs. When supply and demand are both facing liability, safety will be present at the source of the economic process. But above all shared liabilities must create fertile soil for stable, long term relations between supply and demand, between ship owner and cargo owner.

However, for liability to play a constructive role, market players must have a clear

insight into the quality of the ship and the quality of the management of a shipping company. Therefore quality must be transparent.

At this moment there seems to be an overload of inspections. Flag states, port states, cargo owners, class societies, insurers even the ITF, they all are inspecting.

What good did all these inspections bring about? Not enough to my opinion. The quality of a ship is still unclear. There is not even an agreed definition of a sub-standard vessel. The relations between these inspections and safety is questionable when more than 85% of the inspections is about the hardware of a ship, while more than 85% of the accidents is related to human factors.

The most vital element related to safety is the management of the company. The management is decisive for crewing, maintenance, operation, etc. The ISM-code is directed at the management. But it depends on the same flag states not able or not willing to inspect. It cannot be seen as a surprise that present developments of the ISM-code are not very promising.

A lot of inspections for own ends, but no public, objective information on the quality of a ship. A vital condition in a framework for the market is therefore an information system which is giving clear data about quality of ship and company. Developing such a system will not be an easy job. However, it can lead to a necessary shake-up of the system. Such a system must consist of neutral, objective information and must be transparent and on-line available.

With respect to the company, key element in the new information system is the quality management of the shipping company. The ISM-code, directed at safety management, is a first step towards quality management. A furthergoing approach is now introduced in the Netherlands on a voluntarily basis. The Integrated Management system for Shipping consists not only of the mandatory ISM-code and mandatory regulations concerning occupational health and safety, but also voluntarily ISO 9000 certification. In the next presentation you will hear more about it. This system integrates all relevant quality aspects of the company. Based on such a quality system ship owners can be certified. This certification gives cargo owners, insurers, etc. essential information about the management of the company.

Inspections of flag and port states, classification societies, insurers, etc. on the quality of the ship are another key element of the new system. Cooperation between all players cannot only reduce the inspection overload for a ship owner, but will also result in better and cheaper information. Cooperation is also essential for improving the quality of inspections. This improvement is vital, because of the growing complexity. With the ISM-code, there is much more than coming on board to check the date on pyrotechnics and chart corrections, or the validity of the certificates. The inspection has to become a survey with the potential to investigate virtually every detail of ship operation of the whole managed fleet. Upgrading the quality of the inspections and the inspectors is essential and can only be realised in a joint effort.

With such data about quality of ship and company, a cargo owner can be made liable for choosing substandard transport. With such data insurance of substandard ships can be prevented. Compulsory insurance can be the lock on the door. With such data financial institutions can be convinced to introduce quality rating. Classification societies, flag states

and port states can play an important role in the collection of data. Before developing such a system a discussion on new roles of and relations between flag states, port states and class societies is vital. E.g. class societies as the core of such a new system, flag states formulating quality standards for and carrying out quality control on class societies, port states as a last check on the system.

However, at this moment class societies are not able to fulfill such a crucial role. A major problem to be solved is the dual relation between class society and ship owner. Class societies are being paid by ship owners at one hand and at the other are supposed to inspect objectively the same ship owner and his ships.

Governments must create a coherent maritime strategy with conditions for an efficient shipping market. For safety policies no more rules are needed, but effective enforcement. Therefore, governments must improve the safety net, i.e. flag state and port state control. It is an end of the pipeline solution which must safeguard the conditions for the market, must safeguard the self-organisation of the market, as a result of shared liabilities.

Governments must abandon all state aid policies distorting the market. This is a blessing in disguise for governments. These policies did cost a lot of money to the tax payer and they were not effective anyway.

This coherent maritime strategy must also have an eye for the shore-related aspects. One of the detrimental aspects of the flagging-out process is that nowadays in Europe there is a lack of national seafarers. Detrimental not only for safety, but also for the maritime industry as a whole. Skills and know-how of seafarers, vital for many functions in the maritime industry, are becoming scarce.

Creating conditions for a new organized market is easily said, but not so easily done. It can distort the market even further in stead of making it more efficient. It is crucial that market players and governments together are designing such a frame work. If not, public opinion can take over, not necessarily leading to a more efficient and safer market, as OPA 90 has shown. It is therefore important that all market players do take up their responsibilities and seek a dialogue with governments. In the end an efficient shipping market where a price is being paid for safety is in the interest of us all.

Integrated Managementsystem in Shipping

A facilitation tool and a means for sharing responsibility for safety within the industry

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1. Introduction

This paper describes the development of regulations to enhance the safety of shipping in international conventions. It will be shown that the existing philosophy of designing rules and regulations for ships alone leads to increasingly detailed rule-making burdening the industry as well as the regulators. Next the change is described towards a more process-minded approach which results in the mandatory implementation of system-management in all aspects of a shipping operation and the impact this will have on the creation of a "safety culture" within the maritime industry.

2. Towards a fully prescriptive industry

The International Convention for protection of the Safety of Life at Sea (SOLAS) was created in 1914 in reaction to the disaster, two years earlier, with the passenger vessel "Titanic". This was not the first time regulators concerned themselves with shipping as we may remember earlier activities of Samuel Plimsoll against overloading of ships and the existence for some decades already of the "Rules of the Road", but Solas was for many decades the most important international achievement in the field of maritime safety.

Throughout the years the convention has been amended and brought up-to-date to reflect technical evolutions and revolutions. The largest number of amendments however were triggered after a shipping disaster by the sudden realisation that "something had to be done". In recent years the "Herald of Free Enterprise", the "Scandinavian Star" and the "Estonia" may be remembered as incidents with great impact on the regulatory process within IMO. The SOLAS Convention, and similar conventions in other fields of the maritime industry have always focused on hardware and in a lesser way on the manner to operate this hardware. This focus towards technical regulations was so strong that in recent years the shipping industry was dubbed by some speakers "the most regulated industry on earth". Despite all this regulating accidents do still occur, sometimes with great loss of life or with a great negative impact on the environment, both of which are no longer taken for

granted by society. The rather reactive way in which new regulations are created often leaves the impression of always running behind the facts. Newly designed rules need time for formal acceptance and are often only applicable to new ships, leaving older vessels in an apparent unsafe condition! Also the amount of new regulations makes it difficult for the owner, the captain as well as the (government) inspector to keep up with changes.

No wonder that critics of IMO and the way it works voiced the opinion that all this technical rulemaking serves no effect and some Administrations bypassed the workings of international conventions by resorting to unilateral measures to speed up the implementation of, what they thought were the best methods to enhance safety, regardless of international acceptance.

3. Recognition of the "Human Element"

In the early eighties the recognition emerged that the effort put into an ever increasing number of measures to improve hardware in order to prevent accidents did in fact not deliver the decrease in accident rates that might be expected. Clearly something else posed a limit to the reduction in accidents that could be achieved by technical measures alone.

Borrowing from other fields of industry (a.o. aviation and the process industry) researchers recognized and tried to define the "human element" in the chain of events leading to shipping accidents (in the Netherlands a.o. Wagenaar et al.). This caused a way of thinking about accident prevention that was unknown in most shipping circles, although in hindsight it can be said that the phenomenon known as "good seamanship" was in fact an experience based combination of practical knowledge and the human element.

In the old days the way sailors lived and worked on ships in close reach of the elements bred a certain additional sense for safety. Knowing the limits of working a ship up in a storm was second nature to an old salt, but this knowledge faded away as the advance of technology built larger and faster vessels with comfortable wheelhouses were those in charge worked well protected and away from the elements.

Another important element that influenced the diminishing of pride in a well kept vessel with owners and crews alike was the emergence, after the second world war of many new shipping nations. The competition resulting from the oversupply of tonnage led shipowners to ever greater economics in maintenance and repair and, not to be forgotten, in manning their vessels. The resulting emergence of substandard vessels and their impact on the industry is dealt with elsewhere. We will continue by describing the measures created within the SOLAS Convention to try to turn back this trend of poor kept vessels and bring to the industry a new image of quality and safety, established by quality ships and quality crews.

4. Creation of the ISM code

Following recognition of a human element in the chain of events and the recognition of the fact that shipowners and those responsible on board should adopt a more systematic

approach to their daily work, the development of what was to become the International Safety Management code started in the mid-eighties. In some senses a revolutionary development in shipping. For the first time in history regulations were being developed in the context of SOLAS that were not only directed towards building and equipping a ship or towards the master, but directed also to the way it should be operated during its lifetime. Not only by those on board but also by those involved in the decision-making chain ashore, in the offices of owners and operators.

Experience and know-how of system-management was at that time mainly available with experts with knowledge of ISO 9000 quality assurance.

The principles of quality assurance were slowly being adopted in certain areas of the shipping industry, mainly in chemical- and oil trades. In most cases the adoption of ISO standards within a shipping company was triggered by the industry they served. ISO certification was already well-developed in the shorebased oil- and chemical industry and those customers of seaborne transport often required ISO certification for the shipping companies they dealt with.

The initial results of the development of the ISM-code tended to be rather detailed and prescriptive, probably being caused by the standard being developed by experts with a strong operational background.

It was recognized that such a detailed and prescriptive code would lead to difficulties during implementation in a very diversified industry. There was also a strong reaction from the industry and some maritime administrations against this trend. Together this resulted in the development of an industry-specific code which was more in line with the principles of the ISO 9000 standards. The broad terms in which the new code was expressed offered the required flexibility, needed to implement the code in a diversified shipping industry. At the same time, because this code was written specifically for the shipping industry, it was easily recognizable for those who were going to live by it and use it in their day to day work.

Three red threads are visible in the ISM-code:

- a clear path of responsibility within all levels of a shipping company,
- planning and preparation of critical and important activities,
- training of the crew for the job to be undertaken

Together they must lead to the development of a "safety culture" within the industry and bring back some of that oldfashioned feeling of a well run ship supported by a responsible shorebased management.

5. Implementation of the code and interaction with (Total) Quality Management

Still, when implementation of the code started, the industry signalled about problems encountered when safety management was introduced parallel to quality management. As already stated before, in the eighties and early nineties quality management was introduced in some parts of the shipping industry in response to requirements from shippers and cargo-owners. It soon showed that the philosophy around the ISM-code, recognizing the widely varied maritime industry, conflicted in many cases with the philosophy of ISO-trained consultants and auditors.

Many attempts have been made in the literature and in publications from consultants and certification bodies to prove that the ISO standard and the ISM code could be superimposed without difficulty. In practice however it appears that in a company implementing both systems often two different and independent sets of manuals are created, despite the similarity of both systems. This is caused by different terminology in both systems and the fact that not all elements of ISO are clearly recognizable in ISM, or put into different paragraphs. The use of external consultants, well versed in one system but not in the other may have amplified this situation.

In the Netherlands the occupational safety and health regulations also require a systematic approach to solving the problem of providing a safe working environment to employees. Risk-analysis has to be undertaken to a certain extent and the employer has to plan in advance what measures he will take to reach a pre-determined result. The employer has however less flexibility than with ISM and ISO because more activities are explicitly prescribed by law.

This complicated the matter considerably. To make things worse, it appeared that experience in implementing system management for any purpose existed only by those working in larger companies. In the Netherlands many small one-vessel shipowners exist, the owner in many cases being the captain of the ship. All guidelines and all sample manuals provided so far catered for organizations of some substance, leaving the poor captain-owner out in the cold, although in the end also his ship and his organization, limited as it may be, has to conform to the requirements laid down in international and national law. And also the captain-owner will be confronted by shippers requiring him to embrace "quality management".

This was reason for the Dutch maritime Administration to facilitate the development of a fully integrated system management scheme, encompassing not only the mandatory ISM code and mandatory regulations concerning occupational health and safety (ARBO wet), but also voluntary ISO 9000 certification.

In close co-operation with the Royal Association of Netherlands Shipowners and management consultants of Coopers & Lybrand a project was started to develop and apply the system in four parallel pilot projects with four participating shipping companies. Those four companies represent the wide variety that exists within the industry.

In many cases it is visible that a managementsystem according a certain standard is developed in close similarity to the outline of the standard. When more then one, not completely equivalent, standards are involved this obviously leads to conflicts, resulting in two or more independent management systems existing next to each other as explained before. Clearly not the perfect point of departure for a broadly supported method of process-control.

The experience of the consultants has shown that better results can be gained by not following the outline of a code or standard, but to build the management system along the process by which an industry is run. This process-oriented approach has been followed with good results in all four pilots.

6. Description of the IMA-S system

Although dubbed a "system", the "Integrated Management system Shipping" (IMa-S) is more a set of guidelines towards designing and implementing a management system than a system in itself.

The basic element by which these guidelines differ from existing products is the process-oriented approach that was adopted. This is best explained by the matrix below.

		MAIN PROCESSES				
		0. General	1. Commercial	2. Operations Planning	3. Operations Support	4. Voyage
	1. Process					
	2. Policy					
	3. Personnel and Organisation					
	4. Communications					
	5. Equipment					
	6. Purchase					
	7. Finances					
	8. Evaluation					

Figure 1. IMA-S matrix.

The vertical column at the left end of the matrix contains the managerial aspects of a commercial operation, while the horizontal axis shows a division in four main processes defined within the organization.

The basic principle is that all activities that lead to the product of the organization, in this case seaborne transport, can be placed in a unique square in the matrix. In real life activities expand beyond the borders of the previously defined main-processes. This "border crossing" however may be dealt with when defining the relevant procedures. The main-process from which a certain activity originates, or the main-process for which the activity has the greatest impact defines the position of that activity in the matrix.

By looking at the vertical column at the left of the matrix it should be noted that the "process" is placed on top, thereby making all other aspects visually subordinate to the process. This reflects real life. Within a company the business-process is the aspect generating income while all other aspects are in fact supporting activities, although it should be recognized that the business-process may not be viable when some of the supporting aspects are neglected.

The first item on the horizontal axis "general", which is placed outside the defined main-processes seems to be conflicting with the basic principle of the matrix that each single activity within the operation should be allocated to a main-process. During the development phase it became clear that some, mainly supporting, subprocesses were so much interwoven with more than one or even all defined main-processes that the choice was made to position these subprocesses in a column of their own in the matrix. Looking

again to a real life organization it shows that this model conforms with the way a commercial organization is constructed and functions.

All the elements on the vertical axis will be recognized in any organization, no matter its size. In small organizations more managerial aspects may be found in a single person culminating in the captain-owner where (virtually) all managerial aspects are combined in one person. For him the distinction between the various aspects will enable him to organize his business more efficiently.

The elements on the horizontal axis however are not fixed. They may be left out when certain processes do not occur within a company, or are so much interwoven that it is impractical to make a distinction, while it is also possible for a large diversified organization to discern additional main processes. The basic principle of allocating activities to a single aspect and a single main process remains aloft.

Although the requirements of SOLAS and national occupational health and safety regulations focus on safety and those of the voluntary ISO 9000 system on quality, favouring the customer, it was stated from the start that the integrated system to be developed should provide additional advantage to the shipowner embracing it. He should in the end run a better, more efficient and more economic business, at the same time fully complying with all legal and customer requirements.

Critics of shipping and the way it evolved in the last decennia would have considered it impossible or at least extremely costly to combine these two ends of the scale. The simple fact however that a company embarks on the task of fully describing its organization gives the opportunity to reflect on past and present procedures and improve where improvement is feasible.

The results of more than two years development, which took place under pressure of an imminent statutory implementation—date of 1 July 1998, have proved that integration of different system-management philosophies is possible and workable in real life. Two of the pilot companies are now in the final phase of the implementation process, i.e. external auditing and certification, with good results.

About 40 Dutch shipowners have now chosen to follow the lead of their four colleagues and are now implementing the Integrated Management system-Shipping (IMa-S). This is done in "circles" of about ten owners with similar needs and a similar required timesteps, who meet regularly to exchange views and experiences and receive guidance from a consultant. This well known concept was borrowed from quality assurance practice.

7. Towards a "Safety Partnership"

A number of trends are visible these days which have impact on the relationship between the maritime Administration (the public sector) and the shipowners and classification societies (the private sector).

In the first place a trend within the public sector to "privatize", resulting in a growing number of statutory inspections of compliance with regulations now being performed by private bodies, while the Administration retreats to a greater distance from the industry.

In the second place the developments sketched in this paper, where a clearly defined own responsibility is placed with the shipowners, requiring them to plan ahead and develop a safety culture within their organization.

The third trend is a growing notion that the Administration and the direct shipping-related industry are not the only elements in the chain that influence the safety of the maritime industry as a whole. Shippers, cargo-owners, insurers and financial institutions play their own part in this field and ultimately have influence on, and responsibility for, the safety of shipping.

The Administration, representing the Government that ratified and signed the international SOLAS Convention, still has the responsibility for safety in shipping, by maintaining compliance with the regulations. It is clear however that the Administration, without exercising a very restrictive regime can not take this responsibility alone. A restrictive regime is "not done" anymore in modern society, so other means have to be found to obtain the involvement of all other interested parties.

The mandatory implementation of the ISM code, and possibly also voluntary implementation of quality assurance, provides a basis for the shipowner to take his share of responsibility for the safety of shipping in a manner that is both effective and cost-efficient.

Responsibility should not be confused with liability. Much has been written in the shipping press in the past year on the subject of liability and the limitation of liability by shipowners and the impact of the ISM code on this issue. Most comments lauding the suggestion that the ISM code robs the owner of his limitation refer to the requirement that

"to ensure the safe operation of each ship and to provide a link between the company and those on board, every company, as appropriate, should designate a person or persons ashore having direct access to the highest level of management...."

It was never the intention of the ISM code to provide specifically for an information system keeping the directors of a shipping company fully informed on all details of the state of maintenance and other operational aspects of the fleet. The purpose of the designated person is a.o. to ensure that legitimate requests for repair and supply are followed up by cost-conscious superintendents, that reports on nonconformities are followed up and the necessary corrections be made. To assist him in this function and to provide him with the enforcing powers needed, he must be provided with a direct link to the management, in order to obtain their commitment if necessary.

Discussions on the status of limitation of liability after the implementation of the ISM code may have a serious negative effect on the effectiveness of implementation. Fear of the shipowner being confronted with nonrefutable claims may well result in "paper tigers" being installed, completely ignoring the wish for effectiveness and efficiency that prevailed when the IMA-S system was developed.

Ways have still to be found to make the other parties in the shipping industry such as insurers, charterers and cargo interests take their responsibility, but for the transport industry itself the implementation of an integrated managementsystem may provide the right tools and be the first stepping stone for the shipowner on the road towards a real "partnership in transport safety".

Ships, Safe and Sure

J.J. Westerbeek

Managing Director, Seatrade Groningen BV, The Netherlands

It is an honour for me being present here amongst all the experts, knowing most probably much more about safety and shipping than myself. I have been asked to give a presentation about safety of transportation related to the activities surrounding this subject within our organisation Seatrade Groningen BV.

As you can see the presentation is titled "Ships, Safe and Sure", because we think and believe transportation by ship is safe and sure, if you work on it, if you control the process. Seatrade's internal quality policy has been defined for years by the so called triple S standard:

- Safety
- Speed
- Service

being a combination of quality and commercial goals. Today in this presentation we will concentrate on the first S of Safety.

Before telling more about Safety of Transportation and about Ships, Safe and Sure, I'd like to give a little bit more background information about our company. Seatrade Groningen BV is a ship management and ship owning company, specialised in reefer vessels and residing in Groningen. Since 3 years Seatrade is a fully ISMA/ISM certified organisation. ISMA stands for International Ship Management Association and ISM stands for International Safety Management.

It has been internationally agreed that compliance with the code for general cargo vessels is compulsory as per 2002. Reefer vessels are generally cargo vessels.

Question could be: "Why certified so early, 7 years ahead of schedule"?

Answer is: Changing an old-fashioned shipping mentality and modifying an organisational structure takes time, almost a generation. Some figures about Seatrade Groningen BV:

- 51 Vessels in management and ownership (47 reefers and 4 bulkers).
- 55 Employees in the office.
- 800 Employees on the fleet.
- Established 47 years ago.

Some figures about the vessels:

- Length betw. 80/150 m.
- Beam betw. 13/24 m.
- D.w.t. betw. 3000/11.000 tons
- Engine power betw. 2000/10.000 kW
- Crew 10/20 persons
- Speed 12/21 knots
- Age 0/18 years

- Cargo: fruit, bananas, meat, fish, potatoes, garlic, reefer containers etc. Sometimes general cargo like cars, flour, fertiliser and containers.
- Operational 365 days a year with an off-hire percentage of 1,4% average.
- Crew Dutch, Russian, Filipino, Croatian.

A picture of the organisation should give an idea of the main departments of this organisation, being T.D., C.D., F.D. and the separate departments of QA and Insurance falling directly under the responsibility of the Managing Director.

In the past the insurance department was called claims department and the G.M. was handling all insurances. The philosophy was the more (damage) claims, the better, because the premium paid was so high. Nowadays a claims manager is called a risk/insurance manager and the G.M. should have more time for its core activities like shipping (developments) and ship management.

As mentioned earlier, there are two departments working close together, having similar goals: optimising safety awareness and executing risk assessments by means of Risk management. These departments are:

- Insurance and Claims department.
- Quality Assurance department.

These departments have their own responsibility, but on the other hand a joined objective of creating an environment in which our vessels and crew can work on the transportation of goods safe and sure without delays, as efficient as possible, without accidents etc. These risk management tools are:

- to have / to develop a clear and open organisational structure.
- to collect information/figures, creating statistics, analysing the figures.
- to make evaluations and developing preventive measures.
- to develop necessary additional training, pressurising on increased experience and safety awareness.

1. Organisational structure

The office organisation, ships organisation and the communication between office and ship, constitute the major parts within the organisational structure.

Lack of communication is still a major cause for accidents and also a major factor in the attempt to avoid accidents. ISMA and ISM are excellent organisational aids for creating a ship/office organisation based on the typical experience in the ship transportation sector.

2. Statistics

From statistics we create trends. A major task is collecting all information by means of damages/accidents/near misses and casualty reports, indicating all relevant details. Many reports lack relevant details for developing correct statistics.

Analysing the figures is an experienced task due to - very often - a shortage of information.

3. Evaluation/preventive measures

80% of all accidents is related to a human error. During the evaluation of an accident it should be clear that punishment of the person who has caused the accident is not the best approach for avoiding a similar accident in the future.

Priority should be given to which circumstances, lack of training, skill or experience or omission in the organisation did cause the accident. The following simple questions are relevant for a correct evaluation:

- Why could it happen? (circumstances).
- Why did it happen to this person? (training, skill).
- Why is it happening more often? (organisation/system).

Examples of above are:

- Bad weather, act of god, beyond control, damage to forecastle or superstructure.
- Overriding a lightbuoy or breakwater in good weather and without failure of machinery.
- Fore castle full of water during sailing from A to B. Lack of organisation, no checking before departure and no checking during sailing.

4. Training, skill, increased experience and awareness

Lack of training and experience remains a major factor when it comes to accidents. To concentrate on this issue is still of major importance, like the bridge/engine room "heavy weather" training. Although accidents are being excersized, in reality accidents are getting out of hand because there is no control of the situation.

Communication of the results/recommendations through major internal investigations towards all concerned in the organisation, including the findings, results and recommendations from third parties.

Improving existing checklists, procedures for E.R. and bridge, like mooring and unmooring, bad weather passage, pilots on board etc. etc. Communicating this company policy "accidents only cost money" or "plan what you do and do what you plan" from bottom up and top down in the organisation and by making risk management a part of this policy by asking "how to save on spending money for insurance premiums".

The shipping community has made the first steps toward this new approach of accidents, how to avoid them and what kind of preventive measures to be taken. Many other parts of the industry are ahead of us, like aviation, chemical industry, nuclear industry. This fact could be a valid reason why investigators of a third party without having detailed experience in shipping, will never have the knowledge to make a good judgement.

To give an example, in aviation it is quite common to keep all planes out of the air when a technical mishap is discovered in one plane. This is automatically distributed to all users with the obligation to check their plane. It never happened in shipping that when one ship sunk with crew onboard - the cause of the disaster being unknown - all sister vessels were held in port till all investigations were over. It should not come this far as we should be able to organise our own safety in transportation with the experienced knowledge of third parties like IMO, SI and the "Raad voor de Scheepvaart".

The result of a full implementation of risk management is that there are:

- less lives lost.
- less accidents.
- less delays in transportation of cargo.
- less pollution due to less accidents.
- less costs for insurance premiums.
- less human frustration.
- less deviation from the prime objective in shipping "Safe transportation of cargo".

With this policy we believe Ships are more Safe and Sure.

Can Pilotage Performed in Competition Provide a Safe Environment for the Shipping Industry

The balance between safety and economics

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1. Introduction

World-wide a call for the introduction of competition within all fields of economic activities is heard. Lately this call has also been heard in sectors that belong to the domain of public interest. Even in maritime pilotage the introduction of competition is being considered, and in some cases competition is actually introduced. Pilotage in the Torres Strait in Australia, for instance, has been opened up for competition.

After the downfall of communism in the former East-Bloc countries, self proclaimed "bizznizzmen" started pilot organisations that in some ports was allowed - by the (absence of) authorities - to compete with the former state/municipal pilot organisation.

In 1995, a commission led by professor Frissen was installed by the Dutch government to review the structure of pilotage in the Netherlands. The Frissen Committee's report, issued in 1997, contained amongst others the conclusion that pilotage should be subjected to market forces. Just one - and in my opinion not the least - of the topics that becomes interesting with these proposed changes is whether the balance between economics and safety will change.

For many centuries, pilots have world-wide been walking the fine line between many limiting factors. Without wanting to oversimplify matters I would like to focus in this paper on the safety factor and its related elements. In general it can be said that in pilotage a workable situation requires a proper balance between this factor and economics.

2. Chain of events

Let us, first of all, conclude that a 100% safe situation may only be found in the port of Utopia in a country called Never-Neverland. If 100% safety does not exist, then we must ask ourselves what the reality is.

An indication (how many incidents go unnoticed) may be found by looking at the number of incidents. Some insurance companies have provided us with information about

incidents in the shipping industry. Det Norske Veritas has for instance reported that 90% of all ship accidents happen in restricted pilotage waters and that in 60% of these there is a pilot on board.

I would, first of all, like to shed a proper light on these findings. To illustrate this, I would like to use one of the sayings used in our Bridge Resource Management course. "Failure is an event, failure is not a person." As far as the event is concerned, I would like to go even further and conclude that (almost) all incidents are the result of a chain of events. The final event is the one that puts the last connecting shackle in its place, i.e. that finally links the chain together.

Let us, therefore, not link the piloted area and the mere fact that the pilot is on board to the incident. As a comparison 99.9% of the incidents takes place with the master on board. I would hardly see evidence in this statement to identify the master as a "dangerous good". Finally let us realise that there may be thousands of shipmovements within an area where pilotage is compulsory.

To put things completely in the right perspective let me give you the practical figure of all incidents (including technical failure) within the piloted area in the Netherlands. It may come as a surprise but the number can not be measured in percentages. We have to resort to permillages. The number is $\pm 2,4$ in every thousand and has since the privatisation of the pilotage service in 1988 been falling consistently.

3. Connecting links

Do we know all there is to know about the links in the chain of events? In a minority of the cases the causes only come to light after a thorough investigation.

We have found that in a minority of incidents the final cause can not be identified; for the other incidents however, we can identify amongst others technical factors and human factors. As far as the technical factors are concerned, practical observations in the Netherlands have shown that 15% to 20 % of the incidents happening within the piloted area is finally caused by failure of either the steering engine or the main engine. The closing link in the remaining 80% to 85% of the number of incidents can be attributed to various other causes. These incidents are caused by actions of other vessels, acts by assisting vessels, acts by third parties not on board, pilot error, design faults and acts by crewmembers and/or officers of the ship. Most incidents go unnoticed, but some incidents may have a broad social and public impact. For instance when the environment is harmed or when there are casualties.

4. Safety and unsafety

Over the years, I have seen many attempts to tackle the problem to define what safety is. I have found that this definition may differ according to the person or organisation that addresses the issue. Perhaps this has to do with the variety of fields and interests from which issues regarding maritime traffic are approached. From the public interest side some overall

important issues emerge that lead to questions like:

- Is a safe and efficient traffic flow secured?
- Are the navigable waters well maintained and is their continuous use secured?
- Is shipping prevented from damaging the environment, bridges, locks, quays etc.?

In the field of private interest we see that issues have for some years been overshadowed by the circumstance that here is fierce competition in some sectors of the shipping industry. A decrease in the companies margin has prompted many companies to follow a short term strategy and look at all possibilities to reduce costs. This continuous necessity to cut costs reduces the quality of global shipping. It is not only the crew that is becoming smaller, also the level of their professional skills is reduced by the same rate in which ships are being switched to flags of convenience.

Every day, we see ships arriving in our ports of which the crew is hardly capable to do their jobs properly on account of e.g. too much work to be done by too few, or ships in such poor state of maintenance that their equipment is only partly operational. And what to think of those cases of ill will or culpable indifference when owners are not prepared to spend money on their ships or their crews. Many other parties – ports, agencies etc. – have other interests. What all views have in common though is that they acknowledge that maintaining safety carries costs.

5. Safety by numbers

Given the circumstance that safety has many sides and approaches – and is therefore difficult to grasp – we go sometimes through exercises to simplify matters. The unwanted side effect is that this often results in a tendency to oversimplify matters.

One of the oddest approaches that I ever have been confronted with was the one that safety could be given marks on a range from 0 to 10. Safety in its present state could then, for instance, be expressed by the number 9. If so, the conclusion then seems to be justified that a mere 7 or 6 would be sufficient! First of all, this approach does not sufficiently recognise the various interests that are at stake. Nor does it recognise that there is a chain of events leading up to an incident. Furthermore – although not explicitly stated –, one can sense that a strong economic component is entering into the argument. Maintaining safety at level 9 would cost more than maintaining safety at level 6. Such an argument might then be translated into: "Safety, but at what cost". Giving marks between 0 and 10 is an exercise that carries too much subjectivity of the person or organisation giving the marks. What one person experiences as a 9 may for another person be marked as an 8 and vice versa. Most importantly, there is no evidence to support the theory that safety behaves rationally, and slowly descends from 9 through 8 and 7 to 6.

That may very well be because there are various sides (public and private) to safety and because all the links in a chain of events carry various weights giving safety a more "elastic" nature. When we look at some of the recent incidents that have happened after changes in the economic surrounding in which pilotage is performed (Sea Empress, Peacock, etc.: we will return to those items later) we can see that there is more evidence of safety having a certain "elasticity". Safety stretching for a reasonable amount of years (during

which minor incidents may still occur) until the last shackle in the chain of events locks and an incident takes place that nobody entering any discussion on safety (be it public or private) would ever want to occur, is the last thing anyone would be waiting for.

6. Sea Empress

To illustrate this, let us turn to the grounding of the *Sea Empress*. Many years passed between the change of the British Act on Pilotage in 1987 and the grounding of the ship at Milford Haven in 1996. When we read the report we see how public and private interests evolved and how the chain of events was forged shackle by shackle. Surely, the closing link was a pilot who, with merely two years experience and without adequate training for such a type of ship, was asked to board the ship in a navigational situation that was so critical that it was almost impossible to avoid a grounding.

Let me underline that in the Netherlands no pilot with such a lack of experience and training would ever be allowed to board a ship of the type of the *Sea Empress*. What then did happen in Great Britain. At first sight, one might say that this lack of qualification and training was a problem caused by the pilot himself or the pilot organisation. Closer observation, however, shows that because of changes in the law in 1987 the Competent Harbour Authority (CHA) was given the (enviable) position of rulemaker and sole provider of the service. Over the years we see that the commercial interests of the CHA start to conflict with the running of a reliable pilot service.

We also see evidence in the *Sea Empress* report that the changes in the law pre-empted an "antagonistic" or "confrontational" relationship between the pilot organisation and the CHA. Presumably this was caused and amplified by the aforementioned conflict of interest.

It took nine years and an incident of this magnitude to bring to light what had happened and propose the remedies of which I will mention just a few. In the report it is recommended that the Marine Safety Agency/Department of Transport should prepare national minimum standards of pilot training and examination. Furthermore procedures should be developed and implemented for the effective monitoring of CHA's standards of training and examination of pilots. The Milford Haven Port Authority's Pilotage Authorisation Committee is specifically recommended to amend the qualifying requirements for authorisations to perform pilotage on vessels in excess of 30,000 dwt and to improve the standards for the examination of pilots.

In spite of the report and its recommendations we still find CHA's in Great Britain making, what will certainly in hindsight appear to be, less fortunate choices between economics and safety. In the port of London we find for instance evidence of a dwindling number of pilots without much change in the number of ships to be piloted. This creative way of cost-cutting resulted in waiting time for shipping. The CHA in the London Port Area has tried to "solve" this (self-imposed) "problem" by relaxing the pilotage rules and allowing more ships to proceed without the services of a competent pilot on board. One wonders if the lessons from the *Sea Empress* disaster have really been learned.

Some years ago, a major fire happened in one of London's main subway stations

(King's Cross) in which many people were killed and many more wounded. It was later found that quite some time before the fire happened a report on the safety in subway stations had been issued. One of the findings of that report had been that the safety with regard to fire in the subway stations in London was suboptimal. The last phrase in that report read: "By not upholding the standard of safety we resort to luck. And luck has the very nasty habit of running out." The same phrase could, in my opinion, find a very worthy place in the Sea Empress report and many more reports regarding serious incidents in the maritime industry.

7. Quality as an essential ingredient of safety

A study recently conducted by the EU on maritime pilotage and possible changes therein concluded among the same line that "changes to be introduced do not lower the quality of pilotage services below a good and professional level satisfactory for the safety of navigation". This conclusion draws attention to some of the parameters that I mentioned earlier, namely the quality of the pilotage service and the economic surrounding.

The quality of pilotage services is becoming increasingly important, if only on account of the sad fact that standards of quality on board ships are decreasing. On the other hand we have a society which makes stiff demands with respect to maintaining safety and protecting the environment. This is understandable as there is a wide variety of dangerous goods - explosive, poisonous, inflammable or polluting - being transported, often close to residential areas. Quality has thereby become an essential input to maintaining our maritime infrastructure. Training and certification are necessary ingredients to attain the required quality for individual pilots. Certification in the Netherlands is only possible after the necessary training has been followed and consequent examinations have been passed. Thoughts about the introduction of competition should at least consider how to take care of;

- Selection and training of apprentice pilots.
- Maintaining the individual high quality of the certified pilot through a form of "education permanente" consisting of:
 - Manoeuvring simulator training for certified pilots.
 - Radar training.
 - Personal Safety Training.
 - Bridge Resource Management training.
 - Refreshment trainings.

Let me assure you that the constant training needs of the 600 pilots that are registered in the Netherlands (managed by the Dutch pilots' STODEL foundation) is not an easy task. Let me underline firmly at this point that the pilot training consists of a large practical component and that it needs a pilot to train a pilot.

8. Timely and adequate

The pilotage service also needs to take care of other important ingredients such as the timeliness of the service and the adequacy of the service. Timeliness means that every ship requiring the service of a pilot does, indeed, get a pilot on board in time, and receives a pilot who is proficient for that ship. Timeliness and adequacy of the service are ingredients that have in the past years formed the final link in some of the incidents that are mentioned in this paper.

In the Sea Empress report, for instance, we find that the proficiency of the pilot boarding the ship was not in accordance with what might be expected and that the pilot did not board the ship at the right moment. Another such "quality of pilotage service" related incident took place in Australia.

9. The Peacock incident

What an organisation without adequate control and/or legal framework can achieve is described by the investigation into the stranding of the Peacock in 1996 in the Great Barrier Reef area. Again we see the chain of events slowly building up.

As of 1993, new regulations have come into force concerning pilotage within the compulsory pilotage areas of the Great Barrier Reef Marine Park. At the same time the possibility for competition was created within the field of pilotage. This resulted eventually in the formation of two pilotage services with separate managing companies. The smallest company, that is with the lesser number of pilots, was able to secure the largest share of the available business. In terms of competition one might speak of a success. The result of this success was that the pilots in this company had to take on a greater workload.

Furthermore, there was no proper control by government through the pilot organisation to prevent the pilots from taking on too much of a workload. A combination of shift hours and holidays finally resulted in the workload of the pilot of the Peacock - who had, by the way, had 26 years of experience - being so great that on that specific day while piloting the ship he lost "situational awareness". This euphemistic expression covers the circumstances that the - very experienced 64-year old - pilot probably fell asleep 15 minutes prior to the grounding of the vessel and failed to wake up. The watchkeeping officer during those full 15 minutes never challenged the pilot on the way he conducted his navigation. The vessel was trapped for nine days on the Piper Reef until salvors refloated her.

10. Economic surrounding

The above mentioned incident shows what the result can be if there is no proper control over the organisation providing the services. Let us look further to see what forces are at work in the economic surrounding of organisations.

To illustrate this, I will refer to the model suggested by a well known business consultant called Michael Porter. The model describes five forces at work within and

around the market place. The forces are indicated as Substitutes, Suppliers, Buyers, Competitors, New Entrants.

Competition introduces rivalry among firms. Porter gives an indication of the various forms that this rivalry may take. He indicates that competition in an industry continually works to drive down the rate of return on invested capital toward the competitive floor rate of return, or return that would be earned by the "perfectly competitive" industry. Investors will not tolerate returns below this rate in the long run because of their alternative of investing in other industries, and firms habitually earning less than this return will eventually go out of business. We can observe here a combination of what is covered by the expression "The market is always right" in combination with something that might be called "economical Darwinism".

Here a problem emerges that we recognised earlier. It is related to the various views of public and private interest that were mentioned above. From the former East-Bloc countries we have experienced what economical Darwinism can lead to in the field of pilotage when self proclaimed "bizznizzmen" started to enter the market. Pilots at each other's throat, working - often without good lifesaving material - for many more hours than justified and without proper training.

In some cases this mix of ingredients from the Sea Empress and Peacock incidents was combined with taking risks that nobody in a sound mind would take had the proper environment been created in advance for these professionals to work in.

This pre-empt the question whether the components that are important to the quality of the pilotage service should be subjected to uncontrolled economical Darwinism and whether the "market is always right". On the basis of the experiences in East-Bloc countries in combination with the examples mentioned earlier it is fairly safe to conclude that such is not the case. The quality of the individual pilots, their initial and permanent training and refreshment courses combined with the adequacy and timeliness of the service form elements that make it almost compulsory to take measures well in advance for any organisation that wants to enter the pilotage service.

A purely cost or product driven strategy by the various market parties in question could then take place within a well defined framework. Having concluded this let us then decide whether we need to turn our attention to the individual pilots or the organisation that provides the services.

11. The pilot or the organisation

In marketing and economics the view is held that people behave rational. But it has also been found that individuals are driven to be maximisers and economisers. The Peacock incident from Australia is an example how - without the proper set of measuring and monitoring of the individual pilot - this "more is better" mentality can result in things getting out of hand.

A good organisational framework poses the best solution for this problem. Through a proper organisation we have the opportunity to measure and monitor the performance of the individual pilots and recognise and reward the individual pilots for using their decision

rights in the right way. However - as seen in the Sea Empress incident - the organisation should be prevented from letting the quality of service suffer from the competitive forces of the market.

How can this be established? Organisations that want to enter the market can do so once government has issued a license or given the concession with all the relevant checks and warranties required from that organisation to provide a timely and swift service. The checks of and warranties required from the concession/license holder should of course provide a basis for a good balance between economics and safety. The balance should keep the possibilities open to leave the right incentives in the market for companies to return the rewards of efficiency measures to their customers and still enabling them to keep the quality of the pilotage service on a high and sustainable level. This would allow organisations to improve on efficiency measures without lowering the quality of pilotage. Also, this should lead to a situation that all ships are serviced in time, with a proficient pilot on board at the lowest possible price (the right balance between price and the level of service).

12. Research and development

Let us not forget that research and development play an important role in pilotage (as in any organisation). Let down on R&D and in the long term your product or service and eventually your organisation and customers will suffer. With this in thought the Dutch Pilotage Organisation has been developing amongst others new launches, fast tenders, a Total Quality Management system, custom made software and Shore Based Pilotage (SBP).

SBP seems to be the catch phrase for quite a few persons and working groups pondering changes in pilotage. It is often heard that a Boeing 747 can land without any human assistance on some airfields. Why should this not be the case with ships.

Yes indeed the display on the synthetic radar screen looks enticing enough. We see ships being projected with vectors, 10 digit accuracy and all seems to be perfectly in order. But is this really the case?

Through the use of the latest computer software we have grown so used to WYSIWYG that we really think that the radar display offers us a WYSIWYG picture. Let us for a moment go back to the principle of radar. The navigators among this audience will appreciate that a radar picture often is what I would call WYNSIWYG or "do you really see what you think you see". From a 900 ft ship we may for instance see a dot or line that represents the bow, or the stern, or the whole ship or sometimes just the superstructure, or even some other parts of the ship.

The original radar display screen used to give us this so called "raw" radar image which - as I indicated above - was difficult enough to interpret. Nowadays the screen offers us a view of this raw radar information that is "enhanced" by a computer with a nice ship like form around what is computed to be the position of the ship. Position, speed, vector length and direction are presented on the basis of the calculation that the computer makes. But how can we, not knowing what part of the ship we see in the first place, be sure that the dot on the radar is "the" ship. You will not be surprised to find that we cannot be sure.

The computer suffers from the same effects as us humans and as a result of it's

"enhancement" and calculations sometimes introduces unwanted side effects. When comparing the raw radar image with the enhanced image we sometimes see for instance that a ship slowing down on the raw radar image does not for quite a while lose speed on the enhanced image. The vector of a ship that is turning most of the time misrepresents the actual course of the ship. I once experienced that a 900 ft tanker in the Europoort broke in half on the synthetic display because of computer misinformation. Had it not been for the raw radar image and the outside view from the radar station I would have believed that a major disaster had been on our hands. It is only with the proper training that an operator giving information or a pilot giving SBP is able to interpret this information. Only with the assistance of the raw radar image is the pilot giving SBP able to guide the ship accurately. SBP is - in spite of all the technical developments - still a second best option and only executed in cases of bad weather when the pilot is not able to board the ship.

The optimal situation still exists with the pilot actually on board. But that does not mean that the pilot organisation does not recognise the developments in technology and will not contemplate possibilities for the further development of SBP. Two years ago an initiative was taken by the Dutch Pilots Corporation to see whether or not SBP would be possible on a more permanent basis. The findings of this investigation were that the present technology is still insufficient to create a situation comparable to that when the pilot is actually on board.

At this moment further research is done how to compensate for the present lack of technology. This might (in part) be found in extra training and equipment. For instance extra training for the master and extra equipment on board of the ship (e.g. certain types of transponders). Furthermore we should not forget that the pilot will (even in the future) only be able to guide a limited amount of ships which may in the case of a permanent form of SBP lead to congestion.

Again we see public and private interests, safety and economics emerging as factors. Therefore we are at this moment still discussing the items mentioned in the report with the government and the municipal authorities. We will of course keep the maritime industry informed about our progress. But you may also rest assured that we see no point realising a project if it does not provide a safe possibility for a ship to enter port while at the same time keeping the port free from congestion.

Research and development are important for the future. Trying to press pilot organisations into action by repeatedly stating (without any foundation whatsoever) that the new technology age is upon us and that the pilot will - perhaps not today but certainly at one minute past twelve tonight - be obsolete does in our view not represent the present state of things properly and does not create the proper atmosphere in which the development of new technology can prosper. Any economic surrounding for the pilotage services should not disable the possibilities for proper research and development.

13. Conclusion

We return to the question posed at the start of this paper. Can pilotage performed in competition provide a safe environment for the shipping industry. As with many questions

in life the answer is: it depends.

We have seen examples from Great Britain, the former East-Bloc countries, Australia and a comparison with the situation in the Netherlands. The evidence indicates that the introduction of market forces should take into account much more than just the phrase "the market is always right" and the concepts of economic Darwinism. The evidence suggests that whether or not the introduction of market forces into pilotage is successful depends on various factors. As we have stated before "Incentives Work".

There is indication that rational, economising, maximising individuals will - without the right framework, a good organisation and the proper set of incentives - not be able by themselves to set the right standards for the pilotage service to be rendered.

We therefore need to turn our attention from the individual pilots to the organisation providing the service and the creation of a proper framework. Such a proper framework needs to be set by government through a concession or license system for any organisation that is willing to enter the market for pilotage. This should preferably be done by screening the organisations that want to enter the market, and by the authority specifying which criteria need to be met by that organisation. By doing so the organisation will need to fulfil the needs of the market in a more adequate way doing justice to both the quality of the service, efficiency and the swiftness of that service.

With regard to those who are investigating the field of pilotage in any part of the world I would like to recall an article on revitalising corporate performance that I read some years ago. The article made a comparison between top managers and astronauts - to perform well, they need the intelligence that's back on the ground. I would like to carry this saying a bit further and propose that we all return to base and with all the information in hand and both feet firmly on the ground take a good look at the necessities for the best way to secure the quality of pilotage services in the interest of safety. The future rewards are there for the reaping.

References

- Department of Transport and Regional Development on the grounding of the "PEACOCK".
- United Kingdom Marine Accident Investigation Branch report into the stranding of the "SEA EMPRESS".
- EU maritime pilotage study.
- "Strategic intent" by Gary Hamel and C.K. Prahalad - Harvard Business Review.
- "Competitive strategy" by Michael E. Porter - Free press New York.

Methods of Calculation of Risks at Marshalling Yards and Open Track Due to the Rail Transport of Hazardous Goods

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Abstract. Versatile calculation systems for the level of risk at marshalling yards and open track have been developed. Yards that are intensively used for the handling of tankcars with hazardous substances were examined with the calculation method, as well as most sections throughout the country. Main parameters are the type and quantity of hazardous goods, the shunting and transport processes carried out and the urbanisation pattern in the surroundings.

A project was organised to inventory the nationwide risk situation and to devise and take measures to reduce risk at the relevant yards and sections. A wide range of measures was evaluated. Promising actions are the electrification of diesel sections and the building of specific security provisions.

1. Introduction

Impressive disasters, such as those at Bhopal, Seveso and "Los Alfaques" (a camping site in Spain), urged national and international governments to recognise the dangers of large volumes of chemicals, not only for employees, but for all people in the area. The policy field of risk reduction or "external safety" was born. It is relevant for production, storage and transport, and realizing that a large growth of the rail transport of hazardous goods is foreseen, the threatening imbalance with safety is a major topic.

In this paper the Dutch risk approach concerning rail transport is described. Because most marshalling yards and several sections are situated in crowded areas like city centres, risk problems are considered a crucial item for both our railway company and the authorities. In a broader perspective, the dense railway network and the high population density in the whole country require particular attention for this subject. In order to apply general, objective measures for risks caused by railway tankcars, a valuable and versatile calculation method was designed, the so-called QRA. The general name QRA stands for quantitative risk analysis, which has originally been designed to calculate the risks of stationary chemical plants and installations, as well as filling stations for LPG. A major advantage of the computer programmes is their ability to give a quantitative insight into the effects of a wide range of possible measures.

2. Calculation method for marshalling yards

After thorough deliberations, a prescribed method of calculation has been designed for the determination of the risk level. In section 5 of this paper the two resulting risk values, i.e. the IR (individual risk) and the SR (societal risk) are described. The framework of this calculation method is based on an analysis of the Dutch casuistry, mainly in the eighties (because of the availability of data; an up-date is planned). For this purpose, the general casuistry was evaluated, i.e. both passenger and freight transport, covering all of the national rail infrastructure (marshalling yards, industrial lines and open track). As a matter of fact, the Dutch rail casuistry concerning the shunting processes with hazardous substances still brought forth no external victims. However, a recent accident at a yard in Dresden (Germany) has emphasized the possibility of such an event.

In the the risk calculation programme that was designed for marshalling yards [1,2], a large set of input parameters is found, referring to:

- The quantity of hazardous goods (the number of tankcars)
- The type of chemicals
- The length of stay
- The composition of the train
- The infrastructural lay-out of the marshalling yard
- The type of train security and the presence of safety provisions
- The shunting process and the possibility of interference with other traffic
- The urbanisation pattern (surroundings)

In this paper it is not meant to give an explanation for all parameters. Two items have been chosen arbitrarily to exemplify the contents of the QRA, the Dutch computation system. First, a description of the classification of hazardous goods is given, then the crucial aspects of the shunting process are illustrated. Five categories of substances are distinguished:

1. Inflammable gases	HIN-23, 236, 239
2. Toxic gases	HIN-268
3. Very toxic gases	HIN-266 (-> 268 for chlorine since 1997)
4. Very inflammable liquids	HIN-33, 336 (50%), 338, 339, X333, X338
6. Toxic liquids	HIN-336 (50%), 66, 663, 665, 668, 669, 886

Chemical substances are classified according to the so called Hazard Identification Number. The number refers to the type of danger and can be found as the top figure on the well-known orange signs fitted on the tankcars.

268
1005

For example, the toxic gas ammonia has code 268. Knowledge about this code is useful, especially in case of an accident. The fire brigade is able to anticipate any expected consequences. In this example the 2 refers to its form as a gas, the 6 to (the danger of) its toxicity and the 8 to its biting character. The bottom figure is the UN-number of the material, and it corresponds with the chemical identity. However, the UN-number does

not have any coding function: compounds are numbered more or less successively, whatever their structure. The number for ammonia is 1005.

The shunting process is one of the main factors, because the calculation method is framed around it. In the analysis of the casuistry, eight so-called scenarios were indicated which could be considered sources or causes of incidents, each with its own frequency. The following scenarios were identified.

For trains:

- Arrival (or departure) of the freight train, interaction with the head track and its (passenger) traffic.
- Arrival into the marshalling yard itself, interaction with other shunting parts.
- The change of a locomotive.
- Autonomous incidents (derailment etc.).
- General shunting processes (dividing or joining train parts etc.).
- Possibility of a BLEVE (Boiling Liquid Expanding Vapour Explosion) by fire

For wagons:

- Intrinsic failure (e.g. by corrosion or incorrect filling)
- Sorting processes (client; geographical destination)

Most scenarios only say something about the chance, and nothing about the consequences. A train-train conflict does not result in victims in the neighbourhood when the train speeds are very low. Tankcars are strong enough to withstand a quiet collision.

Furthermore, gas wagons are generally much stronger than tankcars for liquids. Therefore, in addition to the basic fail frequency, a follow-up chance is defined: the chance that - after a crash - the transported compound will actually escape (and burn or explode).

3. Yearly selection

In the section above, the methodology for a complete QRA is described. However, it would be a tremendous task to carry out periodic risk analyses for each of the hundred freight yards. Therefore, a simplified QRA was introduced in order to estimate the risk level. Simplifications concern the lay-out and topological (housing pattern) data and many other parameters. This simplified calculation always overestimates the risk situation, so that all marshalling yards that do not exceed the maximum permissible, standardised values for IR and SR are protected from the obligation for a full QRA. This "selection of bottleneck yards" is a yearly activity for our organisation NS Railinfrabeheer. Because NS Railinfrabeheer is licence-holder for the yards in environmental affairs, all information about hazardous freight is elaborated in our company. The yearly selection is always done afterwards, so that actual and reliable transport data can be used.

Normally about 20 Dutch marshalling yards are selected by this method. They have been studied intensively in the course of a major national project called PAGE (a Dutch abbreviation). The explanation for their occurrence on the "bottleneck" list is usually related to either the vicinity of chemical industry (Sittard, Delfzijl), of a port (Rotterdam), or their function as a frontier station (Roosendaal, Venlo). Most of the yards are found in city centres.

4. Calculation method for the open track

No doubt that the nature of the risk on the open track differs from its equivalent at marshalling yards. Especially two factors illustrate this difference: the speed of the train and the occurrence of crossing (road) traffic.

The maximum speed of a freight train on the open track is dependent on several parameters; in general, maximum speeds of about 80–100 km/hr are not unusual. Apart from that, special rules just for chlorine transport prescribe a limited speed of 60 km/hr. Of course, a collision or derailment at high speed enhances the chance of serious damage to tankcars.

Fortunately, higher speed is favourable in one respect: the Dutch type of train traffic security, i.e. the ATB, requires a minimum speed of 40 km/hr. The ATB technology, designed to prevent undesirable train movements, is able to stop a train that has wrongly passed a red signal. However, at speeds below 40 km/hr the automatic brake system is not active in such - possibly risky - situations. By the way, the newest version of ATB (not yet installed), has no speed discrimination.

On the open track two severe incidents took place during the past decade. The most impressive one happened in Boxtel in January 1989. In this town near Eindhoven, a train derailed at a speed of 75 km/hr due to the loss of an axle component from one of the wagons. Many wagons toppled or ended their ride in a zigzagging movement. A tankcar with 30 tons of methanol broke, causing a great fire. Enormous damage was experienced. Another serious accident took place in October 1993 in Lage Zwaluwe, south of Rotterdam. In this case many tankcars derailed while passing a switch, but fortunately they did not burst open.

The input for the calculation programme for the open track [3] consists of various parameters related to the quantity and identity of the hazardous goods, the infrastructural lay-out and the built-on surroundings (cf. section 1). A specific parameter is the number of level crossings on a certain section, although it has to be remarked that train-car collisions do not predominate in the casuistry. Therefore, level crossings do only contribute moderately to the risk calculation.

5. Policy and legislation [4]

Two concepts are used in the field of external safety, i.e. the individual risk (IR) and the societal risk (SR). First, the official definitions are given:

Individual risk (IR):

The frequency per year at which a person would be killed in a serious accident if that person were to stay perpetually in a given place without protection.

Societal risk (SR):

The frequency per year at which a group of a specified minimum size is killed all at once in a serious accident.

The definition of the first type of risk seems more or less theoretical. Obviously, only an imaginary person would stay in the same place for 365 days per year, 24 hours a day. In fact the IR is a measure of the level of risk itself, independent of the surroundings. No matter what kind of location (industrial, rural or urban), the danger caused by the source determines the level of risk. On a map places of equal risk can be connected by an iso-risk contour. For yards the contour has an elliptic shape, for sections it is more or less a line, parallel to the track. In the Netherlands the value of the maximum permissible IR represents an obligatory limit. Exceeding this value means the necessity of taking measures.

In contrast with the individual risk, the societal risk is closely related to the surroundings. A serious disaster, for instance resulting in an explosion, is far more favourable if it happens in an unbuilt environment. As already mentioned, however, marshalling yards are often found in the very city centre and for those locations the possibility of a - considerable - group of victims is conceivable. Because the social reaction to accidents with victims aggravates in proportion to the number of deaths, this non-linear phenomenon is incorporated in environmental law.

The value of the maximum permissible SR (for 10, 100, respectively 1000 or even more casualties) only represents a target value: under certain circumstances the authorities may accept deviation from this specific value. The societal risk is represented as a diagram, the so-called fN -curve (frequency vs. number of casualties). With respect to the numerical values, the SR-standards for marshalling yards are not identical with those for the open track. The difference can be explained by the history of the risk approach in both policy fields: marshalling yards are classified as stationary installations, sections as transport modalities. These target groups undergo their own policy development.

6. Means for risk reduction

The best approach to tackle the risk problem is to define exactly what undesirable events ought to be excluded. Once these potential dangers have been identified, measures can be devised. However, such events are not only undesirable; by definition they are also unpredictable. In the regular moving and shunting activities an incident "cannot happen", because security systems and rules or instructions prevent its occurrence. In practice, incidents do occur.

In the risk approach concerning marshalling yards, where speeds are always below 40 km/hr, attention was directed to two sources, i.e. to the - forbidden! - passage of a red stopping signal and to the exact position of switch tongues. The latter subject is not discussed in this paper.

NS Railinfrabeheer, the central organisation for the building and maintenance of the Dutch rail infrastructure, is going to combine this item with the already started programme of replacing all (i.e. thousands) of the manually operated switches by motor-driven switches. The choice is between a visual and an acoustic control for the right position of the tongue (resulting in a reduced chance of derailment).

Trains, shunting parts or locomotives passing a stopping signal usually do not meet another barrier on their way. They are free to enter the forbidden (perhaps occupied) zone.

Whatever the reason of this unintended and prohibited movement, it is clear that this situation represents a certain risk. For those tracks on the marshalling yards where such a situation is recognised as possible and extra dangerous (transport or surroundings), our organisation intends to build either security provisions such as temporary track barriers or guide away tracks. These and other tools in the tool box resulting from the PAGE project are presented in the lecture. A nice example of such technical means is a movable buffer.

Improvement of the safety on the open track is amongst others possible by hot-box detectors. The earlier mentioned accident in Bortel might have been prevented by this security device. A hot-box detector is able to detect unusual heat radiated from a passing train, for example caused by a defect on the axle or wheel. After any warning signal from the detector, the train driver will be asked to stop soon for an inspection.

Finally, a very attractive solution for risk reduction at marshalling yards is the following measure taken on the open track: electrification of diesel sections. Electrification of certain diesel sections can take away the necessity of a visit at the nearby marshalling yard. If changing the locomotive is the only reason that a freight train has to visit the yard, maximum risk reduction is feasible in case it is no longer necessary. This measure is interesting for the busy marshalling yard in Roosendaal.

7. Balance between growth and safety

Apart from measures in the infrastructure or - more general - in the cargo and transport field, one can also influence the contribution from the surroundings. Therefore, all plans for new estate of houses near marshalling yards have to be judged. The risk calculation method is applied to compute whether the increment in people satisfies the standard for SR. This point of view is one of the solutions to mitigate the size of the future risk problem.

An imbalance between growth and safety is imminent, when all autonomous developments in transport and in housing go their own way. In the Netherlands several new rail projects are or come under construction (e.g. The Betuwe Line for freight!) and a growth of even more than 100% for chemical cargo in the next decade is expected. Therefore a large number of measures is necessary to maintain at least the present level of safety. NS Railinfrabeheer, together with the relevant sister companies within NS, intends to meet this challenge.

References

- [1] (a) Basisfaalfrequenties voor het transport van gevaarlijke stoffen per spoor; emplacements, SAVE {see ref. 2} (Sept. 1995); (b) Handleiding/protocol voor het uitvoeren van een QRA voor goederenemplacements, SAVE (July 1997).
- [2] Calculation programme: SAVE-II, by SAVE, Apeldoorn (Netherlands, tel. +31-55-5217133).
- [3] Calculation programme: IPO-RBM, by AVIV, Enschede (Netherlands, tel. + 31-53-4306088).
- [4] Dick van den Brand, papers in Chemical Hazards in Ports and Marshalling Yards (Livorno, 22/24 May 1996).

Investigation of Railway-Incidents with SAMOS: A Reactive Tool for Proactive Safety Improvement

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1. Introduction

In 1993 the Dutch government agreed to separate the management of the railway infrastructure and the commercial exploitation as indicated in the EC-guideline 91/440. The management of the infrastructure is separated in 1994 by establishing a task sector, consisting of Infrastructure Management, Traffic Control and Railned Capacity Allocation and Railway Safety. A number of new operators has applied to the central government. The first one, Lovers Rail, started in 1996 with the exploitation of a passenger service. Railned Railway Safety took over the investigation of accidents and incidents related to railway safety from the "old NS". To get more effort of the investigations, more efficiency in investigations and more independence related to all operators on the national railway network, a new investigation method (called SAMOS) has been developed. The method is based on the so-called TRIPOD-approach. SAMOS has been in use since mid 1997.

1.1 Organisation of the Netherlands Railways (NS)

The organisation of the NS was drastically changed in 1994: a separation into a commercial sector (NS Passengers, NS Cargo, NS Stations and NS Real Estate) and a task sector. The task sector is financed by the central government and carries out tasks for that same central government.

The task sector consists of three departments: Railinfrastructure management, Traffic Control and Railned. Railned is the organisation for capacity management (Capacity allocation and Development of new infrastructure) and Railway Safety

1.2 Tasks Railned Railway Safety

- policy-making, formulating regulations and specifications in the field of Railway Safety
- advising the Minister of Transport, Public Works and Water Management on matters concerning railway safety and legislation
- risk-analyses and integral safety plans for new infrastructure, new processes and new

techniques

- inspections and audits
- investigations into accidents and incidents
- testing whether new participants in the rail transport system meet the requirements concerning expertise, organisation and ensuring safety
- certification of rolling stock-maintenance companies, "arbo"-services (concerned with working conditions as specified in the Factories Act) and examination institutions

1.3 Investigations into accidents and incidents

Approximately 400 investigations take place each year. The reports are sent to the Minister of Transport, Public Works and Water Management, to the Railway Inspectorate and to the Railway Accident Investigation Board. There is little criticism on the quality of the reports. Even so, Railed Railway Safety itself is not entirely satisfied with the investigations. Compared to Railed Railway Safety's other activities, these investigations take up too much time. The completion time is often long and the implementation of the large numbers of recommendations is often an uphill battle. In a company that feels very strongly about quality, there must always be the question of whether it can improve the quality of its products/services.

Which is why a research method was developed in co-operation with the University of Leiden in the Netherlands (Prof. Wagenaar, Dr. Groeneweg) which is more in keeping with Railed Railway Safety's wishes. The TRIPOD-philosophy constitutes the essence of the new procedure. The method was put into use mid 1997 after all of the researchers had received training. The method is to be further developed as a safety-audit instrument in 1998, which will make it easy to compare the results of accident investigations with those of the audits.

2. Why improve accident investigations?

Before the separation of the management of the infrastructure and the commercial organisations in accordance with the EC-guideline 91/440, investigations into accidents and incidents were carried out by the Traffic Operating Department. Railed Railway Safety was charged with these investigations in 1994, in order to guarantee the independence of the accident investigations.

2.1 Problems

The old method and procedures employed resulted in investigations of a reasonable quality and in many recommendations for preventing a recurrence. Even so, there were reasons to adjust the research method and the procedures:

- The time elapsing between the incident/accident itself and the final report (completion time) is too long.

- The involved railway staff is questioned by their own management; the statement is sent to the railned investigator. The time between incident and statements is mostly too long and the information, needed for the investigation, is often insufficient (additional interviews).
- Too much time is spent on each investigation. One must consider whether the efforts are worth what is accomplished in terms of safety.
- There are a great many recommendations.
- The research results are strongly influenced by the background, experience and creativity of the researchers.
- Improvements often focus on the railway staff involved.
- It is difficult to compare the results of accident investigations with the results of audits and inspections.
- It is often difficult to justify drastic or costly recommendations on the basis of one single incident.
- The investigations cost a great deal of time, even if the researcher knows in advance that the results in terms of safety will be limited.

3. New method: SAMOS

A new method has been developed in co-operation with Prof. Wagenaar and Dr. Groeneweg from the University of Leiden, which is based on the so-called TRIPOD-approach. This approach departs from the concept that there are 11 problem areas in organisations which are the basic causes of all incidents. These 11 so-called Basic Risk Factors (BRF's) or General Failure Types (GFT's) are factors which can be controlled by the management. The development started in 1996. Following the complete implementation of SAMOS for accident investigations, the method is to be further developed as a means to carry out safety audits. SAMOS is the Dutch abbreviation for "Spoorwegveiligheids Audit Methodiek en Onderzoeks Systeem" (= Railway Safety Audit Methodology and Accident Analysis System). The audit-method is scheduled to be completed in 1998.

3.1 Introduction

Accidents, incidents and health hazards do not just appear out of the blue: the ultimate causes of such events can often be found in the distant past. When writing a research report following an accident, a researcher can present the "circumstances" of an accident in the form of a scenario. The sequence of events is largely brought to light and the result is a chronological survey of what led to the undesired situation.

The standard procedure in accident investigations is to depart from the last phase in the process. Using logical reasoning, investigators attempt to discover the underlying causes of the accident, or to gain a clear view of the factors that contributed to the accident. Examples include the STEP- (Sequentially Timed Events Plotting) and MORT- (Management Oversight and Risk Tree) method. There are countless methodologies which

focus a certain degree of attention on behaviour-related factors. In most cases, these are visualised with a herringbone model, or are presented as variations on Heinrich's domino's, such as SCAT (Systematic Causal Analysis Technique). A characteristic feature of accident analyses is their retrospective (looking back) nature.

However, this approach has its disadvantages. The reliability of the final results of the analysis is relatively low, and the results are strongly influenced by the style, interests and background of the researcher and by the culture prevailing within the organisation.

SAMOS on the other hand uses a different approach. One that focuses on the different phases in the process of disruption. Each phase has its own distinguishing features and also varies in the degree to which the management can exercise control over it. As the model presented here only describes the accident chain which leads to human failure, it cannot replace a technical analysis of a failing system or an undesired exposure. However, because organisational failures often lie at the root of technical failures, one will frequently find that the chain can also be applied to accidents which, at first sight, appear to be solely technical in nature.

3.2 The underlying philosophy on accidents

An important component of SAMOS is the description of the accident process. Accidents, or other undesired disruptions in the normal routine of things, do not occur "without reason", but are the result of a concurrence of circumstances. Attempting to "manage" the accidents themselves, is an impossible task: there are just too many coincidences involved. Which is why SAMOS focuses on preventing the concurrence of circumstances by identifying and eliminating the risks which will lead to these circumstances. The accidents and "near accidents" or "incidents" are the result of dangerous operations or dangerous circumstances. Whether these will subsequently lead to an accident or a "near accident", is primarily determined by chance: it is almost impossible to influence the outcome.

Undesired disruptions in the operations only occur if dangerous circumstances and dangerous operations coincide. And so it seems obvious that we should ensure that they no longer occur or, if they do occur, that they are identified and subsequently eliminated as quickly as possible. However, it would be impossible to detect and eliminate each and every one of these dangerous operations and situations. In addition to that, reports on dangerous operations or situations generally focus on technical factors, rather than on organisational factors. Even so, the investigations into recent disasters tell a different tale: it is not so much the technical aspects that contribute a great deal to accidents, but rather these organisational aspects.

It is much more effective and efficient to focus on the causes of these dangerous operations and situations: the risks. How did these circumstances come about, and can we prevent them from happening before they result in undesired disruptions? These risks are factors which can be influenced by the management, and so they can be controlled to a great extent. These are the answers to the question "How is it possible that such a dangerous situation occurred, or that a dangerous operation was carried out?" If we can locate, examine and eliminate these risks, employees will no longer find themselves in a situation in which they may display dangerous behaviour.

3.3 The accident model

The SAMOS- (and Tripod-) method distinguishes between the following phases in the accident process:

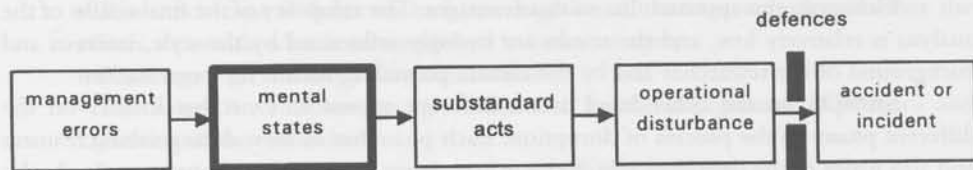


Figure 1.

The diagram in Figure 1 displays the model as a process of disruption which consists of a number of phases. The model can be used for large-scale disasters and accidents and incidents, as well as for health problems resulting from exposure to hazardous substances. The model can be used regardless of how much time has gone by between the time the unfavourable environmental factors were created and the ultimate negative result (whether this is an hour, a month or twenty years). The term "incident" is used to indicate what one wishes to avoid, whether this is a safety, environment or health problem.

3.4 The BRF's

It is plain that we can identify a "human factor" in every accident or unintentional exposure: someone, whether unconsciously or deliberately, did something that was not consistent with what is considered to be the correct operations at that particular company: the sub-standard operation. This person, before he or she did this act, was in a certain mental state, for example irritated, in a rush, or misled: which brings us to the next phase in the model. It has a broad black edge around it in the figure: years of psychological research have shown that it is virtually impossible to directly influence these kinds of mental states of employees. It is much more efficient to adjust the environmental factors in such a way that employees no longer reach a certain unfavourable mental state which would cause them to perform a "sub-standard" operation.

These factors, the so-called General Failure Types (GFT's) or Basic Risk Factors (BRF's), can however be influenced by the management. There are eleven of these "control areas" (see Table 1).

Each of these eleven BRF's is present in every organisation to a certain degree, whether accidents occur or not. These BRF's, depending upon the extent to which they apply, cause people to reach a state in which they are more likely to make an error. If, for example, the necessary equipment is defective or not available, chances are the employee in question will improvise in order to get the job done, and then make an error when doing so. The most important aim in an organisation's policy on safety should be to deal with the underlying factors which may result in human failure. It is possible to make an inventory of these mechanisms and to develop an instrument that can measure their impact: The SAMOS accident analysis methodology.

Table 1.

No.	Description and abbreviation
1	The quality, state, availability and usability of the infrastructure, materials, equipment and tools: Hardware (HW);
2	The ergonomic design of the infrastructure, materials, equipment and tools: Design (DE);
3	The organisation and the manner in which maintenance, repairs and inspections are carried out: Maintenance Management(MM);
4	The availability, comprehensibility, usability and correctness of work procedures, regulations and manuals: Procedures (PR);
5	The physical and social working conditions in the workplace and individual factors which increase the chance that errors will occur: Error Enforcing (EE);
6	Daily maintenance and cleaning of the workplace:Housekeeping (HK);
7	The management of conflicting goals such as working conditions versus production: Incompatible Goals (IG);
8	The communication between employees, departments and business units: Communication (CO);
9	Steering processes and persons, the structure of the organisation in which people have to work: Organisation (OR);
10	The education, experience and selection of employees: Training (TR);
11	The existence and effects of control measures and safety means as part of the philosophy of the company: Defences (DF).

By optimally managing all of these factors, the employees of a business unit will hardly ever reach a mental state which causes them to make errors which, in turn, will lead to disruptions in the production process. The aim is to tackle the source of the errors, rather than focusing first and foremost on the errors themselves. In order to influence the human factor as effectively and efficiently as possible, it is necessary to take active measures in the earliest possible phase of the process: at the level of the BRF's.

There is already a variety of instruments available, both for making up an inventory of risks and for risk evaluation, which can provide insight into the state of a company, and which may serve as a basis for taking measures. Depending upon which approach is followed, these techniques focus on the various phases of the disruption process.

Each technique has its limits, and none of them can replace all the others. It would not be wise to rely too much on the effects of one technique alone, especially if the technique cannot detect and identify any errors until late in the accident process. Incorrectly designating the actual problem will result in incorrect recommendations. Experiences in traffic safety with ABS-systems (anti-block systems) and airbags in automobiles, reflectors on bicycles and having motorcycles drive with lights during the day, reveal that the effects of technical measures, thought to be very effective, on the number of accidents, are sometimes negligible. The phenomenon "risk compensation" should also be taken into account in the work situation. Prevention is the best cure, but it is simply not possible to control the whole world and so defensive techniques are (still) necessary in each phase of the process.

It is possible to measure the contribution of the eleven BRF's for each accident. This analysis reveals the sources of human failures in specific accidents or series of accidents.

3.5 The SAMOS method of analysis

The eleven BRF's can be found at the beginning of every cause-effect chain. In order to positively influence these factors, so that employees no longer perform incorrect operations, it is possible to measure their relative influence within the scope of a risk inventory and risk evaluation. Following an accident, one can analyse the circumstances surrounding the accident and then subsequently categorise the causes in terms of the BRF's. The identification of the contributing factors and the subsequent classification in terms of the BRF's can be performed in a very reliable manner using the SAMOS analysis instrument.

The SAMOS analysis instrument aids Railed researchers in detecting BRF-symptoms and the root causes of these symptoms in a structured manner. All of the information is divided into one of the 11 BRF's. The instrument consists of two checklists and, for each BRF, a number of items which fall under this BRF: the Symptoms list and the Root Causes list. The Symptoms list is used to identify all of the symptoms which contributed to the development of an accident or incident. Furthermore, the sub-standard acts which resulted from these symptoms are designated as well. The next step is to locate the structural, underlying causes of the occurrence of the symptoms using the descriptions of the problem areas in the Root Causes list. The method is based on the modified general accident chain as shown in Figure 2.

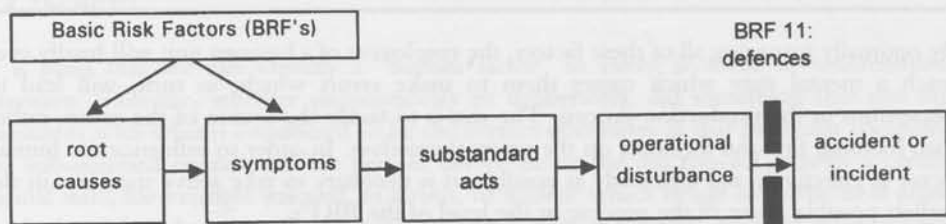


Figure 2.

The 11 *Basic Risk Factors (BRF's)* are 11 different "control areas" which can be distinguished in every organisation, or part of an organisation. The extent to which the BRF's are controlled is assessed by identifying and "counting" the symptoms which contributed to the development of accidents and incidents. Poorly controlled BRF's result in many symptoms, and so they are the main sources of risk.

Root causes are structural deficiencies in the organisation and the working environment. They are the result of inadequate decisions on the part of the management.

Symptoms are local problems which are present in the workplace before an accident or incident occurs and which are the result of Basic Causes.

Sub-standard acts are the final links in the accident chain, before the disruption in operations occurs.

The *Operational disturbance* is the direct result of a sub-standard act. It is the moment at which a process deviates from normal, and a situation involving risks occurs. It must be viewed separately from the nature and magnitude of any consequences. The operational

disturbance is the starting point of every SAMOS-analysis because this is what we initially want to prevent.

Defences are the systems, procedures and actions which should be present in order to prevent or limit the effects of a disruption in operations, once such a disruption has occurred. The effectiveness of the safety measures is determined by BRF 11: Defences.

The *accident or incident* is the effect, or result, of an operational disturbance that is not "counter-acted" or contained by adequate safety measures.

Besides being a methodology for research and screening, SAMOS is also a *safety measurement tool and therefore a proactive tool*. The method assesses the risks systematically and in terms of quantity. Every time a certain BRF is involved in an incident, the BRF's score is "increased". A BRF-profile can be made by adding up the factors involved in various incidents. This provides a reliable picture of the degree to which each of the BRF's is controlled in an organisation or part of an organisation. BRF-profiles can be made for the entire railway traffic system, for each transport operator, for each business unit or for a local department of a business unit. This results in a profile as shown in Figure 3.

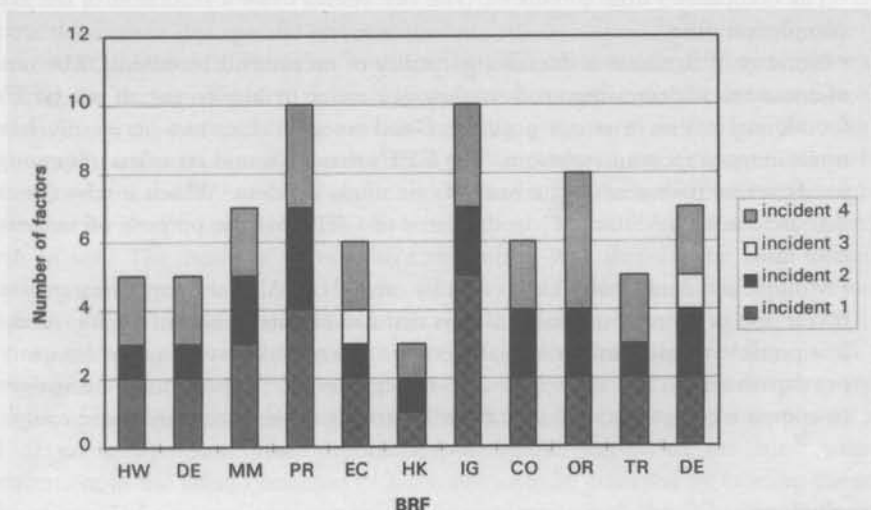


Figure 3. An example of a profile of four accidents.

3.6 Changes in the method of working

The introduction of SAMOS has led to a number of changes. The most important changes are listed below:

- An investigation always starts with the railway staff involved. They are usually the only ones who know what went wrong and particularly which circumstances prevailed at the time. It is no longer required that one wait for the statements taken by the management or the railway police, the railway staff involved is interviewed by the researchers within a period of 5 days (max.). The 11 GFT's function as a guideline when conducting these interviews. The persons involved have filled out a

simplified list stating the 11 GFT's beforehand. The answers serve as points of departure in the investigation.

- Only investigate what needs to be investigated. If the interviews reveal that there were no controllable factors (GFT's) involved, the investigation is to be concluded with a so-called "oops"-report as soon as possible. This is a simple form of reporting, which does include recording the data that is to be entered in the accident-database for use in analyses at a later time.
- Not investigating any longer than necessary. It is more important to detect controllable factors (GFT's), than to try to discover the truth at any cost. Sometimes the statements of, for example, the driver and the travelling ticket inspector, are contradictory. Trying to get them to agree will often be very time-consuming, whereas this is not really relevant as far as improving safety is concerned.
- The researcher has less influence in the research. The method allows the researcher less liberties. The researcher is obliged to work according to a certain pattern and to focus attention on all relevant subjects.
- The completion time is reduced. The first results show a reduction in the average completion time.
- Number of measures is decreasing, quality of measures is increasing. The number of measures is decreasing, and so they are easier to implement. If no GFT's are found, improvement is not possible. Good research does not necessarily have to result in more recommendations. The GFT's that are found are often not enough to justify severe measures on the basis of one single incident. Which is why the causes that are found are "stacked" in the form of GFT's for the purpose of analysis at a later time.
- Multiple incidents analysis can easily be carried out. Almost every investigation will reveal one or more controllable factors that can be categorised in GFT's. After that, it is possible to gain insight into the entire railway traffic system, per company and per department. This can then be used to begin specific improvement campaigns and to compare companies, and will allow for trends to be discovered more easily.

4. Conclusions

4.1 SAMOS-methodology

In this introduction of the SAMOS-methodology, we discussed the relationship between human errors and accident prevention. Human failures are very difficult to control. Adjusting the work situation and the organisation in which people work, is a promising approach. We need to deal with the situations in which people almost can't help but fail, instead of focusing on the employees who make mistakes/errors. They do not take risks, but are primarily at risk. Naturally, it is essential that the management gains insight into what these poor working conditions are exactly, and what kinds of steps they should take to improve the situations. SAMOS does both.

The method we have described is not a "miracle drug" in the field of safety. It is an

addition to what is already being done in the field of safety within the railway system. The high level of safety already found in most of the business units, has been achieved by successfully applying these techniques. However, this method focuses on an important component of the accident process, the human factor, and how the management can control this factor as effectively as possible. An important aspect of this approach, is that the management should only try to control what it can control, and that no measures are taken which cost a great deal of time, money and effort, but which lack result because they are based on an incorrect philosophy on safety, or because they were taken at the wrong level. Tackling the human factor starting from the philosophy of control, is an underexposed approach in most other analysis techniques.

The method we have described has the characteristics of both an inventory technique and an evaluation technique. The method provides an assessment of the risks or, to put it in a better way, the underlying factors of the risks, whereas the "importance" of these risks is determined by "clustering" factors at the level of BRF's. Which means that if specific risks are to be arranged in order of magnitude, this may require other additional techniques. Human Reliability Assessment (HRA) -techniques, for example, can be used to estimate the chance that specific errors will occur.

SAMOS allows the user to evaluate the effectiveness of safety care systems with respect to the extent to which the management has control over the human factor. The question is not whether there are certain statutory procedures in the business unit with which employees must comply, but rather if the employees have a clear understanding of these procedures and if there are certain circumstances in which the procedures cannot be adopted or are inadequate. This evaluation can be carried out *independent* of the safety care system in use. The result is an objective measuring staff that can be used to compare companies and departments, and that provides a reliable picture of any improvement or decline occurring between two consecutive measurements.

In addition, the approach we have outlined here can also be very useful when answering the question: "Where does the risk come from?" and so it offers opportunities for improvement. In recognition of everything that has already been accomplished in the field of safety by using other techniques, it would seem that the most important improvement in the safety condition of a company can be achieved by tackling the sources of the errors. This process approach has strong similarities with the "Quality-programmes" that are currently being used in many companies, and the method also concurs with the ISO 9000- and 10000-series. We should not focus on "human beings who make mistakes", but on the situations which cause people to make errors. Safety does not stand alone in this view, but is the automatic result of optimally managing a company. Working in a safe and healthy manner is not so much the responsibility of the individual employee, but mainly that of the management of the organisation in which people work.

4.2 SAMOS-use

The new method has been in use for relative short time. However, the results indicate that the most important aim, "control the controllable", will be reached. The first conclusions are:

- The average completion time is decreasing.
- The railway staff and the management involved are usually very enthusiastic about the new approach, particularly its direct and personal character.
- The quality of the investigations has improved. Though it is true that the structured method results in less liberties for the researchers, the method provides more points of view which were never dealt with in the past.
- Contributing to a no-blame culture.
- Good communications with the companies involved has proved to be essential.
- The number of recommendations has decreased, the quality of the recommendations has improved. Evaluation of the implementation (monitoring) has yet to occur.
- Decreasing number of recommendations, improved quality of recommendations.
- A start has made with multiple incident analysis.
- A start will be made with the development of the audit-instrument in 1998.

The Role of NGO in the Process of Road Safety Improvement in Poland

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1. Introduction - road safety in Poland

The recent years in Poland have been a time of a fast development of motorization. Over the last 15 years the number of passenger cars has tripled, making Poland one of the best auto markets. It is this factor and the fairly modest investments in the area of modernisation and development of the infrastructure plus the minimal interest in road safety issues shown by the government and local authorities that have turned road accidents into Poland's major economic and social problem (Figure 1).

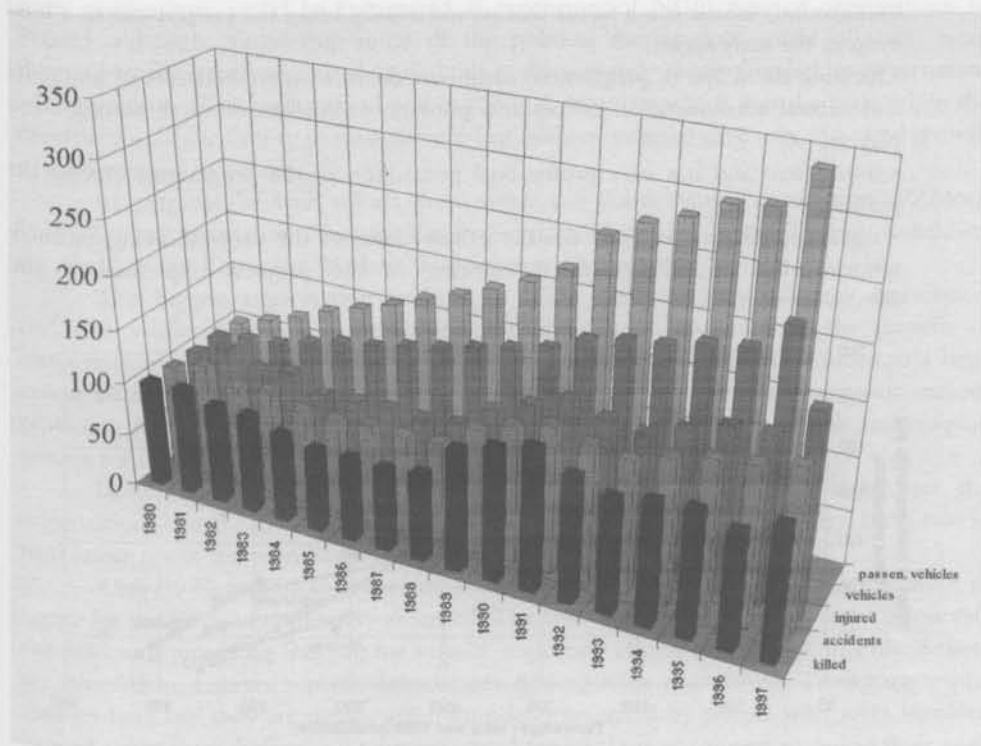


Figure 1. Growth of motorization and increase in the number of accidents in Poland 1980-1995 (1997 - estimated on the basis of 11 months).

2. Preventive action

For many years, Poland has been making efforts to reduce the negative effects of the growing motorization. The first significant action is said to have been started in the early sixties. Over the last 30 years, many different programmes of road safety have been developed. Among those were programmes elaborated by central authorities, institutions related to road safety in the broad sense, as well as by numerous non-governmental organisations. Analysis of these programs has shown that Poland has shaped a certain specific method of problem solving in the area of road safety. In very general terms, this method could be characterised in the following way:

- concentration on selected preventive projects and making use solely of these projects which are easy to implement and to notice irrespective of their effectiveness,
- no co-ordination of activities and simultaneous realisation of many unrelated activities,
- poor subject-matter background of the developed programmes and single projects, ignoring the results of scientific research and basing on word-of-mouth opinions on the ramifications of road traffic and ways of eliminating them,
- ignoring the weight of systemic solutions which make possible the implementation of a programme (organisational structures, funds, legal solutions, subject matter background) which was a factor that would usually bring the programme to a hold even in the early stages,
- limiting the scope of programme organisers down to representatives of ministries and central administration offices and poor co-ordination of work among these players,
- insufficient and not very professional promotion of the programme among the public,
- no accountability assigned for the effectiveness of the projects being pursued; ignoring the significance of monitoring of the projects implemented and effectiveness evaluation.

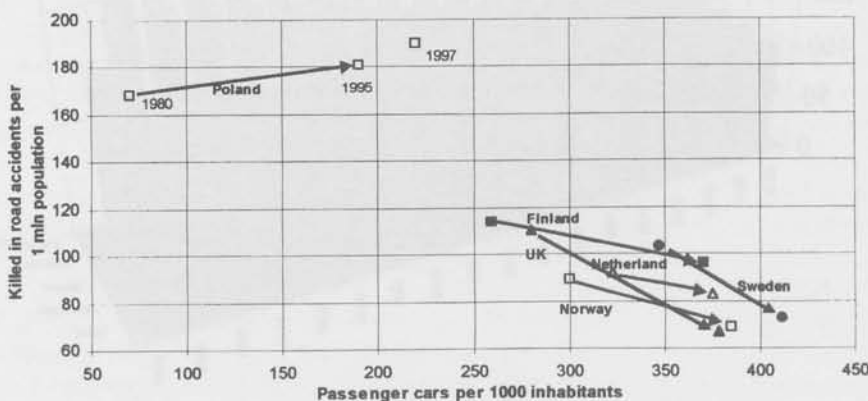


Figure 2. Changes in motorisation levels and the risk to citizens in selected European countries between 1980 and 1995.

To illustrate the scale of the tasks that Poland is facing it is best to use the example of the differences in the level of road safety risk between Poland and some selected countries. Figure 2 shows a comparison of the changes of motorization levels and the levels of risk to Poland's public and that of some selected, OECD countries leading in road safety.

Analysis of this and other experience has shown that growth of motorization in our country is not accompanied by changes in the levels of safety of road users that could be compared to those in other countries. One could say that in spite of a 30 year long tradition in the area of preventive action, Poland still has not been able to develop an effective system of counteracting the negative effects of the growth of motorization.

3. The history of non-governmental organisations in Poland

Poland's awareness of how necessary it is to carry out road safety improvement activities has taken a long time to develop. It was still in the seventies and eighties that Poland was pursuing an informal division. State authorities concentrated their efforts first of all on perfecting the highway code and the procedures to enforce it. On the other hand, safety education in the broad sense and promotion of road safety was left to a large extent to the discretion of various non-governmental organisations. These organisations, though with some reservations, could be recognised as precursors of NGO type of organisations in Poland, although considering some of the political ramifications, most of them were financed by the state budget and carried out projects mainly recommended by government administration. Their peak period was in the mid seventies which was the time when the construction of the factory to manufacture Fiat licensed vehicles gave way to a rapid growth of motorization in Poland.

As examples of such efforts there were: the Polish Motor Association (PZMot), Polish Scouts' Association (Teenage Traffic Service), Campaign "Stop! There is a child on the road" or the Transport Workers' For Sobriety Organisation.

The biggest organisation without a doubt was the Polish Motor Association (PZMot) whose members were drivers and individuals interested in the growth of motorization and the motor sport in our country. The organisation was funded to a large extent by membership fees and revenues made from its businesses (car diagnostic stations providing services of periodic inspection, car repair garages, driving schools and training centres for drivers).

In the early eighties, devoid of subject matter and financial support of the state, the organisations began to slowly fade away and despite being active even today, their role in road safety is not that significant any more.

After 1989 parallel to the change of the political system in Poland, new ways of acting for the cause of road safety emerged. The law on foundations has created favourable conditions of providing funding for socially important efforts. At present, in Poland there are more than a dozen various foundations dealing with road safety. The characteristic features here are: they are usually small foundations created by people who were involved in road safety issues before and who perceived foundations as a means to realise their goals faster. However, already during the initial stages, it was found that acquiring funds is not as easy a task as was expected. In the period of the political and economic transformation there

were problems and expenditure that was recognised as more urgent. Therefore despite the ambitious plans, the activities of these foundations quickly became limited. What is more, the projects were conducted practically without any subject matter bases, in an isolated way and limited only to a small area or a small number of road users. It was for these reasons that the influence these organisations exerted on the level of road safety was minimal.

4. The GAMBIT Programme

The kind of treatment applied to the risk in road traffic had changed to one of an important social and economic problem after a visit paid by a group of experts from the World Bank in Poland and after the 1993 report titled "Road Safety in Poland" (Gerondeau, 1993). This report evaluated the state of road safety and what is most important it stated some general recommendations as to further action to be taken. In response to the recommendations given by the experts of the World Bank at the end of 1993, the National Road Safety Council was appointed in Poland. Its last chairman was the Prime Minister. Next, the Minister of Transport commissioned the Scientific Research Committee to develop a project titled "Road safety improvement programme in Poland". This programme called with the acronym GAMBIT, was developed by a multidisciplinary team of specialists from across Poland with substantial assistance given by specialists from several OECD countries (Gambit, 1996; Krystek, 1996).

It is the opinion of the authors of the Programme that an improvement of the state of road safety in Poland will require not just an implementation of effective preventive measures and handling of organisational, legal and financial issues, it will also entail the acquisition of public support for the programme. In practice this should mean that the Polish public:

- will become aware of the complexity of the problems of growing motorization and the risk associated with it,
- will treat road safety improvement as an indispensable element leading to higher levels and quality of living,
- will accept having to apply self-discipline to their own behaviour in road traffic,
- will have an interest in active search for new solutions of road safety problems and co-operation in this area with the respective administrative authorities, local authorities and non-governmental organisations.

The vision of a society sensitive to road safety problems and one taking over part of the responsibility for its state is the fundamental principle of the GAMBIT programme. As results from the research of SARTRE 2 (1997) the situation in this area in Poland is not one that is best. A schematic knowledge on the state of road safety in the country, lack of a feeling of risk on the road, conviction of one's high skills make the Polish public, so far, one that cannot be treated as a strong partner in preventive measures. Realisation of this vision for Poland will be a complex and long-term process because it will require a change of habits and preferences of the entire public. However, it remains the necessary thing to do if our goal is to implement effective mechanisms of reducing risk on the roads.

Getting the public's support for the issue of road safety will require the involvement

of all options, namely government administration, local authorities and non-governmental organisations (Muhlrad, 1994). Poland has certain traditions of preventive measures conducted by government bodies and very little experience in terms of the participation of local authorities and non-governmental in this area.

In the GAMBIT Programme NGOs are defined as organisations of people who act on voluntary basis beyond the structures of government and local authorities, make efforts to solve problems that are important for the given group. The main task of NGOs should be to obtain public support, help in verbalising social expectations, education and promotion, developing new forms of co-operation and social communication and a forum to activate the largest social groups and to organise their activities.

5. The role of NGO in a road safety improvement programme

In Poland there is a large unmanned area that could be used for the activities of NGO type of organisations. The emergence of various formulas of organisations interested in the problems of road safety proves that more and more frequently various groups of road users are trying to look for ways to present their views and possibilities of realising their ideas in practice. What is more - it all points to the fact that an uncontrolled growth of motorization in Poland may lead to an increased demand for this type of activities in the near future. In the recent months in Poland for the first time, residents of a small town of Sochaczew blocked for a half hour the international road E 30 (Berlin - Warsaw - Moscow) staging a protest against the effects of road traffic on the quality of their living. This is all the evidence we need to state that in Poland there are many people who do not ignore the problems related to life, health or safety and that it is possible to obtain new allies for the problems.

The short period of non-governmental organisations' history means that at least in the early stages of shaping the profiles of these organisations what they will need will be the help of government administration and local authorities, especially in the area of co-ordination of activities and subject-matter and financial assistance which in the present situation seems very difficult. Besides, it is difficult to clearly define who should be the recipient of NGO work and how the effects of their work would be utilised.

There was some hope that the establishment of the National Road Safety Council and the Social Road Safety Council that it appointed, would bring order into the problems faced by non-governmental organisations. A great many organisations were invited to participate in the work of the Social Road Safety Council. However, lack of a concept of operating of such a forum and unregulated legal and financial problems have made the Social Council just an organisation on paper. Moreover, the optimism of the authors of the GAMBIT Programme triggered off by the fact the Prime Minister assumed leadership of the National Road Safety Council quickly faded. The benefits that this fact brought along, namely the high standing of the issue, were modest when compared to the losses. The Prime Minister was hardly ever there, attending to his numerous responsibilities. Apart from that, after the September parliamentary election and the change of the political option, the process of obtaining the political will for the support of the Programme must be resumed basically from scratch.

Despite these problems, the continuing growth of motorization observed in Poland proves that it is necessary to take quick action to improve road safety. The seriousness of the situation is marked by road accidents statistics from the recent months of this year (Figure 1). Until the end of November 1997 in Poland, compared to the previous year a 15% increase in the number of road accidents and casualties has been observed. Never before has Poland had such a big increase in the risk in one year.

6. The GAMBIT Foundation

The concept of establishing the GAMBIT Foundation of Independent Scientific Research was created at the time of developing the Programme of Road Safety Improvement GAMBIT. According to the assumptions of the programme, the basis for all effective activities in the area of road safety should be provided by results of scientific research. However, for many years in Poland there had been no comprehensive scientific analyses of the conditions and safety of traffic. All it came down to was a schematic presentation of statistical data on accidents. What is especially painful is the lack of domestic studies on seven major problems of road safety selected within the GAMBIT programme. Therefore it was assumed that the Foundation would fill out the gap and will consequently make the implementation of a road safety improvement programme easier in Poland.

The Foundation looked for sources of funds mainly in insurance companies which due to civil liability insurance that they offer, had already been traditional participants in financing preventive measures in the area of road safety. The first contacts turned out to be very difficult - representatives of insurance companies were sceptical about the statement that studies are the necessary condition leading to a reduction of risk on Polish roads and the actual drop in the number of road accidents can be beneficial also for the insurance company itself because it reduces the amount of damages awarded. It took the presentation of the experience of two renowned institutions operating on the insurance market: Verband VDS (Germany) and VALT (Finland) to help change this attitude.

A concrete outcome of the meeting was a trip of representatives of Poland's two major insurance companies PZU and WARTA to Finland prepared by the GAMBIT Foundation, VALT and FINNRA. A report on the role of Finnish insurance companies in the process of road safety improvement and the funds provided by the insurance companies for Poland's first public opinion study on speed were the effect of the I stage of the Foundation's activities.

The second report by the Foundation GAMBIT "Speed as the main factor of high risk in road traffic in Poland" was published in 1996 and even though it was received with great interest both in and out of Poland, it did not help to implement any mechanisms of permanent financing of scientific research by insurance companies (Buttler, 1996). Last year, PZU concentrated its efforts on privatisation of the company and clearing the damages caused by the floods, and a rapid increase in road accidents observed in 1997 was once more commented on only by a significant increase in civil liability insurance for the next year.

Putting the financing of the GAMBIT Foundation on hold by insurance companies practically questions its further operations. Fortunately, recently a new partner of the

Foundation emerged - the SHELL Polska company which accepted our proposal of cooperation in the area of educational activities which enforce the implementation of the Programme of road safety improvement GAMBIT. At the same time, the Foundation established a contact with the European Federation of Road Traffic Victims and published in Polish a report on the effects of accidents on the life of the victims (FEVR, 1995) and is going to carry out the same research in Poland within one of the four currently realised regional programmes of road safety, the so called Suwalki region GAMBIT.

7. Conclusion

The scarce NGO type organisations that operate in Poland only minimally represent the weaker road traffic users. The effects are clearly visible. In April this year the Parliament rejected a motion to reduce the speed limit in built-up areas to 50 km/h which was an effect of efforts of a strong lobby of car owners, interested in not pursuing speed limits.

Pedestrians do not have any organisation that could represent their interests with local authorities or government administration. The rapid growth of motorization in the recent years (more than three times more vehicles over the last 15 years) and a decrease in expenditure on construction and maintenance of roads brought about a situation where vehicles are occupying the little space that is left normally to be used by unprotected road users. Parking cars on pavements was made legal provided there is a 1.50 meter wide stretch of pavement left for pedestrians. The practical meaning of that is that very often the entire width of the pavement is occupied and also vehicles drive on the pavements because they do not have access to that particular place from the street.

Similarly, road traffic victims are not organised in anyway. After an accident, especially one caused under the influence of alcohol, the casualties are treated as witnesses by the legal system. A report written by a policeman and signed by the victim is considered sufficient testimony in the court without the victim appearing in court to testify. Next they are left alone to face a huge enemy which is the insurance company. Practically there is nobody they could turn to for legal advice. Before they can get any financial support, they have to wait until the damages are legally awarded. And so nobody answers the question of how to survive the period of medical treatment, the formal and legal procedures and a possible convalescence.

The above examples prove that it is necessary to develop a broad programme of social education. Its realisation is only possible if there is sufficient public demand for those activities. This is the role of NGOs whose programmes of action should follow the patterns of experience made by similar organisations of many years of experience, existing in OECD countries and with well grounded knowledge on programming road safety improvement activities (OECD, 1994).

The above description of the role to be played by NGOs in the process of road safety improvement is not Poland's specific feature, it may just as well be recognised as a standard of CEEC. Currently, the idea of development of NGOs is in a deadlock; it is difficult to obtain funds from the government for activities which basically will be a means of exerting pressure on the same government to intensify work on implementing a programme of road

safety improvement. And without a programme it is difficult to begin a methodical education which could generate public support for the programme. Therefore, one could ask the fundamental question, appropriate for all CEEC countries, how to break the vicious circle? Otherwise the time ahead of us will be a time of many years of iteration which every year costs Poland 7000 human lives and one hospital of an average size town (200 beds) filled with road accidents injuries every single day.

References

- Buttler I., Krystek R. (1997): Speed as the primary factor of high risk in road traffic in Poland. Part I. Analysis of public opinion. GAMBIT Foundation for Independent Road Safety Research. Warsaw.
- FEVR (1995): Impact of road death and injury - research into the principal causes of the decline in quality of life & living standard suffered by road crash victims and victim families. M. Haegi. Geneva.
- Gerondeau C. (1993) - Road Safety in Poland. World Bank Report.
- GAMBIT 96 (1996): International Seminar on GAMBIT - Integrated Programme of Road Safety Improvement in Poland. Gdansk, March 21-23.1996. Unpublished reports of experts from Austria, Canada, Czech Republic, Finland, France, Germany, the Netherlands, Norway, Sweden, United Kingdom and United States.
- Krystek R. et al.(1996): GAMBIT - Integrated Programme of Road Safety Improvement in Poland Final report. Associated Authors' Team.
- Muhlar N. (1994): Improving Decision Making Processes in Road Safety. III International Conference on Safety and the Environment in the 21st Century. Tel-Aviv.
- OECD (1994): Targeted road safety programmes. Paris.
- SARTRE 2 (1997): Social attitudes to road traffic risk in Europe - Contextual data. National Research Institute on Transports and their Safety, France.

Rewards to Stimulate Safety Belt Use: An Overview of Research Findings

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1. Introduction

A multitude of psychological theories - generally in the field of learning and motivation - reserve an important place for the principle of reward. In theories varying from those postulated by Skinner and Banduras modern stimulus response theories to theories with a more cognitive orientation, such as Festingers cognitive dissonance theory, goal-setting and expectancy theory, rewards are explicitly regarded as powerful influences on behaviour, even though the principles and presumed mechanisms of effect of the individual theories can vary greatly (see for an overview Lindzey and Aronson, 1985, for example). No matter how different these theories may be, the effect of reward is generally considered greater than that of punishment. Nevertheless, it has been traditional practice in the (Dutch) traffic system for desirable behaviour to be stimulated by rules and laws, resulting in the punishment of offences. The possible role of reward in influencing safe behaviour in traffic is hardly recognised. In recent years, however, this concept is also beginning to reach this field of application.

This paper gives an overview of the research that has been performed to determine the effect of rewards (incentives) on safety belt use. In particular the effect of offering material rewards is considered. The greatest proportion of research was performed in the United States; in the Netherlands, only a few studies have been done in this field.

2. Research conducted in the U.S.

In the past 150 years a large number of incentive programs to stimulate safety belt usage have been implemented and evaluated, most of them in the U.S. Their initial application appears to have been inspired by the absence of mandatory safety belt use laws in many states at the time excluding enforcement activities as a possibility to influence use rates and by learning theory and behaviour modification techniques. More recent incentive programs have been conducted to investigate their effect as an alternative for or in addition to enforcement strategies to increase safety belt use.

Most of the incentive campaigns studied were conducted amongst relatively small, homogeneous groups, for example company employees, university personnel or confined to a particular city or region. Generally, rewards are given on the basis of actual observed use of the safety belt. The rewards vary from certain privileges in the working environment,

such as extra time off, small gifts and gift coupons to the chance of winning a prize or gaining social attention, such as ones name or picture in the paper. Most rewards for safety belt use are presented immediately upon observation; mostly in situations where cars have to stop anyway, for example at the point where workers enter an industrial complex. Sometimes, there is question of a postponed (delayed) reward, in the form of a lottery. Car number plates of safety belt users are noted down and selected, and the owners of the winning number plates can then collect their prize (Geller, 1984). Such incentive campaigns roughly led to a doubling in the percentage of safety belt users. It should be noted in this context that at the time of study, it was not compulsory to use a safety belt in most American states, and hence the usage percentages were very low: often no more than about 10%. Because the various forms and types of rewards were virtually never systematically varied, it is difficult to deduce the ideal incentive campaign from the results.

In general, the safety belt usage declined considerably once the incentive campaign had stopped, but in most cases, the usage still remained higher than prior to introduction of the campaign.

It has been suggested that social pressure (for example, encouraging others to wear their safety belts in support of the group performance) can have a stimulating effect. In large companies, for example, the workers could be divided into groups and the group with the highest safety belt use percentage measured during the campaign wins a prize. If rewards depend on reaching a collective target, rather than an individual target, then the effect is expected to be even greater since the social pressure brought to bear on the individual to contribute to the success of the group works as extra stimulus (see, e.g. Bandura, 1986). Like methods of individual reward, it appears that rewards which depend on group performance are often successful (see e.g. Cope, Smith and Grossnickle, 1986). However, such group-oriented campaigns, generally initiated by companies, are also associated with negative effects. Workers start to check on each other and do not want to perform inadequately and risk letting the group down by spoiling the chances of winning a prize. Maier (1973) in this context suggests that, in linking group competition to safety, the actual competition and winning of prizes becomes the objective, rather than achieving a safer traffic situation.

3. Research in the Netherlands

Inspired by the "success stories" from abroad, interest was also aroused in the Netherlands to reward safe behaviour in traffic (see e.g. Hagenzieker, 1988). Empirical studies demonstrating large effects are however hardly available, because in contrast to many American states, the usage of safety belts is already relatively high in the Netherlands (around 70-75%) - hence a doubling of safety belt use as a result of incentive campaigns simply cannot occur. Nevertheless, the "ceiling" has not yet been reached by any means, in view of the safety belt use percentages of over 95% in Germany and the United Kingdom, for example. And although modest results are also welcome, the question arises whether in the Dutch situation, police enforcement is not a more effective approach.

The American studies into the effects of incentive campaigns were generally

performed in cases where safety belt use was in fact voluntary, with the exception of a study conducted by Kalsher, Geller, Clarke and Lehman (1989). This study was performed at two large military bases in Virginia, where it is compulsory to wear a safety belt. At one base, a incentive campaign was organised, while at the other, the campaign consisted of increased police enforcement. In this way, the effect of a reward strategy could be compared to the effect of a different, more traditional measure. The researchers found that both campaigns realised an equivalent increase in safety belt use.

Hagenzieker (1991) performed a similar study in the Netherlands at twelve military bases. The effects of various forms of incentive campaigns were compared to those of increased police enforcement. The purpose of the campaigns was to stimulate the personnel of these bases to use the safety belts in their own car more frequently. Individual incentive campaigns proved to be particularly effective: a rise of approximately 20% in safety belt use. Group-dependent rewards showed at best a (small) short-term effect. In both studies, the average effect of punishment (police enforcement) and reward (individual and group) was shown to be of the same order of magnitude: an average rise in the medium term of 10-15 percentage points for both methods, whereby it should be noted that the personnel effort needed for police enforcement was considerably greater than that needed for the incentive campaigns. In addition, the initial levels of safety belt use for both campaigns were comparable, between 50 and 60%. In view of the often heard assumption that whilst reward may encourage voluntary behaviour, punishment is more effective to stimulate compulsory behaviour, these results can be considered surprising. In addition, Mortimer, Goldsteen, Armstrong and Macrina (1990) found that the greatest effect was demonstrated when reward and police enforcement were applied in combination. It should be noted that the initial level of compliance to safety belt use in this study was quite low (25-30%).

Not all incentive campaigns to stimulate safety belt use are successful. An incentive campaign conducted in the province of Friesland, for example, had no effect at all on percentages safety belt use (Hagenzieker, 1989). Perhaps the campaign had not been sufficiently publicised; it has already been noted that when people are rewarded if they do not expect it, the effect is not as great. People will not change their behaviour if they are not aware of the promise of a reward (also in the future).

4. Meta-analysis

As stated above, a problematic aspect in reviewing the results of individual studies is the poor systematic variation in campaign characteristics and settings, or a subset of these aspects within studies. This problem can, partly, be overcome by choosing a meta-analytic approach instead of a more "traditional", narrative literature review to analyse the reported results and other variables of incentive programs to promote safety belt use; meta-analysis is considered to be better able to integrate research findings across studies (see, e.g. Hedges and Olkin, 1985; Hunter and Schmidt, 1990).

Although the specific contents of the incentive programs often vary, a first inspection of the findings indicates that all types of intervention seem to give similar results. For instance, rewards have been given directly or indirectly, immediate or delayed, they could

be contingent or noncontingent upon actual safety belt use, the probability, type and value of the reward could vary, they have been based on group or individual behaviour etc. Also the type of population in which the program was implemented varies from work settings to schools and universities, or even large community settings. Long-term effects are usually reported as being smaller than short-term effects, but the follow-up belt usage rates are generally higher than the initial baseline levels. However, more specific (quantitative) effect sizes are not available. Besides the general conclusion that various kinds of incentive programs seem to work equally well, it is not known which characteristics of the incentive programs are more effective than others, and to what extent, and in which settings such programs are most effective (cf. Peters, 1991). Hagenzieker et al. (1997) conducted a meta-analysis to determine the short- and long-term effects of incentive programs to stimulate safety belt use. They furthermore attempted to locate moderating variables that are related to the magnitude of these effects. A summary of this meta-analysis is presented below.

Two coders extracted a total number of 136 short-term and 116 long-term effect sizes from 34 journal articles and research reports. They also coded many other variables in three general classes: 1. background characteristics (e.g., year of publication; publication form; type of population involved etc.); 2. research characteristics (e.g. research design; observation method); 3. characteristics of the incentive program (e.g. duration of the intervention period, group or individual rewards, immediate or delayed delivery of rewards, whether rewards were contingent or noncontingent upon the actual usage of a safety belt, number and type of rewards, the value of the reward, probability to receive the reward).

4.1 Short-term effect sizes

A total of 136 short-term effect sizes were calculated. The minimum calculated short-term effect was slightly negative, the maximum effect was over 60 percentage points. The (unweighted) mean short-term effect was 20.6 percentage points (± 2.4 ; median 19.5). The number of observations on which the percentages of belt use were based varied enormously between studies. It appears that the largest studies on average report the smallest effect sizes. When studies were weighted by the (estimated) number of observations, the mean short-term effect size was 12.0 percentage points (± 1.9).

4.2 Long-term effect sizes

Not all studies included follow-up observations; a total of 116 long-term effect sizes were calculated. The mean long-term effect was 13.7 percentage points. The minimum calculated long-term effects were slightly negative; the maximum calculated effects were over 30 percentage points. When studies were weighted by the (estimated) number of observations, the mean long-term effect size was 9.6 percentage points (± 1.2).

4.3 Impact of moderating variables

GLM-analyses were performed to investigate the impact of moderating variables on the short- and long-term effect sizes. The results of these analyses are summarized below (see

Hagenzieker et al., 1997 for a more detailed description).

Short-term effect sizes were larger when no mandatory safety belt use law was in effect during the incentive campaign; under these circumstances baseline belt use was relatively low: 22.5% belt use as compared to 52.7% with mandatory belt use law. Low baseline levels were connected with relatively high short-term effect sizes (Pearson $r = -0.25$; $p < 0.01$). The presence or absence of a mandatory safety belt use law did not have any effect on the mean long-term effect size. When the research design included a control group both short- and long-term effect sizes were smaller than when no control group was present. The main effect of "control group" was only significant when weighted effect sizes were used in the GLM-analyses; it appears that in particular large scale studies (with higher weights) had included control groups. Counter to expectations, campaigns with contingent rewards showed smaller effect sizes than those with noncontingent rewards; the difference was more pronounced for long-term effect measures and for certain adjusted measures, which implies that noncontingent rewards were relatively more often applied in settings with high baseline levels. For long-term effect sizes, and when adjusted short-term effect sizes were used in the GLM-analyses, the main factor "theory referred to" was significant; larger effect sizes were reported when motivational theories were referred to as compared to "no theory referred to". In addition, for adjusted long-term effects main effects of "publication year" (more recent studies had high baseline levels and relatively large long-term effect sizes), and "country and/or state of study" were significant (Netherlands differed from U.S. because of high baseline levels and relatively large long-term effect sizes). The probability of receiving a reward was positively related to long-term effect sizes (Pearson $r = 0.36$; $p < 0.001$). The length of the follow-up period was not related to the long-term effect sizes (Pearson $r = -0.004$; $p = 0.97$).

5. Conclusions

The results of the meta-analysis confirms the conclusion of earlier narrative reviews (e.g. Geller, 1984b; Geller et al., 1987; Hagenzieker, 1988, 1992) that incentive campaigns to stimulate safety belt use generally lead to substantial short-term effects; and that long-term effects are smaller than short-term effects, but belt use during follow-up measurements after withdrawal of the incentive campaigns is generally higher than initial baselines. Whereas earlier narrative reviews did not quantify the effect sizes of incentive campaigns, the results of this meta-analysis indicate that the mean effect sizes of incentive treatments that were reported in the literature amount to 12.0 (unweighted mean 20.6) and 9.6 (unweighted mean 13.7) percentage points over baseline for short- and long-term effects, respectively.

The findings of the meta-analysis also reveal that the magnitude of the (short-term) effects depend on a number of moderator variables: the effect is not reached "no matter what" type of incentive campaign is implemented. The results of this meta-analysis show that the short-term effect size is moderated by a number of single variables, and that a combination of the following variables accounted for 64% of its variance:

- (1) The type of population involved; campaigns at elementary schools showed the largest effect sizes, which finding is in line with previous reviews that conclude that

incentive programs implemented in small, homogeneous groups give better results than those in large, heterogeneous groups such as communities.

- (2) The immediacy of delivering the rewards; when incentives were delivered immediately, larger effect sizes were reported than when incentives were delivered delayed; this finding was not reported in earlier reviews on the effects of incentive programs to stimulate safety belt use, but is in line with (learning) theory (see, for example, Bandura, 1986).
- (3) The initial baseline rate (which was highly correlated with the presence or absence of a safety belt usage law); lower initial baselines and absence of a safety belt use law yielded larger effect sizes (see also, Elliot, 1993).

Incentives that were based on group behaviour yielded larger short-term effect sizes than when they were based on individual behaviour. However, the effect of this variable was less stable than the other variables in the models for short-term effect sizes. This may indicate that the relevance of this variable was dependent on a small number of studies. When promotional items or immediate valuables and noncontingent rewards were present larger effect sizes were reported. And when a control group was included in the research design, smaller effect sizes were on average reported than when no control group was present (cf. Elliott, 1993). However, when these variables were included in a model together with other variables, their impact to differentiate between effect sizes disappeared. This suggests that variations of these characteristics coincide with variations in other characteristics (such as the type of population involved, the size of the study etc.), making it difficult to isolate separate contributions to the explanation of variance.

Other variables, such as the duration of the intervention (see also Johnston et al., 1994), the probability of receiving a reward, and the value of the reward appeared unrelated to the short-term effect sizes. However, the latter three variables were difficult to code, and could therefore often be coded incorrectly, which might be a reason for the absence of a statistical significant relationship with effect size.

The results for mediating variables explaining the variance in the long-term effect sizes were less clear. Although a number of variables explained a significant part when entered as single variables in a model, they appeared insignificant in models with combinations of these variables. The presence of a promotional item, and the absence of a control group in the research design were the most important variables for (unadjusted) large long-term effect sizes. The variable "control group" appeared to be the most consistent stable variable across various long-term effect size models. Furthermore, low usage rate during baseline and noncontingent rewards seem to result in large adjusted effect sizes. At first sight, this latter finding is rather puzzling because it was expected that contingent rewards would lead to larger effect sizes than noncontingent rewards (see, for example, Johnson & Geller, 1984; Bandura, 1986). However, this finding could be an artefact of the very unstable long-term-effect models. The confounding of small scale studies, the absence of promotional items or immediate valuables, noncontingent rewards, and large long-term effect sizes has possibly resulted in coincidental significant contributions in some of the hypothesized models. The length of the follow-up period (since ending of program), and the value of the reward had no effect on the long-term effect size. The probability of receiving a reward was positively related to long-term effect size, but was

rarely significant when entered with other variables in a model. Also the type of reward, other than promotional items, did not influence the long-term effect. A clear explanation for the discrepant results for long-term effects as compared to those for short-term effects is difficult to give. It is probable that the way long-term effects have been measured differs so much between studies that this hampers further analysis.

Based on the results of the best fitting models, the largest effect sizes of incentive campaigns to promote safety belt use can be obtained when the population involved consists of elementary school pupils and their parents, when incentives are delivered immediately rather than delayed, and with relatively low baseline levels (and an absence of a mandatory safety belt use law). On the other hand, the smallest effect sizes are obtained for incentive campaigns in community settings with relatively high baseline levels; it seems that for this type of conditions another approach, such as selective enforcement in combination with publicity might be more efficient in enhancing safety belt use (see, for example, Zaal, 1994 for a review of traffic law enforcement research findings).

References

- Bandura, A. (1986). *Social foundations of thought and action. A social cognitive theory*. Englewood Cliffs, N.J.: PrenticeHall.
- Cope, J. G., Grossnickle, W. F., & Geller, E. S. (1986). An evaluation of three corporate strategies for safety belt use promotion. *Accident Analysis & Prevention*, 18(3), 243-251.
- Elliott, B. (1993). *Road safety mass media campaigns: A meta analysis*. Canberra: Federal Office of Road Safety. (CR 118).
- Geller, E. S. (1984a). A delayed reward strategy for largescale motivation of safety belt use: A test of longterm impact. *Accident Analysis & Prevention*, 16(56), 457-463.
- Geller, E. S. (1984b). *Motivating safety belt use with incentives: A critical review of the past and a look to the future*. Warrendale: Society of Automotive Engineers. (SAE Technical Paper Series, No. 840326).
- Geller, E. S., Rudd, J. R., Kalsher, M. J., Streff, F. M., & Lehman, G. R. (1987). Employerbased programs to motivate safety belt use: A review of shortterm and longterm effects. *Journal of Safety Research*, 18, 117.
- Hagenzieker, M. P. (1992). Beloningen voor verkeersveilig gedrag. *De Psycholoog*, September, 349-353.
- Hagenzieker, M. P. (1991). Enforcement or incentives? Promoting safety belt use among military personnel in the Netherlands. *Journal of Applied Behavior Analysis*, 24(1), 2330.
- Hagenzieker, M. P. (1989). *Evaluatie beloningsactie gordelgebruik in Friesland*. Leidschendam: Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV. (R8920).
- Hagenzieker, M. P. (1988). *Toepassingen van vormen van individuele beloningen ter bevordering van verkeersveilig gedrag*. Leidschendam: Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV. (R8812).
- Hagenzieker, M. P., Bijleveld, F. D., & Davidse, R. D. (1997). Effects of incentive programs to stimulate safety belt use: A metaanalysis. *Accident Analysis & Prevention*, 29(6), 759-777.
- Hedges, L. V., & Olkin, I. (1985). *Statistical methods for metaanalysis*. Orlando: Academic Press.
- Hunter, J. E., & Schmidt, F. L. (1990). *Methods of metaanalysis. Correcting error and bias in research findings*. Newbury Park: Sage.
- Johnson, R. P., & Geller, E. S. (1984). Contingent versus noncontingent rewards for promoting seatbelt usage. *Journal of Community Psychology*, 12, 113-122.
- Johnston, J. J., Hendricks, S. A., & Fike, J. M. (1994). Effectiveness of behavioral safety belt interventions. *Accident Analysis & Prevention*, 26(3), 315-323.
- Kalsher, M. J., Geller, E. S., Clarke, S. W., & Lehman, G. R. (1989). Safety belt promotion on a naval base: A comparison of incentives vs. disincentives. *Journal of Safety Research*, 20, 103-113.
- Lindzey, G., & Aronson, E. (eds). (1985). *The handbook of social psychology. Volume I: Theory and method*. New York: Random House.

- Maier, N. R. (1973). *Psychology in industrial organizations*. Boston.
- Mortimer, R. G., Goldstein, K., Armstrong, R. W., & Macrina, D. (1990). Effects of incentives and enforcement on the use of seat belts by drivers. *Journal of Safety Research*, 21, 2537.
- Peters, R. H. (1991). Strategies for encouraging selfprotective employee behavior. *Journal of Safety Research*, 22, 5370.
- Zaal, D. (1994). *Traffic law enforcement: A review of the literature*. Australia: Monash University, Accident Research Centre. (Report No. 53).

Improving the Fate of Road Traffic Victims

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In Europe, every year, more than 50.000 people are killed in road crashes, and more than 150.000 remain disabled for life. Thus, every year, 200.000 new families, who have a family-member killed or disabled, are added to those of previous years. At present in Europe at least 6.000.000 people, whose tragic situation is often underestimated, if not ignored, have suffered in this way. In the world there are 100.000.000 individuals in this situation, an enormous number of people directly affected by death or injury.

In order to reduce the number of these victims, we must obviously reduce the number of accidents, while to decrease the gravity of the suffering, we must provide better emotional, social, and juridical support to the relatives and to the victims, besides more advanced medical care to the injured victims.

1. Socio-economic costs of road traffic accidents

The number of crashes can further be reduced by:

- A more serious implementation of present road safety measures.
- New safety measures addressing principally the behaviour of drivers.

The list of safety measures already proposed is impressive. For example, the Gerondeau Report, prepared a few years ago at the request of the European Commission, gives a list of 80 of these measures. Long term road danger reduction programmes are presently implemented in different countries. For example the *Stratégie des années 90*, elaborated by the Swiss Federal Department for Justice and Police, consists of a detailed plan aimed at decreasing the number of serious accidents by 70% by stages of 5% per year. Similarly the Dutch Ministry of Transport, starting from the good records they already have achieved, have elaborated a comprehensive Long-range programme for road safety, with the target of reducing road deaths further by 50% by the year 2010.

The socio-economic cost of road crashes in the European Union, according to the study COST 313 undertaken by 14 universities (including The Netherlands) and published by the European Commission, amounts each year to more than 200 billion *Ecus*. This sum would permit to construct each year more than 10 million cars.

It is staggering to note that in Europe the cost of the damage caused every year by cars, is comparable to that of the yearly production cost of these cars.

An analysis of the ratio:

$$\frac{\text{costs (of the application of safety measures)}}{\text{benefits (avoiding socio-economic costs)}}$$

shows that it is contained between 1/10 and 1/100. Thus an investment in road safety of for example 1.000.000 \$, would permit to avoid damage of a social cost of 10.000.000 to 100.000.000 \$. Thus, only from the economic point of view, society as a whole would make a significant financial profit investing in road safety, without taking into account the physical and mental suffering that would be avoided.

Significant improvement of road safety does not raise fundamental technical or financial problems, therefore such an improvement must be the result of a political decision.

The major part of these road tragedies are not due to fate, they could be avoided by implementation of existing safety measures, the cost of which is derisory compared with savings that would be made.

Road victim associations, on behalf of the killed and disabled victims, are trying to exert a political pressure on governments to improve road safety. This political action, unfortunately, tends often to be contrasted by economic or commercial interests. Indeed for more than a decade the number of persons injured through road incidents in Europe has remained roughly the same, in spite of the increased number of cars, mainly because of traffic congestion. If the number of people killed has slightly decreased during this period, it is not because of better driving standards but because the emergency services respond faster, and because of the progress in emergency surgery.

2. The situation of victims

Road crashes represent a major public health problem in Europe, because of the huge number of victims, and because of the serious and long lasting consequences for them, their relatives, and for the bereaved.

Up to now, the situation of these victims has never been the object of systematic studies. Therefore the European Federation of Road Traffic Victims (to which more than twenty road victim associations belong) conducted two enquiries among its members, with the financial support of the of the European Commission. The result of these inquiries has been published in the Report: Impact of road death and injury. Research into the principal causes of the decline in quality of life & living standard suffered by road crash victims and victims families. Proposals for improvements (Edited by FEVR 1995. ISBN 2-940183-00-7). Let me comment some diagrams of this Report:

- Figure 5 shows that 80 to 90% of the victims have not been informed about their legal rights.
- Figure 6 shows that the same proportion has not been informed about existing

helping organisations.

- Figure 7 shows that 90% of the relatives of dead victims consider that Criminal Justice has not been done.
- Figure 9 shows that 60 to 75% consider that the charges brought against the offenders were not fair.
- Figure 13 shows that about 80% are not satisfied with the damages offered by the insurance companies. Figure 15 the same proportion consider that the Court gave no financial Justice.
- Figure 17 shows that nearly the unanimity of the victims consider that, in serious cases, it would be useful to appoint a lawyer from the beginning.
- Figure 18 shows that 1/3 of the victims unsatisfied with the damages offered by the insurance companies did not go to Court because they consider the law is not in their favour, 1/3 because of stress, 1/3 because of excessive legal fees.
- Figure 25 shows that the physical suffering of the victims and their relatives consists for most of them in sleeping troubles, headaches, distressing nightmares, and general health problems.
- Figure 31 shows that most of them have an increased consumption of psychotropic products like tranquillisers, sleeping tablets, tobacco etc.
- Figure 26 shows the wide range of psychological suffering of most of these victims: lack of interest, loss of drive and self confidence, anxiety attacks, depression, phobias, eating disorders, anger resentment, feeling suicidal etc. It is impressive that even after several years 1/4 of the victims suffer so much that they feel suicidal.
- Figure 29 the most helpful psychological aid is provided by friends and by families. The aid provided by the institutions and religion is considered irrelevant.

These enquiries have shown that the great majority of victims families undergo a substantial, even dramatic and long lasting decline in their quality of life, and that half of them undergo also a severe worsening of their standard of living. Moreover most families report that they did not receive any information about the existence of organisations able to help them, not to mention information about their legal rights.

It is depressing to realise the depth of distress of these people. A large proportion of them suffers psychological disorders which are often intense, long lasting, and even permanent. They can cause somatic diseases that worsen this psychological distress. It is assumed that these consequences, called legally secondary damage, but which are often more serious and more painful than primary damage, decrease and disappear with time. Our enquiries have shown the contrary, namely that far from disappearing, these psychological disorders get worse with time and require more assistance. In addition, because of this distress, members of these families are often forced to change their job or even leave it completely. Which obviously has serious consequences on their standard of living. These troubles are generally exacerbated by the difficulties victims and victim families encounter with the legal system and insurance companies.

Regarding criminal justice, these families complain of lack of consideration, inefficiency, and above all laxity. Regarding insurance companies and civil justice, victims also complain of lack of consideration and disdain for their suffering, but above of all insufficient compensation, particularly in serious cases where the damages bear no relation

to the damage really suffered. It is our duty to improve the situation of these families, and prevent that victims of a road crash become victims a second time, namely of a system, and a society, unable to understand or help them.

The first step is to provide immediate emotional and psychological support, then juridical and social assistance. The agencies which have contact with the victims must have the duty to inform them of where they can find this support and assistance. In certain countries the police and the emergency services supply pamphlets to victims or their relatives, giving the necessary information.

Further, to satisfy the need for help at such a difficult time, it is necessary to promote the opening of public Centres where the victims or their families could find free emotional, psychological, social and juridical assistance. Such Centres exist already in some countries.

To further improve the situation of victims, reforms of criminal as well as civil legislation are also necessary. At present attention of the lawmakers is still concentrated on the defendant who benefits even from privileges, such as the right to have the last word, a free solicitor etc. In future it will be necessary to establish a balance of legal rights between the victim of violence and the defendant. It is indeed paradoxical to offer a free solicitor to the accused and at the same time require the victim to pay for legal help. Judgements should also consider reparation by the guilty of the effective damage suffered by the victim, in addition to that (often insufficient) provided from his insurance.

3. Recommendations

1. Create public Centres of assistance and advice, where the victims and their families could find besides immediate information, the emotional, juridical and social assistance that they may need, as well as, if necessary, a person of trust who may accompany or represent them in all the actions they have to undertake.
2. Re-value periodically the compensations in order that they correspond effectively to the damage of any kind suffered by the victims. Take in particular into account all consequences of brain trauma. Give immediate advances for the funeral, the medical expenses, and loss of salary. Consider to complement the compensation to the victim by a contribution by the guilty.
3. Equilibrate the criminal procedure in order to guarantee a total balance of rights between the victims and their families respective to the rights guaranteed to the defendants or those who caused the crash.
4. Consider certain violations, such as exceeding speed limits, going through a red light or a stop sign, drinking and driving, as preterintentional offences.
5. Extend to all countries of Europe, the European Convention on the indemnification of victims of violence.

A Risk-Based Analysis Method to Assess the External and Internal Safety in Infrastructure Projects in the Netherlands

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Abstract. Cargo transport is an important pillar of the Dutch economy. Although this transport is economically profitable, it also involves risk. The policy of the Dutch government is aimed at raising the safety of road transport.

The Dutch government develops tools to enhance road safety and to reduce the risk of cargo transport. Within the framework of the Dutch project VeVoWeg (Safety of Road Transport) the risk associated with cargo transport has been studied since 1992. Not only the so-called external safety, the risk to people close to routes where hazardous materials are transported, has been the subject of major research, but also the internal safety, the risk to road-users as a result of all cargo transport. The project VeVoWeg has succeeded in its aim to develop tools to enable decision makers and road controllers to determine safety levels and to initiate measures to enhance the safety levels if necessary. This paper will give insight in the internal and external safety methodologies which were developed in the project VeVoWeg before 1996. Also insight will be given in the applicability and limitations of these methodologies by reporting some of the (at present preliminary) conclusions from the pilot projects of the project VeVoWeg, which have been carried out since 1996. Also an example of a combined internal and external risk analysis study on three alternatives for a motorway is given.

1. Introduction

Cargo transport in the Netherlands is not only economically profitable, it also involves risks. Heavy vehicles carrying cargo cause risks to road-users (internal safety) and the transport of hazardous materials causes risks to both road-users (internal safety) and people close to the roads (external safety). Due to the large difference in mass and speed between the heavy vehicles and other road-users a relatively large number of victims occur in this type of accidents. For example the accident statistics show that 25% of the annual lethal accidents involve cargo transport, although cargo transport makes up only 10% of the total number of road vehicles.

The Long-Term Traffic Safety Plan 1996-2000 (MPV) issued in 1996 addresses the safety problem of heavy vehicles. The Dutch Ministry of Transport, Public Works and Water Management has decided that more insight is needed in risks to people, environment, nature and matter associated with cargo transport. The goal of the Dutch

Government is 25% less (lethal) accidents in 2000 and 50% less in 2010. This will be achieved with a so-called "two-direction-policy": a preventive direction Sustainable Road Safety, and a curative direction, where the most evident accident situations are tackled.

Serious accidents with hazardous materials are rare, but when they happen there may be many victims. For this reason the safety of people close to transport routes is kept by safety standards as described in the document Risk Standards for the Transport of Hazardous Materials (RNVGS) [1]. The goal of the Ministry of Transport, Public Works and Water Management is to maintain the safety level of the transport of hazardous materials in 2000 at the safety level of 1986. This is documented in the Second Structure Plan for Traffic and Transport (SVV2) [2].

The project *Veiligheid Vervoer over de Weg* (VeVoWeg; Safety of Road Transport) aims to work out government policy and to solve problems with regard to internal and external safety. In the next section the background of the project VeVoWeg is clarified. The methodologies to investigate the internal and external safety, as developed in VeVoWeg, are described in section 3, while in section 4 some (at present preliminary) conclusions to the applicability and limitations of these methodologies and an example of an application are presented.

2. The Dutch project VeVoWeg (Safety of road transport)

The project VeVoWeg is a collaborative program of the Ministries of Transport, Public Works and Water Management (V&W), of the Interior (BiZa) and Housing, Spatial Planning and Environment (VROM). It should provide a firm base for decision makers and road controllers to determine the level of risk and to compare potential solutions in safety matters. At the start in 1992 it was aimed to develop tools and methods to:

- calculate risks to mankind, environment, nature and matter;
- identify and select measures to maintain or lower these risks to acceptable limits;
- develop a calculation procedure to quantify the effects of taking risk-reducing measures; and
- develop a methodology to evaluate the effects and costs of these measures.

In the project VeVoWeg the traditional traffic safety is broken down into the safety of cargo transport (internal safety) and the safety of the remaining traffic. External safety is associated with the risks to people close to hazardous materials transport routes.

The first phase of the project was ended by the end of 1996. In this phase first drafts of several technical guidelines have been issued by the project group, each of which contain a guideline and/or backgrounds for internal and external safety analysis. In the second ongoing phase of the project practical experience is being obtained by using these guidelines for real problems such as for instance routing measures for the transport of hazardous materials in Amsterdam and infrastructure problems at various locations in the Netherlands. The results of these pilot studies and the experiences of working with the VeVoWeg guidelines will be reported in the spring of 1998 and used to improve the next issue of the technical guidelines. In the next section the basics of the QRA (Quantitative Risk Analysis) methodologies for the internal and external safety will be addressed.

3. Basics of the QRA methodologies for heavy traffic

Heavy traffic is generally defined as the collective road transport of personnel or cargo. In the project VeVoWeg only the transport of cargo with vehicles weighing over 3.5 tons is considered.

3.1 External safety QRA

Since the Dutch implementation of the SEVESO directive [3] in the Risks of Severe Accidents Decree [4] in 1988 companies involved in the production and handling of large amounts of hazardous materials have been obliged to give the government insight in the risks caused to their immediate surroundings. Consequently, over one hundred companies had to determine the external safety levels by a QRA. This has ensured the development of for example an external safety methodology, scenario modelling and effect modelling. The development of the external safety methodology for the road transport of hazardous materials in the project VeVoWeg has elaborated on these past experiences.

The most important steps in the external safety QRA methodology for road transport are presented in Figure 1. In the first step a system description is made and basic data is gathered. The second step is the identification of all undesired events and assessment of all relevant accident scenarios, which are descriptions of the release of the hazardous materials and the predictable follow-up events. For all flammable goods the accident scenarios are separated into:

- scenarios with direct ignition, which may lead to torch fires, pool fires and fireballs; and
- scenarios with delayed ignition, which may lead to flash-fires and explosions.

In each scenario the proper initial accident frequency and probabilities of follow-up events must be assessed. Specific or default accident frequencies and probabilities will be used depending on the level of the QRA study (see 3.3) and the availability of the data. In the third step the determination of the physical effects starts by assessing the out-flow quantity and duration of the accident scenarios. Next the spatial distributions of the resulting physical effects are calculated for all possible atmospheric conditions (the heat radiation intensity for fire scenarios, the overpressure for explosion scenarios and the concentration profile for all other scenarios). The fourth step is to determine the damage of these heat radiations, overpressures and concentrations to the exposed population, in which the damage is expressed as the probability to die. Finally, in the fifth step the risk is determined by combining all basic data, scenarios, probabilities and effects and is presented as the Individual Risk and Societal Risk.

The Individual Risk is presented on a topographical map as so-called risk contours, lines connecting points of identical risk. It represents the local probability to die per year for a fictive person, who is assumed to be present at that location continuously and unprotected, due to a transport with hazardous materials.

This local character of the Individual Risk is used to appoint safety zones between transport routes and vulnerable developments. In RNVGS the standard for the Individual Risk has been introduced as a limit value of 10^{-6} per year (once in a million years),

indicating that between the 10^{-6} contour and the transport route no vulnerable developments may be present.

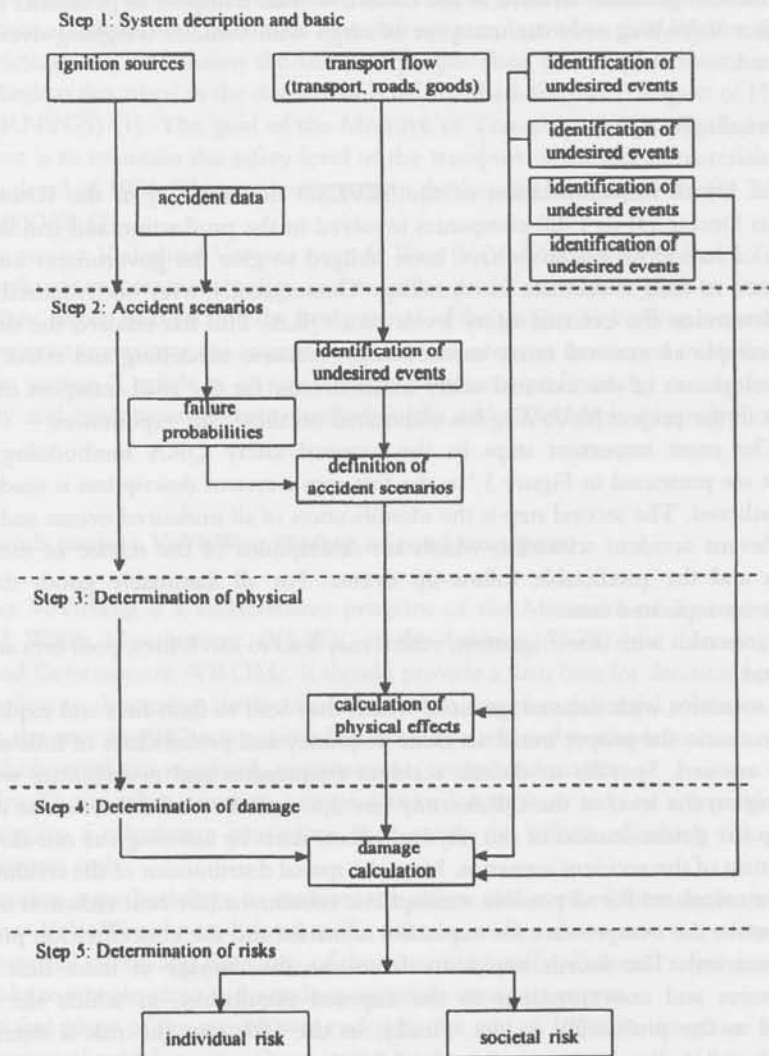


Figure 1. QRA methodology (external safety).

The Societal Risk, which is calculated per kilometre transport route, represents the probability per year that a group of people die simultaneously due to a transport accident with hazardous materials. This risk is presented in a double logarithmic graph where the number of simultaneous deaths N is given on the horizontal axis and the cumulative frequency per year for an accident with at least N deaths on the vertical axis. The societal risk does not have a limit value as standard, the administrators can deviate from this standard

with proper motivation. The standard is formed by a straight line in the double logarithmic graph (see Figure 2) from the point (10 deaths, 10^{-4} per kilometre per year) through the point (100 deaths, 10^{-6} per kilometre per year) and is used to locate possible disaster locations (locations with a high risk of a large number of deaths close to the road).

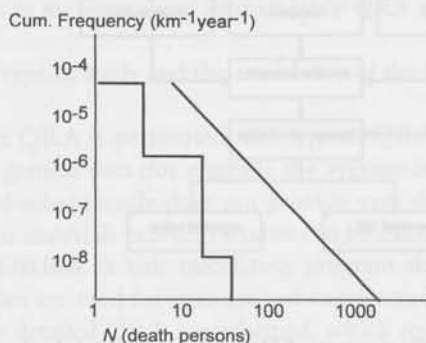


Figure 2. The standard for the external safety Societal Risk.

3.2 Internal Safety QRA

Due to the dens population in the Netherlands there is an increasing problem of meeting the Dutch environmental legislation standards close to transport routes, especially in and near urban areas. In recent years there has been a tendency to solve meeting these standards by building tunnels, sound barriers and roofing in roads (hereafter called tunnels). Although this helps to meet the environmental standards for external safety, noise and air pollution, it increases and introduces extra risks to road-users. This has been the main reason for the development of an internal safety QRA methodology in the project VeVoWeg. Contrary to the external safety, the internal safety methodology includes both accidents with heavy vehicles and accidents with the transport of hazardous materials. The most important steps of this methodology are shown in Figure 3.

The QRA methodology for accidents with heavy vehicles, shown in the upper part of Figure 3, is based on common traffic accidents involving heavy vehicles and fires in heavy vehicles. In the first step a system description is written down and basic data is gathered. In step 2 the accident scenarios of the common accidents and fires are identified and the resulting damage of these accidents is determined in step 3. However, an exception is made for the determination of the damage resulting from fires in tunnels, since the effects of the heat radiation of the fire and the possible formation of toxic combustion products and/or explosions are comparable to the physical effects of the hazardous materials. These damages are determined in the accidents with hazardous materials part of the internal safety methodology. In the fourth step the results of the previous three steps are combined to form the risk, which is presented as the Expected Value and Societal Risk of the number of deaths, the number of injuries and the cost of material damage.

The three Expected Values, which are represented by a number or amount of money, are the sum of the products of the frequencies and the number of deaths, injuries or cost of material damage of all scenarios, respectively, and represents the average number

of deaths, number of injuries and cost of material damage per year for the studied transport route.

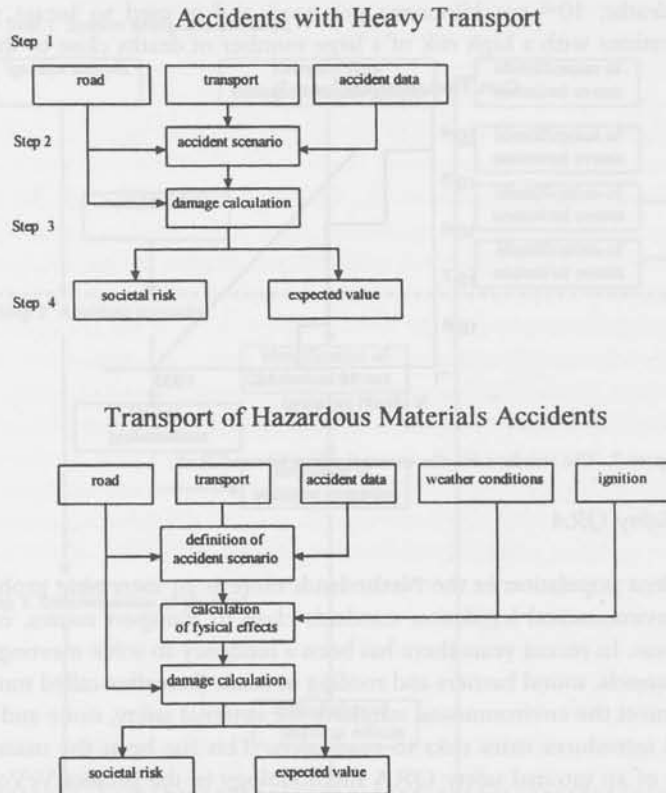


Figure 3. QRA Methodology (Internal safety).

The Societal Risk is represented similar to the external safety Societal Risk, although for the internal safety there are three graphs: the number of deaths (for $N > 1$), the number of injuries (for $N > 1$) and the cost of material damage (for $N > 0$) on the horizontal axis. The Societal Risks can be used to identify disaster locations (locations with a high risk of a large number of victims or material damage on the road).

In the bottom part of Figure 3 the internal safety QRA methodology for the transport of hazardous materials is given, which is basically identical to the external safety methodology. The only differences are:

- instead of calculating the effect on people close to the transport route, here
- the effect on road-users is calculated;
- the effect of heavy vehicle fires in tunnels is included in the methodology; and
- the risk is represented as the Expected Value and Societal Risk. These risks are presented only for the number of deaths, since at present there are no methods to determine the number of injuries and cost of material damage due to accidents with hazardous materials.

Finally the risks resulting from the accidents with heavy transport and transport of hazardous materials are added to form the total internal risks. At present there is no legal standard for the internal risk, but research for a possible standard has already been started.

3.3 Similarities and differences in the internal and external safety QRA methodologies

In both methodologies the type of study and the availability of the basic data determine the depth of the QRA study:

1. In level I studies a rough QRA is performed; this type of QRA requires a relative low amount of input data, uses general data (for example the average initial accident frequency for a specific road type) and subsequently does not provide very detailed results. The risks of the transport of hazardous materials in level I studies can be calculated with the relatively simply computer code IPORBM (a risk calculating program developed by the Dutch provinces) [5]. Level I studies are used for strategic and survey studies.
2. In level II studies a more detailed QRA is performed, which requires more detailed and larger amounts of input data, more complex computer codes (most of these programs are developed by engineering and research institutes) and subsequently will provide more detailed results. Level II studies can be used to determine the effects of safety measures, to compare alternatives (both routes and road types) and to put the aim of internal safety policies to the test.
3. Level III studies are very detailed QRAs, which require a lot of very detailed input data, complex computer codes and provide very detailed results. This study level is at present only used to put external safety risks to the legal standard test.

In case part of the detailed input data can not be obtained, one has to fall back on a lower level of study.

The transport of hazardous materials and fires in tunnels parts of the internal safety methodology is almost equal to the external safety methodology. The only real difference is the location of possible victims close to the road or on the road, the use of the Individual Risk (external safety) or the Expected Value (internal safety) and the modelling of fleeing from tunnels (internal safety).

The accident and fire (outside tunnels) parts of the internal safety methodology differ from the above methodologies in the sense that:

- This methodology only uses statistical data for the number of accidents and fires, number of victims and material damage, whereas the other methodologies also involve modelling of out-flow, formation of toxic combustion products, evaporation, dispersion, heat radiation, overpressure and fleeing;
- The initial accident frequency of this methodology is based on all accidents involving heavy vehicles, whereas the other methodologies use an initial accident frequency based on all accidents in which at least one person in a motorised vehicle was injured; and
- In addition to the risk of death calculated in the other methodologies, this methodology also calculates the risk of injury and the risk of material damage.

4. Application of the internal and external safety methodologies

4.1 The application of the methodologies

In this section an example of the internal and external safety methodologies is given by investigating the risks of three different alternatives for a motorway. The study area is shown in Figure 4. The first alternative is a motorway without a tunnel. The second alternative includes a tunnel of 400 m length in the motorway where all hazardous materials are allowed to pass. The third alternative is similar to the second, but there is a prohibition for LPG trucks in the tunnel; so the LPG trucks will have to use the roads in the city to bypass the tunnel. In this study it is assumed that 1000 LPG trucks and 500.000 other heavy vehicles pass the motorway annually and 50.000 heavy vehicles the roads in the city.

In the Figures 5 till 9 the results of this internal and external risk analysis are shown (only for the number of deaths).

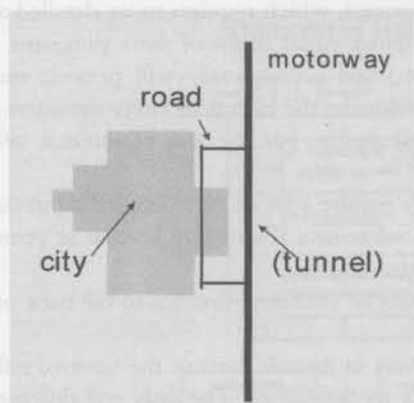


Figure 4. The study area.

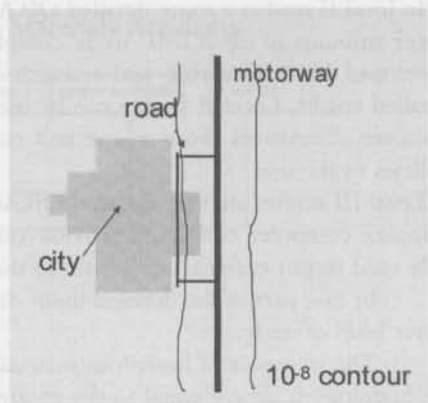


Figure 5. Individual Risk for the motorway without a tunnel.

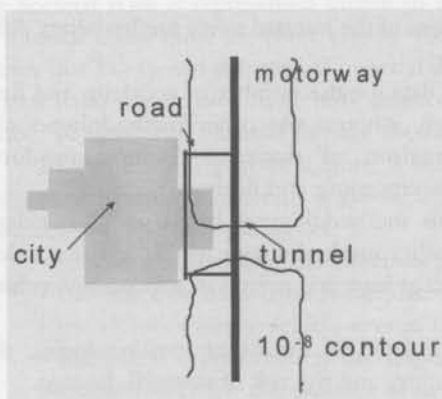


Figure 6. Individual Risk for the motorway with the tunnel (no prohibition).

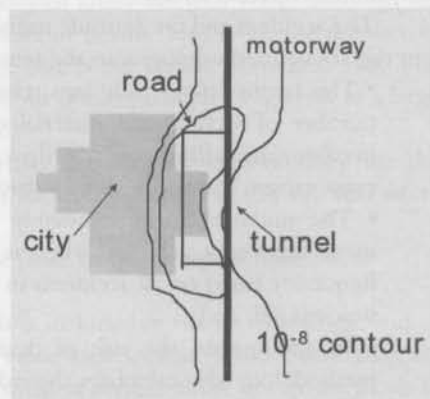


Figure 7. Individual Risk for the motorway with the tunnel (LPG prohibition in tunnel).

Table 1. Expected Value for the number of deaths.

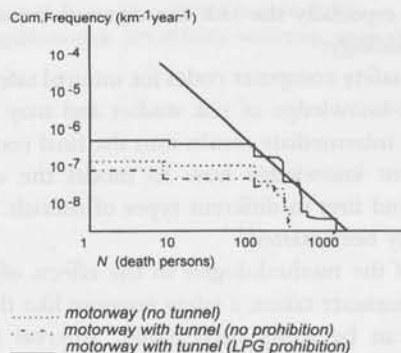
Motorway alternatives	no tunnel	with tunnel	
		no prohibition	LPG prohibition
Expected Value	0.0094	0.0089	0.0088

Figures 5, 6 and 7 show the effect of the different motorway alternatives on the Individual Risk (external safety). It is clear that the incorporation of a tunnel in the motorway will result in less exposure to the risk in the city in case all hazardous materials are allowed to pass the tunnel, whereas a prohibition for LPG trucks to pass the tunnel will dramatically increase the risk in the city.

The Expected Values in Table 1 show a different result. The Expected Values of the first alternative, the motorway without tunnel, has the highest value and the Expected Values of the second and third alternatives, the motorway with the tunnel, are almost equal. This is caused by the fact that, even though the initial accident frequency on a motorway is lower than on urban roads and in tunnels, the average amount of deaths per accident is higher. And since the number of deaths due to the normal accidents make up 99% of the Expected Values in this example, no real difference in Expected Value is found in the two tunnel alternatives. If the tunnel was longer and/or the number of transports of hazardous materials higher, the contribution of the transport of the hazardous materials and fires in tunnels to the Expected Value would be larger. Figures 8 and 9 show that:

- the external Societal Risk drops when a tunnel without prohibitions is introduced in the motorway, but it increases considerably when the LPG trucks have to use the alternative route through the city and even exceeds the standard; and
- the internal Societal Risk will always increase when a tunnel is introduced in the motorway and will cause more risk to the road-users when the LPG trucks are allowed to pass through the tunnel.

Based on these results it seems advisable not to build a tunnel in the motorway of this example, since the motorway without the tunnel seems to cause the least risks to both road-users and people in the city.

**Figure 8.** Societal Risk (external safety).

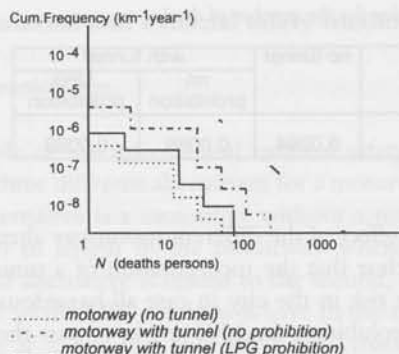


Figure 9. Societal Risk (internal safety).

4.2 Application experiences

In the last year of the project VeVoWeg the technical guidelines, produced in the first phase of the project, have been used in several pilot studies ranging from internal and external safety studies in cities to studies on the effects of safety measures on motorways. These pilot projects have given insight in the applicability of the guidelines. Some of the insights related to the internal and external safety methodologies are:

- Gathering the basic data and remodelling it into a workable format can be very time-consuming;
- The amount of necessary data increases with the size of the study area; especially when the study area includes (part of) a city and/or involves several alternatives, which will effect the traffic flow in a large part of the study area;
- The coverage of the accident data decreases rapidly when the severity of the accident outcome decreases. The statistics cover nearly all accidents resulting in deaths, roughly 75% of the accidents resulting in hospital care, about 25% of other accidents involving injuries and an unknown, small, percentage of accidents involving just material damage. This will cause a high degree of uncertainty in the risk for injuries and especially the risk for material damage determined with the internal safety methodology;
- The use of external safety computer codes for internal safety calculations is possible, but will require user-knowledge of risk studies and may involve time-consuming calculations to fit the intermediate results into the final results;
- There is insufficient knowledge how to model the effects of accidents with hazardous materials and fires in different types of tunnels. A study to improve this knowledge has already been started;
- The applicability of the methodologies to the effects of safety measures depends largely on the safety measure taken; a safety measure like the overtaking prohibition for heavy vehicles can be easily determined, whereas the comparison of risks involved in different lay-outs of an urban road can not be determined accurately at present, due to lack of information on the effects of different lay-outs on the risk;

- Application of the methodologies to alternatives with and without tunnels will supply a good insight into the effects on the internal and external safety;
- In some cases the internal safety methodology may give a distorted picture. Safety measures on roads which will increase the heavy vehicle safety may cause a higher accident frequency for other traffic; and
- The Expected Value for the number of deaths of the internal safety is usually made up for more than 90% out of the deaths due to normal accidents; the deaths due to the transport of hazardous materials and fires in tunnels only have a noticeable effect when very large amounts of hazardous materials are transported or when the tunnels are very long.

5. Conclusions

The internal and external safety methodologies developed in the Dutch project VeVoWeg seem very promising tools. Even though at present not all types of studies can be performed on a satisfactory level of detail, it is already operational for most purposes. One of the most promising applications at present is to study the effects of introducing tunnels in roads, since the combination of both the internal and external safety methodology gives a good insight in the safety effects for both road-users and people close to the roads.

References

- [1] Nota Risico-Normering Vervoer Gevaarlijke Stoffen (RNVGS) en brief van de ministers van VROM en V&W, Tweede Kamer, vergaderjaar 1995-1996, 24 611, nr. 1 en 2, 15 februari 1996.
- [2] Tweede Structuurschema Verkeer en Vervoer, Ministerie van Verkeer en Waterstaat, SDU uitgeverij, Den Haag, 1990.
- [3] Richtlijn nummer. 82/501/EEG van de Raad van de Europese Gemeenschappen van 24 juni 1982 inzake de risico's van zware ongevallen bij bepaalde industriële activiteiten, PbEG L 230, Seveso richtlijn (laatstelijk gewijzigd door Richtlijn 91/692/EEG).
- [4] Besluit van 15 september 1988, houdende regels inzake kennisgeving omtrent risico's van zware ongevallen (Besluit risico's zware ongevallen), Staatsblad van het Koninkrijk der Nederlanden, 432, 1988 (laatstelijk gewijzigd bij besluit van 20 juni 1994 Staatsblad 463).
- [5] IPO RisicoBerekeningsMethodiek (IPORBM): waterweg, spoor, pijp en weg, AVIV, Enschede, juli 1997.

Development in Pipeline Integrity Management at the NV Nederlandse Gasunie, The Netherlands

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Abstract. By Pipeline Integrity Management we mean: the preventive and corrective management of the integrity of the gas transmission system, so that in the longer term this remains in compliance with the minimum technical requirements stipulated in Gasunie's self-imposed standards and with the statutory regulations. Pipeline Integrity Management relates to Safety (risk to the environment), Operational Reliability (in relation to contractual obligations) and basic economic principles (cost effectiveness).

Gasunie uses its Pipeline Integrity Management System to ensure the safety and operational reliability of its transmission pipelines at the lowest possible cost.

This paper indicates the path that is followed in order to transform the current system, predominately based on a qualitative "Condition Monitoring & Maintaining" system, into a more quantitative and appraisal-based system.

The traditional qualitative approach involved taking design and maintenance measures for each individual threat. In order to gain an insight into the extent to which these measures currently cover the known threat adequately, a qualitative appraisal has been carried out. This appraisal shows that the present structural design and maintenance measures are, from a qualitative point of view, sufficient to cope with the threats to the transmission pipelines. Also indicated are what improvements are possible and what actions are now being taken in this connection.

The "new" Pipeline Integrity Management System is based on a quantifiable relationship between threats, measures and performance. This means that the different measures will be mutually interchangeable, so that the most effective measures can be applied in response to specific threats in those locations where they are most needed. The cohesive system of design and maintenance measures can be further optimised if the costs of the different measures are evaluated according to the contribution they make to controlling the overall risk of a pipeline.

1. Introduction

1.1 General

The purpose of this paper is to indicate the path that can be followed in order to transform the current "Condition Monitoring and Maintaining" of transmission pipelines into an appraisal-based system. It will be shown below that the current structural maintenance measures are, from a qualitative point of view, sufficient to cope with the threats that face the pipelines.

Furthermore, the paper will state what improvements can be made and how the

Pipeline Integrity Management model can in the future be further optimised by means of quantitative analyses.

1.2 Motivation

Virtually all gas transmission companies derived their standards for design and maintenance from US standards. These are traditionally aimed at managing threats (factors that determine the probability of the pipeline failing). In the mid-1980s this approach resulted in a formalised Gasunie policy ("Pipeline Condition Monitoring and Maintaining system").

At around the same time the need arose for a more quantified, risk-based approach, both with regard to Gasunie's "Quality Drive" and to the zoning requirements laid down by the Department of Housing, Regional Development and the Environment (VROM). Measurable effectiveness and efficiency make it possible to optimise the Pipeline Integrity Management process. In order to determine cost effectiveness, it is necessary to perform a very detailed quantitative analysis.

Safety and operational reliability

It has been assumed in the first instance that all failure mechanisms have an impact on both Safety and Operational Reliability. In order to meet the objectives in both respects, it is sufficient to manage the safety-related risks. Safety makes the most stringent demands on policy, management and execution.

Cost effectiveness

Cost effectiveness is considered to be extremely important. Pipeline should be managed at the lowest possible cost, provided that:

- the present structural maintenance measures should be effective in preventing damage inflicted to our pipelines. From a quantitative point of view, this requires knowledge of the impact that a measure has on a threat;
- the system of design regulations and maintenance measures as a whole can be optimised.

2. Current pipeline integrity management

2.1 Process improvements

The process of Pipeline Integrity Management relates to the policy, the measures (zoning, design and maintenance), the recording of performance, analysing performance against the standards and guidelines, and evaluating threats and potential consequences, see Figure 1 below. It is Gasunie's aim that the policy should result from, and be adjusted on the basis of, periodical analyses of actual performance. This leads to continuous improvements. This is in contrast to the situation in the past, where measures were, in principle, based one-on-one on the known threats and potential consequences.

New policy is based on a feedback process, in which the maximum possible quantitative benefit is extracted from the connection between the different elements of the process. This means that design and maintenance measures are interchangeable in realising

of the same performance.

Efforts made to maintain a constant overview of potential threats are reflected by means of a sensor function for the threats. The model should also contain a recording of performance, the purpose of which is twofold:

- based on pre defined target values (success factors and indicators), short-term feedback takes place. This results in an improvement in Operational Maintenance procedures without a need for a change in policy.
- long-term feedback is executed every 3 year. This involves identifying deviations with regard to risk standardisation versus performance by means of risk analysis. In this way, an adjustment of policy is accomplished, involving the adaptation of design and maintenance measures or the critical success factors.

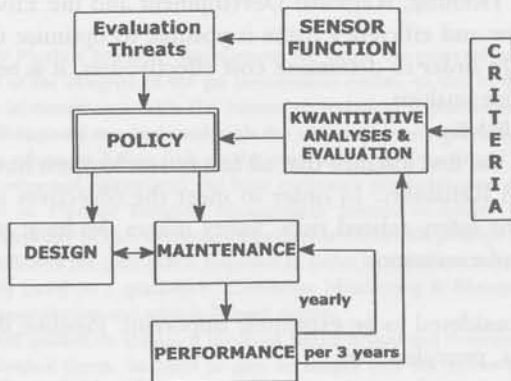


Figure 1. Pipeline Management Process.

Validating and improving the Pipeline Integrity Management policy is a continuous process and is the responsibility of the operational department. The goal is to analyse as much as possible quantitatively. In order to carry out quantitative analysis (i.e. long-term feedback), it will be necessary to have detailed information and validated and advanced analytical models. These models are developed and tested by the Research Department.

2.2. Policy

In general, policy can be formulated as follows:

- Realisation of objectives with regard to Safety and Operational Reliability at the lowest possible cost.
- The design and maintenance of pipelines is aimed at minimising the number of accidents (incidents). Specially agreed criteria are used as indicator values in this respect.
- In the event of a disaster, all necessary measures are taken in order to limit the extent and consequences as far as possible.

Connected to this Risk Management System there is an information system for testing, improving and managing this operational process.

The Pipeline Integrity Management Policy embraces fifteen criteria regarding basic principles, zoning, design and maintenance aspects. The criteria are not global guidelines but are indeed very specific and detailed. It is beyond the goal of this paper to discuss all of these criteria.

2.3 Process and analysis

2.3.1 Recording

Performance yielded by the managementsystem is evaluated against the pre-mentioned critical indicators. Gasunie makes a distinction between two different levels in this respect.

Management indicators

Performance at the management-indicator level requires are set on a relatively broad level for each sub-process; this reveals whether Gasunie meets their basic principles. Based on any instances of indicators being exceeded, it will be possible to initiate corrective actions both as regards the operating processes (quality) and as regards policy. Reporting will take place via the quarterly reports from Operational Management.

Incident registration

To carry out regular analyses (optimisation), careful registration of pipeline incidents is required. This registration is the basis for internal evaluations and analyses or for information handed over to national establishments (Velin) and International Incident Databases (EGIG).

2.3.2 Analysis

Depending on whether the relevant indicators show that performance is above or below the required level, the threats and potential consequences are analysed regularly, at intervals established. This analysis serves three purposes:

- the performance is evaluated against the pre defined criteria, the results of the Pipeline Integrity Management system being demonstrably filed;
- the impact of the maintenance measures on the risk is established;
- possible corrective actions are determined;

At Gasunie, several tools and a large number of actually validated models are used for this analysis of the probability and consequences of threats, the aim being to be able to determine the risk quantitatively. This involves calculating the gas outflow, dispersion and (thermal) radiation levels. The models are really physically validated.

2.3.3 Criteria

The Pipeline Integrity Management system operates with criteria on a number of levels. Many of them are derived from present-day risk standardisation. Risk standardisation in the Netherlands is split into individual- and group-risk standardisation. At present, group risk is not yet a statutory standard, but it is expected to be only a matter of time before this occurs. Gasunie complies with the risk standardisation procedure that forms the basis of the Ministerial guideline.

Individual Risk

The zoning guideline for a pipeline is based on the guidelines applied by the authorities in relation to individual-risk standardisation. The margins set out below are used in these guidelines. Pipeline Integrity Management is today aimed at managing the evaluation and construction zoning distance criteria.

Table 1.

Individual risk [IR]	Associated action	Zoning
$IR < 10^{-8}$	risk negligible, do nothing	$IR = 10^{-8}$ Evaluation distance
$10^{-6} < IR < 10^{-8}$	weigh up implications, take action if necessary	
$IR > 10^{-6}$	do not exceed risk, always take action	$IR = 10^{-6}$ Construction distance

Societal Risk

The Dutch zoning guideline already takes into account in a qualitative way the societal risk (area-category allocation). Gasunie regards the construction zoning distances as sufficient in this respect.

Societal-risk legislation is currently under development and therefore not (yet) fixed, but tends to the guideline illustrated in Figure 2. This means that (societal) risk standardisation depends on the number of potential victims and therefore on the presence of the number of persons per km of pipeline per unit of time.

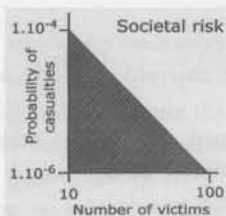


Figure 2. Societal risk.

3. Qualitative appraisal

3.1 AIM

The Pipeline Integrity Management policy is aimed at implementing the whole range of preventive and supplementary measures for each threat in such a way that the probability of the system failing is kept within the accepted criteria. Indicator values have been established in order to prevent these criteria being exceeded. Exceeding these values can result in extra maintenance measures. The following appraisal is carried out in order to ascertain whether enough effort is being carried out from a qualitative point of view in order to manage the threats.

3.2 Approach

The approach adopted in evaluating Pipeline Integrity Management has been as follows:

- known threats are identified. A threat is considered to be known if it cannot be proved beyond any doubt that this threat cannot occur at Gasunie;
- the current design and maintenance measures are evaluated;
- the measures applied in response to specific threats are recorded with respect to their influences in the "Pipeline Management" matrix;
- threats are categorised and the actual probability of failure is determined from the database;
- the consequences of failure are determined with reference to a number of criteria;
- for each threat, the product of the probability of failure and the consequences is assigned a priority, with initiation of corrective action being required in the event of high or medium risk.

Those threats are included in the matrix which, based on the current perceptions, pose a threat to the integrity of the Gasunie transmission system. Threats that do not pose a significant threat are not included in the matrix.

3.3 Corrective actions

The "Pipeline Management" matrix indicates whether an investigation or project has been initiated, as a secondary measure, in order to reduce or minimise the risks of the associated threat. The extra measures serve either to provide greater insight into the effectiveness of a measure that is taken in response to a threat or, temporarily, to invest more effort in a measure taken in response to a specific threat.

The investigations/projects in question are as follows (in the sequence in which they appear in the "Pipeline Management" matrix):

- A project has been carried out in which the behaviour of potential and actual pipeline damaging factors is examined. On this basis, a project is started in order to promote the KLIC procedure (one call system). This involves tightening up the KLIC (Cables and Pipeline Information Centre) regulations, improving the conduct of the excavators and, within Gasunie, the description of the KLIC procedure is improved and re-implemented. This is expected to result in a reduction in the number of incidents caused by third parties.
- Gasunie is participating in an international ac-corrosion project, which involves looking fundamentally at the threat and at the same time carrying out measurements on an ac-influenced pipeline.
- No incident caused by stress corrosion has (yet) occurred within Gasunie. Due to the extremely serious consequences of such a threat and incidents in other gas companies, this threat is very closely monitored. The basic tests for stress corrosion are carried out within PRC/;
- Gasunie is looking into how the ongoing coating degeneration and temporary protective mechanism, which must provide permanent protection, can be inspected and efficiently replaced;

- Once every five years, a gas pipeline is inspected by means of an intelligent pig run. This has a dual purpose, namely to keep up with the requirements of this technique (scan function) and to gain an insight into pipeline metal loss. The pipeline section to be pigged will be selected by means of a ranking tool using up to 30 parameters. The deployment of the pigrun at a given pipeline section will also be carried out to verify the performance of the up-to-date maintenance measures. If necessary extra measures will be taken, criteria and policy will be accordingly adopted.

4. Quantitative appraisal

All possible threats where the pipeline system last from, as well as the potential (design and maintenance) measures as a preventive action against these threats are put in the "Pipeline Management" matrix. The full matrix is given as appendix A, while a very simplified matrix is given in Figure 3. It is the intention to quantify the effectiveness of each measure against a certain threat. First the qualitative effectiveness of the influence of a measure against a threat (one cell of the matrix) has been prioritised. The aim is to analyse and determine the quantitative influence of the effectiveness of a measure. At the end when the functional dependencies are completed, the efficiency of each independent measure can be analysed by comparing the effectiveness with the associated cost.

Risk Management System	Current Accepted Measures	
	Design	Operations
Threats		
excavation	●	
sheepiling		
SCC low/high pH		
groundmovements		

Figure 3. Simplified matrix.

As an example the quantitative influence of the design measure depth of cover of a certain pipeline section against the excavation threat will be given. The probability of hitting the pipeline can be given among others as a function of the depth of cover.

Therefore the number of incidents per depth of cover was divided by the total amount of pipeline section in km.year per specific depth of cover. The resulting data points were fitted and indicated with 95% lower and upper reliability limits [14], as can be seen in Figure 4.

The effectiveness of the design factor "Depth of cover" against excavations given third party interference is given by the equation as: $\ln f(D) = -2.61 \times D - 3.22$. Also the functional dependency of the wall thickness is evaluated, while the analyses for the airborne

(helicopter) inspection effectiveness will be carried out soon. In this way a lot of cells of the matrix will be quantitative defined, see Figure 5.

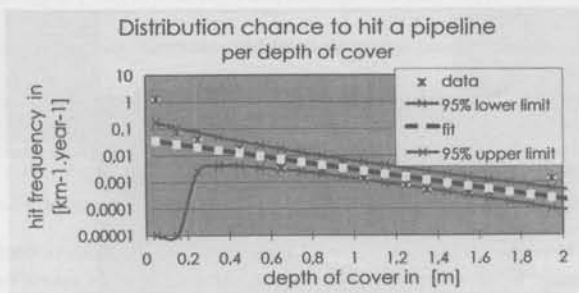


Figure 4. Example quantitative influence.

Threats	Measures	
	design	maintenance
1		
	$f(p,q,...)$	$l(x,y,...)$
..		$k(x,y,z,...)$
	$g(s,t,...)$	$m(a,b,...)$
x		

Figure 5. Quantitative matrix.

If the numerical relations (functions, dependencies) between all relevant measures (design and maintenance) and the impact on associated threats are known, the following aspects can be covered:

- rest risk calculations,
- effectiveness per threat,
- optimisation of a package of measures,

and subsequently it will be possible to optimise the overall efficiency of the Pipeline Integrity Management system.

References

- [1] M.G. Kirkwood and M. Karam, British Gas plc: A scheme for setting pipeline inspection, maintenance and repair priorities. A paper presented at Pipeline pigrun and Integrity Monitoring Conference, April 1994, Amsterdam.
- [2] H.J.M. Jansen, SIPM: Pipeline Integrity, Paper no. 1, probably presented at the Pigrun conference in Amsterdam, April 1995.
- [3] I. Corder, British Gas plc: The application of risk techniques to the design and operations of pipelines, June 1995.
- [4] M.G. Kirkwood and M. Karam, British Gas plc: Priority rating scheme guides maintenance, rehab decisions. Pipeline & Gas Industry, July 1995.
- [5] Mrs I. Chun, Transco: Transco creates new computer system to simplify its business. Pipeline & Gas Industry, July 1995.

- [6] Inspection and Maintenance Techniques applied to U.K. Gas Transmission Pipelines; J.V. Haswell, British Gas Transco.
- [7] P. Hopkins, British Gas plc: Risk Management and Operation of Gas Transportation Network. IMechE, October 1995.
- [8] A. Michel, Electrabel Belgium: Optimisation of Maintenance Planning for Gas Distribution Networks, September 1995.
- [9] A. de Bakker, TR/T 95.R.2523: Rapportage Gasunie Leiding Incidenten [Report on Gasunie Pipeline Incidents], August 1995.*)
- [10] A. Pijnacker Hordijk, TR/T 96.M.2513: Risico Management Beleid [Risk Management Policy], January 1996.*)
- [11] W. Sloterdijk, TV/D 95.R.191: Risico Beoordelingscriteria [Risk Assessment Criteria], December 1995.*)
- [12] A. Pijnacker Hordijk, TR/T 96.M.2520: Fasering bij invulling vd matrix tbv het Risico Management Beleid bij Gasunie [Phasing in connection with the completion of the matrix for the Risk Management Policy at Gasunie], February 1996.*)
- [13] E. Jager, TR/T 96.M.2523: Kosten optimalisatie leidingen [Optimisation of pipeline costs], February 1996.*)
- [14] E. Jager and A. Zwaagstra, TR/T 96.2500: Leiding Incidenten - invloed van gronddekking en wanddikte [Pipeline incidents - Impact of ground cover and wall thickness], January 1996.*)
- [15] A. de Bakker, TR/T 96.M.2542: Invulschema GLDI [GDLI completion chart], 16 April 1996.*)
- [16] Handboek Leidingen en Toebehoren Deel: TracÉbeheer [Pipeline and Accessories Manual, section on Route Management].*)
- [17] Handboek Leidingen en Toebehoren Deel: Corrosie Preventie [Pipeline and Accessories Manual, section on Corrosion Prevention].*)
- [18] P. Rietjens, TB/W 97.M.0048: Beleid aangaande afstandsbediening Calamiteitenafluiters [Policy on remote control of disaster shut-off valves].*)

*) internal Gasunie documents.

Appendix

Pipeline Management System	Current structural measures		EVALUATION	
	Design	Operability	Risk	Improvement
Threats	Depth of cover wall thickness / rest grade pipeline markers maintenance / inspection / recording hydrostatic pressure test pressure and flow control Cathodic Protection Type of coating protective measures ROP levelling & re-covering RILF activities - inspection W/S flights and ear inspection external measurements growing external maintenance CP current measurement safety (shutdown control)		fraction of occurrence 0-100% failure consequences L/M/H	Priority Improvement, Investigation or project initiated ??
incidental excavations/digging (top) by mistake			H	●
drainage			M	
deep plow (shovel) plowing				
ditch cleaning				
excavation (houses/foundations)				
construction of pipelines				
construction of cables				
normal agricultural activities			L	
sub-surface/vandalism/terrorism				
road/ditch construction/renewal				
soil external interference (calamine)				
sewer/ditch excavation				
CP defect (an, par, commit, sacrificial)				
Coating defect (rocking/growth/ degradation)				
dc interference (heavy current)				
dc interferences				
S/C low → high pH				
SRH				
struck savings				
struck vehicles				
pipe material defect				
design failures				
overpressure				
malfunctioning valves				
(gas) temperature circumstances				
fatigue (internal pressure)				
ground movements (not controlled)				
weather conditions				
stream (external)				
fudge (external)				

Legend	
Low influence of a measure at a threat	L
Medium influence of a measure at a threat	M
High influence of a measure at a threat	H
Risk High, improvement in progress	
Risk Mean, investigation necessary	
Risk Low, no activity necessary	
improvement necessary	●

The Transportation of Dangerous Goods: An Industry Perspective

Hennie Standaar

The Netherlands Industry Platform for the Transportation of Dangerous Goods (CTGG)

It is an honour for me to speak to you today at the occasion of this congress about the transportation of dangerous goods. For easy reference during this presentation I have ready for you a hand-out of the slides that I am about to show you, hopefully these will be integrally included in the proceedings.

Lady and Gentlemen, judging from the titles of the other parallel sessions it seems to me that the programme committee of this congress decided that dangerous goods are a transportation mode in their own right and the Industry Platform for the Transportation of Dangerous Goods that I am representing here would wholeheartedly agree with this interpretation. The aforementioned Platform bears the Dutch acronym CTGG. The CTGG is an umbrella platform for co-operation, 14 industry associations totalling some 60 000 enterprises are represented in this, but only 10% deal frequently with dangerous goods. The composition of the CTGG aims to be representative of the market and therefore covers all surface based modes of transportation and strikes a balance between cargo and transport interests. In essence the platform is a group of technical experts with a great deal of practical knowledge. This is important since however complicated regulations are in this field, finally implementation is done "from behind the steering wheel". I do not consider myself to be an expert, but as a chairman my responsibility is the achievement of consensus, a statutory requirement. The word consensus here means agreement based on technical and operational sound arguments, as opposed to the word compromise that may relate more closely to power. In the CTGG the quality of the argument counts, not who is using it. Of course the various industries thus united in a concise field of activity have objectives that tally with the business, risk and costs control, simplicity and the like, all relate to the sustained manageability of the transportation of dangerous goods. In short, dangerous goods should be transported as if ordinary commerce under the guarantee of workable and controllable sets of rules.

Also, competitive elements feature on the objectives list like market conformity, harmonised regulation across borders. Lastly, few experts in this area can be found outside the realm of this set-up. Hence an objective is to foster and expand our expertise.

Obviously there must be some advantages for industries to stay in this platform for 30 years and more. Briefly these are: mutual support and sharing of the workload, to be part of an expert environment, to have access to an early warning system and last but not least to benefit from the CTGG's long standing reputation, which shows in the sound working relationships with the pertaining authorities within the Ministry of Transportation. We find this relationship essential, but such a thing may be viewed differently in other countries.

Lady and gentlemen, if we look at the transportation of dangerous goods in a small and busy country like mine we see volume flows of 10 to 15% of total adding up to about 700 MNgl per annum of added value for the transport sector alone. Of course, product values are orders of magnitude higher. Despite these large volumes of trade accidents are rare and only exceptionally significant.

To put dangerous goods in the context of this conference we may wonder about what dangerous goods are. Besides lists of substances few generic definitions exist, but we all feel that these substances have in common that they can pose immediate danger or are easily triggered to do so to men, environment and equipment and therefore require to be contained during transport and transshipment. Obvious candidates are explosives, compressed gases, inflammables etceteras. Safety then, has at least four different aspects that are seductive to regulators: public, occupational, traffic and environment. And indeed regulations that sometimes are even contradictive can be found, for instance the gas venting of mobile tanks, ie on barges on inland waters, under the ADN (safety of transportation of dangerous goods) and the prevention of air pollution under the European Gasoline directive are fully in conflict. "Contaminated" regulation is an increasing phenomenon. The Safety of Transportation thus is an aspect of the safety of the transportation of dangerous goods, but the transshipment switch between the modes of transportation may be the more important. Safety has more than one face and is without further explication rather undefined. Therefore, the CTGG has always adopted an integral approach, emphasising the need for the identification and quantification of risks.

With respect to this latter aspect, scientifically applicable statistical evidence is generally non-existent everywhere. Yet, we feel that the safety of transportation can and should be made visible and thus manageable by establishing numerical modelling and simulation that are checked against unifiable statistical data. This in turn, should lead to prevention and even to a safer and more optimal use of existing infrastructures.

Lady and gentlemen, I am drawing to a close. In the world of the transportation of dangerous goods we encounter complex and ever more complex regulations and supranational authorities that issue regulations, sometimes leading to conflicting situations. And there are a few: IMO, ECE, EU, CCR. Complexity also is enhanced by regular updating processes. This is wisdom of course, but a pain and a confusion to those who need to implement it. Going through various themes attached to this conference I am now able to comment in the context as presented: Safety of transportation: to dangerous goods only one aspect in the logistic chain, transshipment is at least as important.

Differences between modes: this we find a perilous distinction, by treating dangerous goods as a mode of its own we have been able to balance along the entire logistic chain. In sporting language: the sea tanker cannot go where the pick-up may, but they both could carry the same material albeit in different quantities. For this reason the CTGG has always rigorously applied a non-discriminatory approach towards the transportation modes.

The imbalance between growth and safety: obviously some seem to identify a problem here. But is it? In this country LPG is widely used as an automotive fuel. LPG classifies as a dangerous good and the volume of fuel consumption went up by a factor twenty as of the early sixties towards the late seventies. I do not need to recall the growth in passenger cars in that period. Yet, accidents and particularly serious ones, can be counted

in single digits until this day.

The knowledge infrastructure: I feel that this relates to the previous item. The introduction of LPG as an automotive fuel was accompanied with the early establishment of a technical association, till this very day a distinguished member of our CTGG. All possible parties involved, producers, manufacturers of car appliances, marketers, retailers, etceteras were sitting around the same table sharing and contributing to the same knowledge.

The role of science: again this ties in to the previous two items. Due to 30 years and over of experience of the Industry Platform for the Transportation of Dangerous Goods the answer to the perceived imbalance between growth and safety is the assurance of shared knowledge by those involved. In our increasingly complex societies such a co-operative group or groups would increasingly require to be advised through scientifically generated and well advanced quantified information and simulation.

Stress Corrosion Cracking: The Battle Continues

Daphne Snelgrove

Transportation Safety Board of Canada, Hull, Quebec, Canada

1. Historical overview of the petroleum industry in Canada

Pipelines have been used as a mode of transportation as far back as the 10th century A.D. At that time, the Chinese of Peking were transporting natural gas by bamboo pipeline to use for street lighting. However, it took many more centuries for the interest in the petroleum industry to reach Canada. In 1858, the world's first commercial oil well was dug in Oil Springs, Ontario. Admittedly, the digging of this well had begun as a search for better drinking water. Nevertheless, it did become a viable business operation. Also in 1858, Canada was home to the world's longest natural gas pipeline which carried natural gas 25 kilometres to Trois Rivieres, Quebec to light the streets. The world's first oil pipeline, built in 1867, was also in Canada and connected an oil field in Petrolia, Ontario to Sarnia, Ontario. Canada's petroleum industry also pioneered in northern operations. In 1920, Canada had the world's most northerly oil field.

It wasn't, however, until the discovery of oil and gas near Leduc, Alberta in the mid-to-late 1940's that it became apparent that pipelines were needed to take petroleum from western Canada to the heavily populated central region of Canada and the United States. Large diameter oil and gas transmission pipelines, in excess of 305 mm (12 inches), have been a part of Canada since the early 1950's. Before the end of 1950, the Interprovincial Pipeline system moved crude oil a distance of 1800 kilometres from Edmonton, Alberta to the Great Lakes in central Canada. By 1957, the system had been extended to Toronto, Ontario. It was the world's longest pipeline until late 1958 when the TransCanada pipeline began to transport natural gas from the Alberta-Saskatchewan border to eastern Canada. The TransCanada pipeline remained the longest pipeline in the world until the early 1980's when its length was exceeded by a Soviet pipeline from Siberia to western Europe. It is understood that currently these two Canadian pipeline systems, the Interprovincial pipeline and the TransCanada pipeline, are respectively the world's longest crude oil pipeline and the world's second longest natural gas pipeline.

2. Pipeline system in Canada

Today, nearly two-thirds of Canada's energy supply including petroleum, natural gas, hydroelectricity, nuclear and coal moves through pipelines. In addition, virtually all its oil and gas exports are carried by pipeline. The routes for most of Canada's pipeline

infrastructure were determined in the 1950's when the major transmission lines were constructed. Today, more than forty years later, most of this pipe remains in service.

In Canada, the safe construction, operation, maintenance and abandonment of pipelines is either a provincial or a federal responsibility, depending on the location of the pipeline system. Pipelines operating entirely within a province are regulated by that province while pipelines crossing provincial or international borders are federally regulated. The federal regulatory body is the National Energy Board (NEB), an independent quasi-judicial tribunal which reports to Parliament through the Minister of Natural Resources Canada. Its regulatory powers include the granting of authorizations for: the construction and operation of interprovincial and international oil and gas pipelines, international power lines and designated interprovincial power lines; the setting of tolls and tariffs for oil and gas pipelines under its jurisdiction; the export of oil, gas and electricity; and the import of natural gas. It can be asked to review any of its decisions, however the outcome of such a review is final. Only questions of law or jurisdiction can be referred to the Federal Court of Appeal. Through its Onshore Pipeline Regulation, the NEB has set requirements for the safe design, operation, maintenance and abandonment of pipelines under its jurisdiction.

The Transportation Safety Board (TSB) is an independent federal agency, neither judicial nor quasi-judicial, which reports to Parliament through the President of the Queen's Privy Council for Canada. It has the mandate to advance transportation safety on federally regulated modes of transportation, including pipelines, by investigating accidents and incidents, identifying safety deficiencies, and making safety recommendations designed to eliminate or reduce those deficiencies.

The Canadian Standards Association (CSA) is a non-profit, nonstatutory, voluntary membership association engaged in standards development and certification activities. Its committee volunteers and sustaining members include producers, manufacturers, consumers, retailers, unions and professional organizations and governmental agencies. Its standards reflect a national consensus of these organizations. The standards are used widely by industry and commerce and are often adopted by municipal, provincial governments in their regulations, particularly in the fields of health, safety, building and construction, and the environment. Sustaining memberships represent a major source of income for standards development activity. One standard in particular developed by the CSA covers technical requirements regarding the design, operation and maintenance of oil and gas pipeline systems. This standard, CSA Standard Z662 - Oil and Gas Pipeline Systems, was developed through committees representing the pipeline industry, product manufacturers, and regulatory authorities, both federal and provincial.

In general, federally regulated pipelines are large diameter, high pressure transmission pipelines. However, the systems can vary from 160 metres in length, those which just cross a provincial border, to several thousand kilometres in length, those which cross the country. Nominal diameters range from 154 millimetres (6 inches) to 1219 millimetres (48 inches). The systems transport sour natural gas, sweet natural gas, high vapour pressure products in the liquid state (such as butane, propane and ethane), crude oil and refined products (such as fuel gas and aviation fuel).

Currently, Canada has approximately 18,000 kilometres of oil and liquid pipelines and approximately 19,000 kilometres of natural gas pipelines. This pipeline infrastructure is

buried at or below the frost line, making it an almost invisible transportation network.

The pipeline industry itself is charged with the responsibility of maintaining pipeline safety. It follows national and international codes, and standards have been developed to limit the safety and environmental risk to a reasonable attainable minimum. The NEB has set minimum technical requirements through its Onshore Pipeline Regulations. These regulations require the pipeline companies regulated by the NEB to comply with the CSA Standard Z662 - Oil and Gas Pipeline Systems. Many pipeline companies have developed corporate practices and procedures that go beyond these requirements.

However, since humans design, operate and maintain pipeline systems, human frailty is such that there is always a chance that a pipeline could leak or rupture. From March 1990 through December 1997, the TSB investigated 21 pipeline ruptures, none of which involved loss of life. The majority of these ruptures were caused by corrosion, slope movements and third party damage, issues which the pipeline industry has been dealing with for many years. Five of the ruptures were caused by stress corrosion cracking (SCC), a failure mechanism about which the industry has learned much in recent years and is still learning.

3. Stress Corrosion Cracking - what the industry is facing

External stress corrosion cracking (SCC), a type of environmental cracking, has been recognized as a cause of buried pipeline ruptures since 1965. At that time, the first pipeline rupture ever attributed to SCC occurred in the United States. Since that time, much effort has been spent in identifying the environmental and operating conditions that are conducive to SCC. Pipelines in Australia, Canada, Iran, Iraq, Italy, Pakistan, Saudi Arabia, and the former Soviet Union have experienced failures due to SCC. SCC is a progressive fracture mechanism caused by the simultaneous action of a sustained tensile stress and a corrosive environment. A spontaneous brittle fracture can result when cracks reach a critical crack length which is dependent on the fracture toughness of the material. As the name implies, the formation of cracks is associated with SCC and there is usually little metal loss or general corrosion. SCC is not unique to the pipeline industry; it has been addressed in other industries such as the petrochemical, aerospace and nuclear industries.

In pipelines, cracks are initiated at locations where the coating has become disbonded from the pipe and a corrosive environment can attack on the grain boundaries of the steel or the steel itself. Cracks usually originate at stress risers such as surface irregularities, scratches, machine marks and microscopic pitting.

The sustained tensile stress is mainly due to internal line pressures but may also involve other service stresses, such as bending stress, and residual stress from manufacturing, welding or other processes.

In the early development stages, cracks are microscopic and are often not evident by visual inspection. At the present time, there are no commercially available in-line inspection tools with proven crack detection capabilities, particularly for the longitudinal type of cracking typical of SCC. The pipeline industry currently uses in-line inspection tools to detect geometric defects, such as dents or ovality, and metal loss, such as corrosion.

Development of the technology to detect cracks is in advanced stages and tools are being tested in operating pipelines.

Since crack growth is a function of the local conditions at the crack tip, not all cracks grow continuously, or at the same rate or time. SCC appears in colonies or clusters containing numerous individual cracks which can coalesce when the cracks become large enough. Cracking may be either intergranular and follow the grain boundaries of the metal involved, or transgranular and cross the grain boundaries.

Once a crack has initiated, the principles of fracture mechanics govern crack growth. The rate of growth and coalescence depends on crack size and crack spacing. During the period of subcritical crack growth, risk of failure is negligible.

Hydrostatic tests have been carried out on operating pipelines to detect SCC. The pipe is subjected to pressures higher than normal operating pressures in order to force the larger existing cracks to open up and rupture under controlled conditions. However, if the crack has not reached a critical size, a rupture will not occur. The hydrostatic test will temporarily stop the growth of the crack but the crack may continue to grow at a later date. If the crack growth rate can be established, a subsequent hydrostatic test can be conducted before the crack reaches the critical length under operating conditions. The strength test pressure is most often 125% of operating pressure for a period of one hour followed by a leak test pressure 110% of operating pressure for a period of four hours.

The SCC which has been occurring in Canada has been referred to as non-classical. It typically occurs under near neutral pH conditions, in environments where dilute carbonate-bicarbonate solutions exist next to the pipe surface, is not temperature dependent, and tends to be transgranular in nature. Transgranular cracks tend to be wide open with little branching and are typically concentrated near longitudinal welds where weld reinforcement causes tenting of wrap coating over the weld.

Classical SCC, on the other hand, tends to be intergranular, is temperature dependent and occurs under high pH conditions and in environments where concentrated carbonate-bicarbonate solutions exist next to the pipe surface.

Research into the initiation and growth of non-classical SCC indicates that the main contributing factors are stress, stress fluctuations, a corrosive environment in contact with the pipe steel, electrochemical potential, coating type and condition, and condition of the pipe surface. There is currently no consensus regarding the relative importance of each of these factors.

The first pipeline rupture in Canada attributed to SCC occurred in March 1985 in northern Ontario on the TransCanada PipeLines (TCPL) system. Since that date, TCPL has experienced seven ruptures and one leak during operations attributed to SCC. The leak occurred in southern Manitoba in 1989. Of the seven ruptures, five have occurred in northern Ontario, one in eastern Ontario, and one in southern Manitoba.

TCPL's natural gas pipeline system extends from Alberta to Quebec and consists of more than 13,000 km of buried large diameter pipe, and 56 compressor stations. The system comprises up to six pipelines at certain locations, identified as lines 100-1 to 100-6, and is sectionalized by isolation valves located at approximately 30 km intervals. The pipeline has a maximum allowable operating pressure of 6895 kPa for most of its length and 6455 kPa in the remaining portions. Most of the TCPL system was laid in regions with little or no

human population and is classified as Class 1 pipe according to industry standards. Heavier wall pipe thicknesses, classified as Class 2, 3, or 4, were used in more populated areas or under other circumstances such as proximity to hospitals, schools or compressor stations.

Following the first in-service pipeline failure attributed to SCC, TCPL conducted eight bell-hole excavations along Line 100-2. The purpose of this 1985 work was to determine the origins of SCC and to investigate the overall susceptibility of Line 100-2 to SCC, especially near populated areas. In response to the second SCC failure in August 1985, also on Line 100-2, TCPL began planning an intensive field program for 1986. Referred to as the Pipeline Maintenance Program (PMP), it consisted of hydrostatic testing and investigative excavations. Its purpose was to ensure the continued safe and reliable service of the pipeline system. The third SCC failure occurred in March 1986 and was also on Line 100-2. Initial emphasis of the PMP was therefore placed on Line 100-2 in northern Ontario.

In 1989, TCPL experienced a leak due to SCC on its Line 100-3 downstream of MLV 31 in western Canada. In 1990, it hydrostatically tested Line 100-3 between MLV's 30 and 32.

Between January 1991 and July 1992, TCPL experienced three additional pipeline ruptures in Ontario; one was on Line 100-2, two were on Line 100-1. The TSB's investigations into these ruptures (report numbers P91H0117, P91H0041 and P92T0005) indicated that SCC was evident at the rupture initiation points of the pipe involved in two of the three ruptures. The failure section from the third rupture was never recovered from the swamp where the rupture had occurred. However, two sections which were recovered contained SCC adjacent to the longitudinal seam weld. The TSB determined that because of similarities between this failure site, the results of TCPL's PMP and other SCC-related ruptures, this failure was also due to SCC.

In 1991, TCPL expanded the scope of its PMP to include Line 100-1 in the Toronto-Montreal corridor, Line 100-1 in Northern Ontario, and other selected pipelines in various geographical regions of the TCPL system when it determined that those sections of pipe were susceptible to SCC.

Early in 1992, TCPL developed an SCC soils model to determine the appropriate environmental conditions for initiation of SCC and to identify locations along its pipeline system where those conditions existed. This soils model has evolved since TCPL began developing an SCC severity rating model in 1986. The soils model continues to evolve as TCPL collects and analyzes information from investigative excavations.

During its investigation into the three ruptures which had occurred between January 1991 and July 1992, the TSB determined that although TCPL was taking action to prevent ruptures due to SCC, because of the potential consequences of a rupture, additional measures should be considered. Consequently, in November 1992, the TSB issued three recommendations to the NEB dealing with allowable operating pressures, detection and repair of SCC and operating restrictions for natural gas pipeline systems susceptible to SCC. Subsequent to those recommendations, the NEB conducted an inquiry into SCC through written submissions. As a result of that inquiry, the NEB indicated that it would:

- continue to monitor the development and implementation of TCPL's PMP which includes hydrostatic retesting, investigative excavations and inspections, and selective

pipe replacements;

- monitor the SCC-related activities of pipeline companies under its jurisdiction; and
- continue to encourage and follow developments regarding research into SCC detection and repair techniques and encourage industry to disseminate and utilize relevant information.

In 1994, TCPL expanded the scope of its PMP investigations into SCC with excavations conducted in western Canada. However, until July 1995, TCPL had not expanded the scope and area of the PMP investigations into SCC beyond those areas already investigated in western Canada. It based this decision on the following:

- the soil conditions were classified as being low on the SCC-susceptibility scale and did not rank among the ones of major concern;
- the operating history of the system to that point did not include SCC-related occurrences;
- the 28 excavations conducted since 1988 did not indicate serious SCC activity; and
- the successful hydrostatic retesting of Line 100-3 in 1990.

On July 29, 1995, TCPL experienced a rupture on its Line 100-4 at Rapid City, Manitoba, MLV 30, in western Canada. This was the first time that the company had an SCC rupture on its Line 100-4 and the first time that an SCC rupture had occurred west of Winnipeg.

The TSB's investigation (report number P95H0036) found the following similarities between this occurrence and previous SCC-related ruptures on the TCPL system:

- the external coating on the pipeline at the rupture locations was polyethylene tape;
- soil conditions at the occurrence locations were mainly sand/clay material; and
- soil conditions were rated as being imperfect to poorly drained.

In the 1985 - 1995 time period, extensive field studies have been conducted with a view to understanding the origins and progression of SCC on pipeline systems. It has been found that SCC occurs under both polyethylene tape coated and asphalt coated pipeline sections and in low pH, dilute electrolytes containing carbonic acid, bicarbonate, and other species. Studies, in particular those done by TCPL, have also indicated that the severity of SCC appears to increase with the presence of bacteria and the absence of oxygen. Soil type, drainage pattern and terrain pattern all influence the initiation of SCC.

Following the July 1995 rupture on the TCPL system, the NEB held a wide-ranging public inquiry into SCC on Canadian oil and gas pipelines. The inquiry evaluated the extent of SCC on pipelines and the measures that could be taken to effectively deal with SCC. The report was released in December 1996 and contained 27 recommendations to promote public safety on oil and gas pipelines in Canada. The recommendations covered the following categories: SCC management programs, design changes, research, SCC database, emergency response practices and information sharing. The TSB responded favourably to the report indicating that it believes that implementation of these recommendations will go a long way towards better managing the risks associated with SCC in pipelines.

In 1997, the Canadian Energy Pipeline Association (CEPA), a voluntary non-profit association of pipeline companies, published its Stress Corrosion Cracking Recommended Practices to assist pipeline companies in developing an SCC integrity management programs specific to their pipeline system. An essential component of the program is the need for

continuing surveillance and mitigation depending on the extent and seriousness of the concern.

From the first occurrence of SCC until the present, the pipeline industry has come a long way in its understanding of the mechanics, characterization and detection of SCC on operating pipelines. The pipeline industry has demonstrated a commitment to furthering its knowledge of this failure mechanism and to developing sound integrity management programs to analyze, detect, evaluate, and reduce or eliminate the risks due to SCC facing their pipeline systems.

References

- Canadian Energy Pipeline Association. Stress Corrosion Cracking - Recommended Practices:1997.
- McKenzie-Brown, Peter, Gordon Jaremko and David Finch. The Great Oil Age - The Petroleum Industry in Canada Calgary: Detselig Enterprises Ltd., 1993.
- National Energy Board: Report of the Inquiry Stress Corrosion Cracking on Canadian Oil and Gas Pipelines, Proceeding MH-2-95, November 1996.
- National Energy Board Annual Report, 1996.
- Position Paper Prepared for the TSB Board Members, August 1995.
- Transportation Safety Board of Canada, Commodity Pipeline Occurrence Reports P91H0117, P91H0041, P92T0005, P95H0003 and P95H0036.

Safety Improvement by Cooperation

Session 2

1. The public and **Modality and Nationality**

Much of the moral behavior that makes it not safe and a getting worse with the increase of motor traffic. They believe that the increase in traffic will increase the risk for the people living near the airport and the passengers themselves. Almost every week somewhere in the world an accident happens with loss of hundreds of lives. Every accident and every incident, even when there are no fatalities, makes the headlines from page seven and is part of the news bulletin on TV-type news of earlier page news items, such as the bombing that in the High Government caused by the crash of the Boeing 747 on the 9th of October 1981. It attracts, doubts and speculations about the facts that caused the accident and each investigation report related to it, is discussed in the media. Accidents attract here, because of their nature, the dedicated interests of the media, the public and politicians. Let's be clear: every accident and every failure is one or many and people and the industry have, individually, the right to know what caused the accident and the loss of their beloved. For the uninvolved members of the media or the negative aspects of criticism given by the general public, the impression that accident is not a risk as it usually is. It's also a fact that people's natural fear for safety is sometimes misplaced. There is no crime in saying that aviation is intrinsically safe and that comparing it with other modes of transportation.

Aviation is not a risk as it usually is. It is important for history and a high growth rate any kind of it. The only solution is to have no accidents. That's what the public is asking for and the industry understands that that is the direction to go in, whether it is attainable or not. The development from good global safety to worldwide global safety is what we need and I think we are on the way. On a global, national, or regional level, as far as safety goes, every accident, the individual is to have to find out the cause of the accident, such as in the case of the TWA disaster. And, as a result, some national and international steps to improve aviation safety are implemented.

A. The safety facts

What are the facts? Each year in the history of aviation, Flight International publishes a global overview of total accidents and fatalities in civil aviation over the previous 10 years.

On the left side of this graph you see the number of fatalities and on the right side the number of total accidents. Last year there were 22 fatal accidents with 1295 fatalities. The number of fatalities is 1/20th and total accidents is 1/10th. But still, it's 1295 fatalities. The good news is that, in spite of a traffic increase of over 20% in the last 10 years, there

Session 2

Modality and Nationality

Safety Improvement by Cooperation

Charley Besselink

Amsterdam Airport Schiphaol, The Netherlands

1. The public safety perceptions

Much of the world believes that aviation is not safe and is getting worse with the increase of aviation traffic. They believe that the increase in traffic will increase the risk for the people living near the airport and the passengers themselves. Almost every week somewhere in the world an accident occurs with tens or hundreds of fatalities. Every accident and severe incident, even when there are no fatalities, makes sensational front page news and is part of the news bulletins on TV; pictures of earlier tragedies are shown, such as the burning flats in the Bijlmermeer caused by the crash of the Boeing 747 on the 4th of October 1992. In addition, doubts and speculations about the facts that caused the accident and each investigation report related to it, is discussed in the media. Aviation accidents have, because of their nature, the dedicated interest of the media, the public and politicians. Let's be clear: every air accident and every fatality is one to many and people and the relatives have, undoubtedly, the right to know what caused the accident and the loss of their beloved. But the one-sided interest of the media in the negative aspects of aviation gives the general public the impression that aviation is not as safe as it actually is. It's also a pity that people's natural fears for safety are sometimes mishandled. There is no sense in saying that aviation is extremely safe and then comparing it with other modes of transportation.

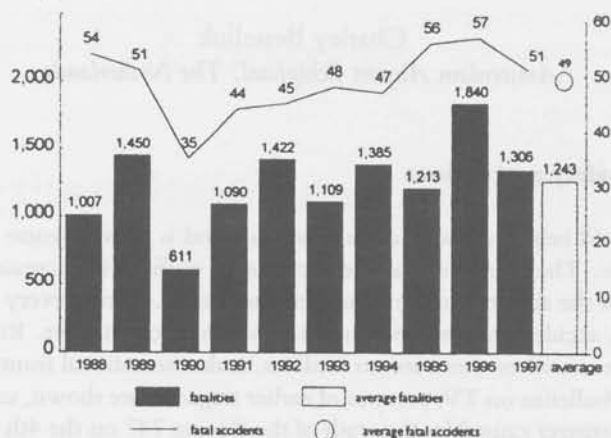
Aviation in itself is sensational. It is unnatural for humans and a high percentage are afraid of it. The only solution is to have no accidents. That's what the public is asking for and the industry understands that that is the direction to go in, whether it is attainable or not. The development from good global safety to excellent global safety is what we need and I think we are on the way. The negative attention of the media motivates us further. After every accident, the unbelievable is done to find out the cause of the accident, such as in the case of the TWA disaster. And, as a result, new measures and initiatives aimed at improving aviation safety are implemented.

2. The safety facts

What are the facts? Each year, in its January edition, Flight International publishes a global overview of fatal accidents and fatalities in civil aviation over the previous 10 years.

On the left side of this graph you see the number of fatalities and on the right side the number of fatal accidents. Last year there were 51 fatal accidents with 1306 fatalities. The number of fatalities in Dutch road traffic alone is more. But still, it's 1306 too many! The good news is that, in spite of a traffic increase of over 50% in the last 10 years, there

seems to be only a gradual increase in the total numbers of fatal accidents and fatalities. Now, this is sensational. And it gives us the reassurance that the expected traffic growth can be realized without an increase in the number of fatal accidents and without an increase of third party risk on a global level.



Source: Flight International, Januari 1998.

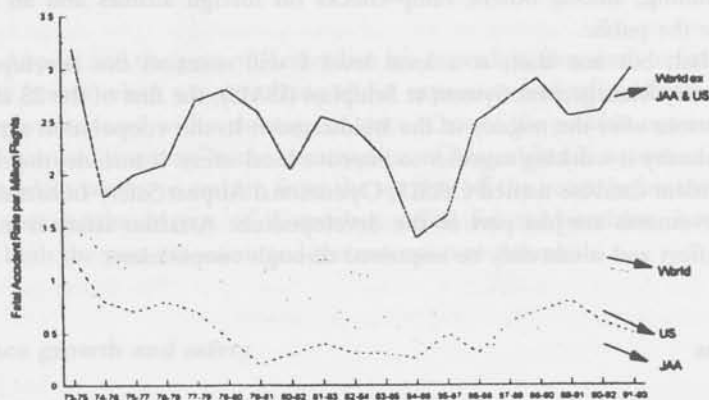
Figure 1. 1997 fatal accidents.

This can only be reached if we continue to strive together towards zero accidents. So, the slogan "doubling the traffic will double the risk for people living round airports" is not true as long as we continue to improve. The problem is that up till now there has been no concrete and, therefore, useable "local safety performance indicators" available that could produce a local safety overview like Figure 2 for global overview. If you look at the figures in this graph you have to take into account that in 1997 there were no fatal accidents involving passenger jet airliners from the traditionally safe Australasian, North American, Western European or Middle Eastern carriers. It is well known that there is a significant difference in safety standards according to country or region.

On the left side of this graph you can see the number of fatal accidents per million jet flights you can see that the world fatal accident rate in 1993 was one per million flights. You can see that the accident rate of US and European supervised airlines was less than one fatal accident per two million flights and they are doing even better now. Unfortunately, I don't have any figures for the last four years.

The US generates about half of the total global civil aviation activity. Europe generates less than a quarter of the global traffic. So, roughly more than a quarter of the global traffic is attaining a lower safety level. This is represented by the upper line on this graph. When you take into account that this group includes traditionally safe countries and carriers as mentioned earlier you will understand that the safety performance of the carriers in this category is even more significant. It is said that 16% of the traffic has caused 70% of the total hull losses. The quality of supervising authorities is essential to safeguard the safety level of the airlines and the other service providers in the system. As ICAO the international civil aviation organisation has no authority to assess the quality of the supervision of the

contracting states, the FAA, started some years ago, to assess the quality of supervision of airlines which fly to and from the U.S.A.. As a result, we now have the information that the quality of supervision of about half of the contracting states is at least according to ICAO requirements. The other half is still unknown, this segment still only represents less than 3 percent of the traffic at Schiphol airport. ICAO have started assessments as well but only on request with confidential results and, this is very important, together with a support program. This is known as the Safety Oversight Program.



Source: Ministerie van Verkeer en Waterstaat, Rijksluchtvaartdienst, Discussienota dd. 7 februari 1996, Veiligheidsbeleid Burgerluchtvaart.

Figure 2. Fatal accident rates: US, non-US, world and JAA jet airliners; 3 year moving averages.

3. Improvements

In spite of the possible impression the general public may get from the sensational attention of the media "aviation is uncommonly safe but there are differences and improvements are still possible and necessary". There is a common awareness that we have to improve and that as well as accident-investigation, improved supervision, incident sharing and investigation, and the use of safety management-techniques will make aviation even safer. I will now mention a few particular improvements:

The first are the activities of the FLIGHT SAFETY FOUNDATION in which the aviation industry and aviation organisations are exchanging results and developments and are taking special initiatives to improve aviation safety. For example to reduce CFIT controlled flight into terrain accidents, which has consistently killed more passengers and crew than any other accident category. And the ALAR approach and landing accident reduction initiative.

Secondly, in the ICAO Conference of last November, the most important recommendations were adopted. Firstly, to develop a system of mandatory, systematic and harmonised safety audits, which should include all contracting states, and should be carried out by ICAO. This is a real breakthrough. Furthermore to expand the Safety Oversight

Program, it is clear that the poorer countries must be helped to improve their performance. Thirdly, the US will continue the IASA International Aviation Safety Assessment program and implement the recommendations of the White House Commission on Aviation Safety and Security. Fourthly, the European safety improvement strategy program and the recent decision of the transport ministers to develop EASA, a European Aviation Safety Authority. Fifthly, the Russians recently decided to improve their system and to reorganise their aviation industry. Sixthly, in 1996, in the Netherlands, an Aviation Safety Policy was adopted including, among others, ramp-checks on foreign airlines and an information telephone for the public.

And last, but not least, at a local level I will mention the development of an Integrated Safety Management System at Schiphol (ISMS), the first of the 25 implemented recommendations after the tragedy in the Bijlmermeer. In this cooperation agreement, the airport community is working together to improve local safety. It includes the development of a local incident database named OASIS, Operational Airport Safety Information System. These improvements are just part of the developments. Aviation safety is an attitude, a continuous effort and it can only be improved through cooperation.

4. Questions

We are making progress, but questions still remain.

- Facts and further improvements do not seem to be sensational enough for the media and the public. How can we get a more balanced and realistic perception from the media and the public?
- Do we just continue with what we are doing now, in the direction we are moving, or do we have to add new initiatives, new directions?

An Industrial View on Shipping and Safety

Pieter Struijs

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Amsterdam Airport and the port of Rotterdam are nowadays frequently referred to in one and the same breath when we are talking about expansion and safety. Both our port and Schiphol airport are faced with a shortage of space. One of the possible options to bring an end to this "cramped situation" is the construction of Maasvlakte 2, an area of land that the port of Rotterdam wishes to reclaim from the sea just off the coast. In his traditional New Year's Eve speech, the Mayor of Rotterdam called for a Maasvlakte 2 which would incorporate both the port extension and the extension to Schiphol.

1. Imbalance growth and safety

Mr Hengst, thank you very much for providing me with the opportunity to participate in this conference. The main theme of the congress "imbalance between growth and safety" greatly appeals to Rotterdam. Or perhaps I should say: does not appeal to us! A few years ago, the municipal authority began a large-scale project known as "ROM Rijnmond" aimed at achieving further growth of the port and at the same time an improvement in the environment and safety in the port and industrial area. Rotterdam firmly believes that these aspects go hand in hand. Today we - the Rotterdam Municipal Port Authority - see investment in safety and the port environment not as a cost item but rather as a basic condition to achieve economic growth by creating an efficient port and a high quality and competitive port.

2. Efficiency and safety

A perfect example of this is the fire brigade shared by the businesses in the chemical port of Rotterdam. In this huge chemical cluster, Botlek and Europoort companies combined their industrial fire brigades. This resulted in a highly specialized and well-equipped fire brigade which has taken over the tasks of the municipal fire brigade and all those small individual brigades. Economic growth has led here to an improvement in safety and also to cheaper protection for both industry and the community.

In my presentation I intend to explain how we in Rotterdam feel about safety. This should be an industrial point of view because there are more industrial sites in Rotterdam than anywhere else. But first of all, some brief information about the port and the organisation of the Rotterdam Municipal Port Management, in other words the port authority.

3. Rotterdam Mainport of Europe

Rotterdam is a tidal port with a minimum low tide draught of 13 metres and a maximum draught of some 24 metres. The port extends over an area of 40 kilometres. From the centre of Rotterdam to the North Sea. The port and the industrial area cover almost 10,000 hectares of which 5,250 hectares consist of sites for port and industrial activities. The port is surrounded by residential areas, particularly to the east.

In the port more than 300 million tons of goods are transhipped yearly. Rotterdam receives around 32,000 seagoing vessels and approximately 110,000 inland barges a year. This figure makes Rotterdam still one of the biggest ports in the world.

4. VTS

The Vessel Traffic System of Rotterdam covers an area stretching from 60 kilometres off the coast to 40 kilometres inland. This system is used to track 80,000 movements of seagoing ships and 360,000 movements of barges every year. The hardware of the VTS includes 31 radar stations and five manned traffic stations.

5. Rotterdam municipal port management

The Rotterdam Municipal City Council has allocated responsibility for management of the port area, the port basins and the industrial sites to the Port Authority. The Port Authority consists of two directorates and a number of corporate functions.

The directorates are directly linked with the two main functions of the Port Authority:

1. the Directorate of Commercial Development is responsible for the landside; the management of port infrastructure and commercial affairs
2. the Directorate of Shipping takes care of the waterside; provision of nautical services which includes the office of the Harbour Master.

The Port Authority's main objective is to strengthen the position of the port and industrial complex in a European perspective. In our view, this is only possible in a clean and safe environment. Only a clean port will be able to survive. No multinational would wish to be associated with a heavily polluted port environment.

"Safety" and "Environment" are therefore essential basic criteria for the process of promoting economic activity. "Sustainability" plays an important role in relation to the "Environment" criterium. And with considerable success. The environmental quality of our soil, air and water has improved substantially over the last 20 years. This is not only evident from chemical analyses, but is also demonstrated by flora and fauna in the port area.

The port authority is responsible for safety and order on the water of the port. The harbour master in Holland has traditionally borne public responsibility for traffic safety and enforcement of environmental legislation. But the port authority is not the only party involved. In Rotterdam - being a landlord port - the private companies have their own

responsibilities. It is also not the only regulatory authority in the port. Other local authorities - police, fire brigade - regional and national authorities play an important role at a strategic, tactical and operational level, even though they have in some cases delegated their operational responsibilities to the port management.

Safety management in the port area deals with prevention as well as damage control. From these, prevention naturally is the first choice, but not everything can be prevented. In a port, where many different operations take place, small accidents are more frequent than on sea and damage control is relatively more important.

6. Safety (4 points)

Safety may be broadly divided into four different issues:

- nautical safety
- transport safety
- emergency preparedness and response
- environmental safety

7. Nautical safety

Each year 30,000 sea vessels and 110,000 inland barges call at Rotterdam. But the traffic in the port also consists of push-combinations, special transport, harbour patrol boats, pilot tenders, tugs, police and customs patrol vessels, various types of small craft such as workshops, fishing vessels, yachts etc. Rotterdam is one of the busiest ports in the world. From time immemorial, the harbour master in Holland has borne public responsibility for nautical safety and enforcement of environmental legislation. This safety is determined by a combination of actors, facilities and procedures.

For instance the Vessel Traffic System clearly has a very positive impact on the safety control of shipping. The system ensures that traffic is handled smoothly and safely. It provides a complete overview of traffic in the port, the control of this traffic, information concerning sea-going ships and communication between nautical services 24 hours a day.

Uniform data interchange via EDI (Electronic Data Interchange) promotes safety in the port. More than 80 percent of the official notifications we receive take place electronically. In addition to Rotterdam, a number of other European ports are also aiming to receive the compulsory notifications of dangerous substances on board ships electronically. In order to standardize these notifications and facilitate international data interchange, the Port Community Systems in six European ports - Antwerp, Bremen, Felixtowe, Hamburg, Le Havre and Rotterdam - are working together on the PROTECT project. The International Maritime Organisation has adopted the standard of this group. Japan, Malaysia and Singapore are now also going to apply this standard. It would be ideal if the same standard could be used around the world. Even if notification does not take place electronically. Standardized information improves safety. Approximately 45% of the total cargo in tonnes handled in the port of Rotterdam is classified as dangerous.

8. Transport safety

Transport safety depends on the quality of the ship and the quality of the management. With so many shipping movements, the port authority focuses every attention on minimizing and controlling the risk of disasters and incidents. Limitation of the impact of any incident also receives a great deal of attention. In recent years the Port Authorities have therefore invested time and energy in developing risk standards for shipping. Control of transport safety is one of the spearheads of Dutch safety policy. This includes the minimization and control of the risk of disasters and incidents and limitation of their impact.

International policy in this respect is established mainly in the International Maritime Organization of the United Nations. Several treaties have been concluded and are more or less regularly updated. Subscribing nations commit themselves to implementing the treaties in national law.

A recently implemented issue is the ISM - International Safety Management - code. This is a code which prescribes that ship-managing companies have to establish their own internal safety management system. This states, for example, that a responsible person must be appointed, that safety procedures are drawn up and applied and that the company ensures that it learns from feedback from dangerous situations. This code has been in force for RoRo passenger ships in Europe as of July 1996. As from July 1998 it will be in force for oil, chemical and gas tankers, bulkcarriers and passenger ships.

9. Emergency preparedness and response

Guaranteeing adequate incident control demands a constant minimum level of the requisite people and resources. This necessitates continual investment in training and publicity concerning hazardous substances and their related risks. Risk analyses have to be carried out to see how serious the threat of catastrophes in the port area is.

10. Environmental safety

The main objective for environmental safety is to achieve a safe and clean port: sustainable development. Since in our opinion only a clean port can survive, environment-friendly behaviour is encouraged on the part of both maritime and inland shipping. But we do have soil, water and air pollution and noise problems. The Port Authority is currently endeavouring to give the concept of sustainability a practical interpretation in all these problem areas.

11. Internal and external

Ladies and gentlemen, we like to profile Rotterdam as one of the safest ports in the world. We are fully aware that we are skating on thin ice with this assertion. Risk management is

not yet an exact science and human error is always a possibility. Nevertheless we attach a great deal of importance to providing a sound statistical basis for a concept such as "safety" which is so difficult to define.

Risk management mostly concentrates on the internal risk, that is the risk experienced within the shipping sector itself. This is both a natural and a good thing to do, because prevention starts on board the ships. The port area is surrounded by densely populated residential areas. External risk management therefore also plays an important role. The external risk, that is the risk that is experienced by those in the vicinity, has to be assessed on the basis of criteria. If the criteria are not met, this can lead to measures in respect of the risk source (that is shipping) or to the establishment of zones that must be kept free of housing.

12. External risk

This external risk is expressed by two parameters:

- Individual risk, defined as the chance per year that an unprotected person located at a specific position relative to the risk source is affected by the consequence of the event.
- social risk, defined as the relationship between the number of people killed in a single accident and the chance that this number will be exceeded. The use of this criterion makes it possible to take into account the size of the group of people who can simultaneously become victims of an accident.

These parameters differ fundamentally. The individual risk by definition is solely dependent of the activity itself. The social risk results from the activity in relation to the population density around it.

In the Netherlands the maximum level of the individual risk has been taken as the risk level which increases the risk of death from all other causes by a maximum of one percent. The individual natural death risk run by the population group of 10 to 14 years old - the most healthy population group - which is one per ten thousand per year has hereby been taken as the basic risk.

The maximum acceptable individual risk has thus been established at one per million per year. For the maximum level of social risk a chance of one in 100,000 per year of an incident with 10 or more deaths had been set.

Initially developed for the industrial plants, these criteria are now also being applied to transport, transshipment and storage. With regard to individual risk, there is a little technical difficulty in doing this. For the social risk the norms were set to a chance of one in 10,000 per year for 10 or more deaths due to accidents per km stretch of transport route.

13. Risk analysis

Basically a risk analysis process consists of three activities:

1. calculating risk levels in a way which is acceptable to all parties involved.

2. deciding whether or not there is a need to reduce the risks. This means that risk criteria must be available.
3. deciding what measures should be taken. This is the most important aspect of a risk analysis.

In the Netherlands the use of Quantitative Risk Analysis is well established as a method of managing the risk of major hazard activities. It must be stressed though that the results of this analysis are based on the input and that the input may become part of the negotiating process. In step 3 other factors, such as economic and social considerations, have to be taken into account.

14. Risk analysis in ports

Several studies have shown that the use of QRA techniques in port areas are technically feasible.

In the Netherlands the Rotterdam Municipal Port Management has made a number of studies of the risks involved with the transport and transshipment of dangerous goods by ship. In combination with the QRA's performed by local companies a fairly comprehensive insight has been gained into the risk levels in the Port of Rotterdam and its surrounding areas.

A specific problem in the case of transportation related activities such as ports, is that the handled substances are classified according to international transport codes and that these codes do not relate directly to parameters that are indicative for the actual risk to man or the environment by these substances. Therefore a method has been developed that enables the conversion of transport categories into categories suited for performing risk analyses.

Some general conclusions from these studies are:

- The overall risk to the public is dominated by the transport in bulk of flammable and toxic liquid substances. This is caused by the high transport volume combined with the fact that these substances are transported in single hull tankers, which makes these ships relatively (as compared to double hull ships or gas carriers) vulnerable in case of collision.
- The contribution to the overall risk of the transport of gases is considerably lower. This is caused by the relatively low transport volume combined with the very solid construction of gas carriers. The probability of loss of containment in case of a collision is appreciably lower.
- Frequency of spills in port basins is dominated by loading and unloading accidents. The average volume spilled is much smaller than the volume spilled due to collisions. Collisions in port basins are not to be neglected even though speeds are lower than outside the basins. Collision frequency in port basins is higher than on the waterways, even if the extent of damage is lower.

Safety remains a difficult subject. Rotterdam is a safe port, a very safe one but how safe is hard to tell.

15. Incidents and transshipment

One sees a remarkable decline in the total number of incidents in the port. Last year Rotterdam port had a throughput of 307 million tonnes; a historic record.

16. The acceptability of transport by ship and urban developments

In order to get an insight into the future possibilities and limitations for urban development, apartment - and office buildings in the City of Rotterdam close to the river Nieuwe Maas, one of the major transport routes for inland barges, a risk analysis has been performed.

From the notification to the harbour master transport frequencies in the Port of Rotterdam were derived. Per stretch of 1 km. length the frequency of transport for a UN-number in a certain containment was determined. Using the accident rates the individual risk due to the transport by ship were calculated and presented as iso-risk contours on a map of the area. In the reference situation - as an average - the maximum acceptable risk level lies at the edge of the fairway. The neglectable risk level lies between 200 and 500 meters landinward.

In the future (2000 and 2010) the maximum acceptable risk level shifts approximately 5 to 10 meters into the fairway and the neglectable risk level shifts to the edge of the fairway. These risk levels can be achieved if all (volatile) toxic and flammable liquids have to be transported in double hull ships, even though the volumes transported increase considerably. As a result of this study: it is advisable to build at distances over 20 meters from the edge of the fairway in areas where the traffic is dominated by inland craft.

A similar study for the sea entrance of the port (Hook of Holland) and the Botlek area, close to the town of Rozenburg, showed that in areas where the traffic mainly consists of sea-going vessels a distance of 50 meters is advised. This zone free of buildings at the same time guarantees a free access for the Fire Brigade and other Services in case of accidents.

Railroad Safety Management and the Re-Engineering of European Railway Transport: A Welcome Challenge

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1. Introduction

Railways traditionally have a high public reputation for safety. This perception converges with the statistical proof: The accident-rate of the UIC-related railroad companies shows a continuously decreasing curve on a whole over the last 15-20 years. Therefore, one could straight come up to the conclusion that European railway safety levels and managements are quite sufficient and have scarcely to tackle significant risks, but little improvements in addition to existing procedures and rules. Nevertheless, there were arising some indicators which have got the sky slightly overcasted:

- single catastrophes of different kinds on several networks
- regular fatalities other than by train accidents: i.e. staff fatalities, fatalities of joining and alighting from trains, falling from moving trains or fatalities of trespassers
- arising perception and awareness of railway accidents by the public attitude

The following survey briefly outlines the safety practice of European railways in the past compared to the new requirements due to the development of the EU-common market. It further tries to find a convergent path for a joint safety management approach for the European Railway Transport in the near future.

2. Safety practice before EU-railway reform

The classical European railway transport organisation is respectively was based on some typical characteristics as:

- dominant or single national railway companies
- focus on national transport market
- focus on inter-modal competition
- state owned/funded companies
- own competence as a safety authority (or at least elements of it)

Within this well-defined and state-influenced market framework, safety practice was developed over a long period of decades with its own safety culture. The main characteristics can be described as follows (valuable in general, may not apply to a specific case):

- focus on "technical" safety (i.e. well-settled "fail-safe"-practice in the signalling-technology)
- measures based on statistical evaluation found in the past
- broad rule-based practice (with a tendency to be overruled)
- different methodical approaches from country to country respectively from company to company
- in addition to national safety rules and standards, European railway safety is largely based on "UIC-Standards" (= leaflets) with mutual agreements among the railway companies (without supranational legal basis) and on the railway application of the CEN/CENELEC-normalization framework as well

To summarize the safety practice from the past until the 1980s, we identify a period of continuous consolidation. Safety improvements continued at a slow rate, but the railway managements were mainly concerned with the problems of financial performance, productivity and increasingly, the attractiveness and quality of the product for passenger and freight customers. Safety was not ignored, but a tendency to manage safety with drive was not always the top priority.

Society was tolerant of the occasional lapses in the system. Rare catastrophes in the transport industry were accepted as part of the price of increasing mobility.

In the second half of the 1980s and during the first 1990s, however, some severe railway accidents with fatalities among passengers and damages to the environment occurred in several countries and arose the attention of the public (incl. authorities) in a significant way. The conclusion that these remarkable events were a final catalyst to end the era of a long experienced railway safety practice, is confirmed by many European Railway companies. A new page for safety is to be turned.

3. EU-railway reform and safety (change) management

The decision of the European Union to encourage in an active way the development and reform of the European Railway Transport is based on the well-known directive 91/440 of 1991 (and its descendants 95/18 and 95/19). With this new strategic axis the changed market framework can be described as follows:

- focus on open markets (= deregulation) instead of state-regulation
- privatization of state-influenced national railway companies
- encouragement of international (cross-border) transport services
- introduction of intra-modal competition among railway companies (incl. "new entrants")
- financial and organizational separation between infrastructure management and transport business

Nowadays, the influence of these legal acts become more and more visible in the form of a growing number of "separated" companies, joint-ventures and new entrants on the railway market. What impacts has this development on the practice of railway safety management?

- growing cross-border transport needs a harmonization of transparent safety practice

among all players (market, regulation)

- heterogeneous safety levels and practice (i.e. too detailed specifications) hamper the innovation of new technologies
- safety can no longer be considered as intrinsic to technical equipment alone, but it must be regarded in a global sense
- through the privatization process, the national railway companies "loose" their traditional safety authority competence
- safety cultures between traditional "herited" railway companies and new railway undertakings may diverge to a considerable extent

Therefore, two main strategic lines are well-designed to provide the required and new safety approach on a common basis:

- Safety interoperability (= safety competitiveness) on a European level
- focus on comparable safety performances

In consequence, these strategic lines result in a significant and decisive conclusion for railway safety management: the change from a rather deterministic culture to a more probabilistic one is inevitable!

If it appears to you until here that railway companies in general were ignorant towards new and especially probabilistic safety management approaches, then I should point out that such a picture is incorrect. Many companies and more and more also authorities develop and apply such methods. It is therefore very informative to have a short view over to the "scenery" of the various approaches:

- *Safety Culture*: A key component in safety management is the requirement to be proactive, to commit management and staff, to identify potential accidents and incidents before they happen and to take protective measures to prevent them or minimize their effect.
- *focus in the prevent area* (not the event area.../change management)
- *risk-assessment methods and tools on a probabilistic basis* (= safety performance, safety levels). The numerical methods applied to safety are efficient, but they are not the only ones. Combined with other, more experimental methods, they thereby form a coherent and diversified whole, in which the elements complement each other. It would be a pity to ignore the probabilistic tools, but it would also be dangerous to consider it as the only tool valid and to disregard all the others. This approach leads to the fixation of safety levels in terms of indicators which estimates the injuries of people in fixed periods of time and links them to traffic levels on one hand. On the other hand to the introduction of the value of life concept, the amount that community is ready to pay to save human life, in order to establish a relation between economical advantages and accidents.
- *cost-benefit analysis of safety-related measures* (= safety as a "value-added" or "value-loss" factor to reach economic efficiency)
- *focus on human-factor integration* (i.e. man-machine-interface): In the past, railway accident investigations tended to focus upon the active failure of those at the sharp end. The spotlight was upon the errors and violations committed by drivers, shunters, track workers and others in direct contact with hazards. These unsafe acts usually had an immediate adverse impact upon safety and were the direct causes of

any accident. Remedial efforts were then directed at preventing the recurrence of these particular actions through engineered safety measures, amendments to the Rule Book and other containment measures. The focus must be concentrated on the environment of work situations, respectively on the impact of external influences.

- *focus on a "safety-case"-approach* (= instruments for a global, transparent and comparative safety policy between different partners to reach fixed safety performance/safety levels).

4. Conclusions

In the next few years the deregulation of the European railway market will provide a certain number of new market players and, as a consequence of the higher market efficiency, a significant increase of the transport volume.

Thus, the preventive and comparable risk-assessment and the establishment of harmonized safety levels on a European scale become definitely a key factor for the Railway Safety Management. Therefore, one should fully profit from the following actions and initiatives already launched:

- Introduction of the "safety certificate" in the new railway "freight-freeways" (corridors) throughout Europe with the "one-stop-shop" principle for customers. This platform as an ideal trial step for a common safety case-approach.
- Harmonization of the homologation bodies for railway systems and components (CEN/CENELEC, UIC, AEIF) on a European level (including the legalization the existing voluntary industrial standards).
- Active support of EU-initiatives (i.e. "DG III-studies") to develop the railway interoperability in key fields as minimal European safety rules and regulations and common methodical framework for a railway risk analysis.

To push forward and converge all these promising paths, one could imagine the creation of a "shelter"-platform like a sort of "European Joint Railway Authorities - JRA" (in analogy to the "European Joint Aviation Authority - JAA"). Similar to the JAA, a "IRA" would contribute to fair, equal and "safe" competition within the Member States and companies through the application of common standards.

At the end of the day, the change in Safety Management Systems, the proactive risk-prevention approach, the better understanding of human factors, the introduction of audits, validation and safety case regimes - the change in safety culture - has to be judged by its effectiveness, and the results sustained over a sufficient length of time. Measurements of "societal risk" show the step by step change to safety that occurred a generation ago through the introduction of new technology.

This leads to the final observation that as in other industries, a well-experienced truth is valid for the whole transportation industry, but especially for railways: "Good business is safe business"!

Remarks on General Safety

Jim Hall

National Transportation Safety Board, U.S.A.

I am very pleased to be here this morning before such a distinguished international group. As chairman of the United States National Transportation Safety Board, I welcome this opportunity and appreciate your hospitality.

You have asked me to address three major issues in the brief time I have with you this morning: an overview of the NTSB, including our use of the party system in investigating accidents; our safety recommendation process; and the victims family assistance function.

Last year marked the 30th anniversary of the Safety Board and I take pride in leading what many consider to be one of the finest transportation investigative bodies in the world. Over the past 30 years, in cooperation with other organizations in the United States and abroad, the Safety Board has raised the level of transportation safety. It has done so by improving and standardizing the investigative process in all areas of transportation, and has served as a model for other nations that have established similar agencies.

As you may know, the Safety Board is an independent agency of the United States government whose mission, since its creation in 1967, has been to determine the "probable cause" of accidents and to make recommendations to improve transportation safety and prevent future accidents. Over the years, our Congress has recognized the value of the agency, first establishing its primacy over investigations conducted by other Federal agencies and then broadening its inter-modal jurisdiction.

The independence of the Safety Board and its clear mandate to conduct in-depth investigations, draw conclusions from its findings, and make recommendations to improve safety, without bias or undue influence from industry and other government agencies, are essential to maintaining the safety of the traveling public. It is not unusual for the Safety Board to address safety issues that are controversial or that may be critical of government or industry standards or operations.

One highly publicized example of this was the Safety Board's criticism of the FAA for not adopting recommendations issued during the previous decade that would require smoke detection and fire suppression systems in airliner cargo holds. The Board cited the FAA in its probable cause of the ValuJet accident of May 1996 for its failure to require those systems that, the Board felt, could have prevented or greatly mitigated the effects of that accident.

My goal as Chairman is to fully support and advance our mission to investigate accidents and make recommendations to prevent future accidents. I seek to foster relationships in the U.S. and abroad to further that goal. One way to do this is through conferences such as this where we can share experiences and information on accidents and recommendations.

I hope you will see through my presentation that information sharing and a common agenda are the backbone of the Safety Board's investigations.

We share a common agenda with many different organizations - other safety agencies like the FAA and ICAO, the owners and operators of the transportation system, the Congress and the travelling public. In fact, this common agenda - to make air transportation as safe as possible - is one of the primary reasons that the Safety Board conducts its investigations using the party system. To illustrate how the party system works, let me use the example of a domestic airline accident. However, keep in mind that the procedure I'm describing is the same for accidents in all modes of transportation.

When an airplane crashes, there are many interested parties who wish to be part of the investigation - the Federal Aviation Administration; the air carrier; the aircraft manufacturer; the major component manufacturers; and the pilots, flight attendants and maintenance unions. All have a vested interest in learning what went wrong and what to do to correct it. It is this common concern that sets the stage for the party system or "team concept" used by the Board to investigate an accident. It also necessitates a high degree of organization and coordination before a proper investigation can begin.

When a major accident occurs, a "Go-Team," led by a NTSB investigator-in-charge (IIC), is dispatched from Washington, D.C. to the accident site within a few hours of notification. The Safety Board Go-Team for a typical aviation accident usually consists of about 10 specialists who will serve as group chairmen in specialty areas to be examined during the investigation. Examples of the groups include: powerplants, structures, systems, operations, air traffic control, weather, human performance and survival factors. Cockpit Voice Recorder (CVR) and Flight Data Recorder (FDR) groups are formed in the Safety Board's laboratories in Washington. Other groups are formed as needed. A Safety Board Member accompanies the team and serves as principal spokesperson for the on-scene phase of the investigation.

The Go-Team is complemented by substantive experts from the pertinent manufacturers, operators, unions, and the FAA - each of whom brings an array of resources and talent to a Safety Board investigation. It should be noted that, except for the FAA, party status to a Safety Board investigation is a "privilege," not a "right." No news media, lawyers, insurance or public relations personnel representing any party are permitted to participate in any phase of the investigation. Often more than 100 individuals will be working on a major investigation. As the team is being organized and dispatched, there is already significant interaction between the Safety Board staff, FAA officials, and representatives of the other interested organizations. In the event of an overseas accident, similar communications take place with the officials of the country involved.

To ensure a continuous flow of information throughout the fact finding or on-scene portion of an investigation, the IIC holds progress meetings at the end of each day during which all parties come together and report to the full investigative team on their findings to that point in time. This allows all participants in the investigation to have all of the available information, enabling them to continue their work more efficiently and with a broad understanding of the known events.

Through nightly meetings with all investigative parties, the Safety Board acts as a filter through which only information that can be documented will be released. Generally,

after the daily progress meetings, the Safety Board Member on-scene will convene a press briefing to provide an update on the status of the investigation. By having just one voice serving as spokesperson for an accident, we assure that the public is receiving only factually based information from official sources. The inevitable speculation in the news media can therefore be distinguished from the information coming from the investigation itself.

Throughout the investigation, every fact is shared with the parties, giving them an opportunity to dispute the evidence and share their perspectives. Indeed, we invite them to submit their analyses, proposed findings, probable cause, and safety recommendations to us. In the end, however, it is the Board and the Board alone that develops the final report and probable cause determination of an accident.

The party system has been challenged and reevaluated over the years. But we believe that in terms of addressing a common agenda when an accident occurs, this system is clearly the most efficient and productive means of sharing and receiving information. This system also provides an opportunity early in the investigation to immediately identify and correct problems that can prevent similar accidents from occurring.

Throughout the process, parties are required to keep the IIC apprised of ongoing or potential corrective actions. For example, airline and manufacturers' service letters or bulletins and FAA directives that result from the parties' participation must be shared with the Safety Board as the information is developed. No restrictions are placed on the timely development of corrective actions by the parties; we merely ask that the Board be informed as they are developed.

If the Safety Board determines that corrective action needs to be taken as a result of information gathered during an investigation, it issues a safety recommendation letter with the necessary factual information to support the recommended action. In many cases, urgent or interim safety recommendations are developed early in an investigation based on initial findings. Each recommendation designates a person or party expected to take action, describes the action recommended, and clearly states the safety need to be satisfied. Although our recommendations are not mandatory, their importance is such that Congress requires the U.S. Department of Transportation to respond to each recommendation within 90 days. Although non-DOT organizations are not required to respond to our recommendations, they, too, have adopted a large majority of them.

Since our first recommendation more than 30 years ago, more than 10,700 others have followed and 3,900 of them have been targeted to aviation. They have been issued to government agencies, manufacturers, operators, pilots, engineers, flight attendants and labor unions and others - more than 190 different recipients over the past 30 years.

More than 82 percent of all of our recommendations over the years have been implemented, resulting in a safer environment for everyone who travels, both in the United States and worldwide.

The success of the safety recommendation program is also due in large part to the Congress, the media, and an aggressive follow-up program. It would be naïve to think that the public does not play a significant role in the success of our recommendation program. Often as the result of media scrutiny, public pressure is brought to bear on the recommendation recipient. If the recipient is unable to move quickly because of institutional roadblocks, the Congress often responds to lift those roadblocks - making way

for the needed changes. For instance, recommendations regarding pilot record sharing have been largely adopted by the FAA, but only after Congress mandated that the agency take action.

To put this process in context, let me give you a real world example of how this process works. On July 17, 1996, at approximately 8:30 p.m., TWA flight 800, a Boeing 747, blew up shortly after takeoff from New York's John F. Kennedy Airport, killing all 230 persons aboard. That night, the Safety Board launched the largest investigation in its history.

This investigation has marked a lot of firsts for the Safety Board. It has been by far the most expensive and extensive in the Board's history. It was also the longest on-scene investigation - well over a year and a half - and has involved more Safety Board staff than any investigation - almost 1/3 of the Board's 370 employees.

Five months into the investigation, the Safety Board identified a potentially dangerous situation and issued four recommendations to the FAA urging short- and long-term actions to reduce the potential for a fuel/air vapor explosion in the center wing fuel tanks of B-747's, as well as in fuel tanks on other aircraft. Although the industry did not initially embrace our recommendations, since our hearing last December, they are now examining their practicality and developing measures to meet the recommendations' intent.

It is important to understand that although we may never pinpoint what sparked the explosion of the center wing fuel tank on flight 800, we have identified possible means of preventing similar explosions in the future.

Let me illustrate the importance of international cooperation in aviation investigations by citing a recent example. The SilkAir Boeing 737 accident in December is the latest involving close coordination between my agency and a foreign government in accordance with international protocols. We sent 2 investigators to Indonesia, one of who served as the U.S. accredited representative, together with investigators from the FAA and Boeing. The Indonesians asked us to read-out both flight recorders in our Washington laboratories. Singapore sent investigators to the scene and to our laboratories. In addition, Australia sent investigators to the scene and to our labs as part of an agreement to provide technical support to Indonesia.

Such cooperation between nations is imperative. The 737 is the world's most widely used airliner, with approximately 3,000 worldwide. It is imperative that any airworthiness concerns brought out in an investigation are dealt with immediately. My country has a clear obligation to verify the airworthiness of U.S.-manufactured aircraft. Similarly, information on an Airbus, Embraer, Fokker, Bombardier or Saab could affect the safety of millions of travelers, and those particular States of manufacture have similar concerns. Obviously, our common concerns will continue to require multinational cooperation in accident investigations.

I would like to discuss one last issue before I close - the Safety Board's new role of coordinating assistance to the families of accident victims. For those of you who have been involved with a major aircraft crash, I do not need to tell you that some past responses lacked organization, coordination, and far too often, compassion. Based on Congressional testimony and other forums, we've heard numerous horror stories - continuous busy signals from the airline's 800 accident information number; misidentified remains; personal effects

being mishandled; unidentified remains not handled with dignity, including mass burials without informing families; and the use of confidential information obtained during this grief process against families in court. I think we can all agree that this type of treatment should not and cannot be tolerated.

Family members of victims, not just in the United States, are demanding more accountability in the aftermath of accidents. Their concerns are rather basic and reasonable - timely notification of the accident and information on the process for the recovery and identification of victims, disposition of unidentifiable remains, and return of personal effects. Yet, more often than not, this fundamental desire for information has been ignored in the past.

The NTSB's experiences while at accident sites and the increasing activism on the part of victims' families brought their perceived mistreatment to the Nation's attention. To rectify the problem, in September 1996, President Clinton named the Safety Board as the coordinator for federal services to families of victims of transportation accidents. The following month, Congress enacted legislation that gave us the family affairs responsibilities for aviation disasters. Although the Board did not seek that responsibility - it was assigned to us because of our long and respected history at crash sites as the eyes and ears of the American people.

Our new seven-person Office of Family Assistance coordinates and integrates the resources of the federal government and other organizations to help support local and state governments and airlines to meet the needs of aviation disaster victims and their families. Federal resources can provide assistance in areas such as family counseling, victim identification and forensic services, communicating with foreign governments, and translation services, to help local authorities and airlines support victims' families more effectively following a major aviation disaster.

Since passage of the law in the U.S., our family assistance plan has been used 4 times including the KAL flight 801 accident in Guam. As a result of that accident, Congress recently passed legislation amending the Aviation Disaster Family Assistance Act of 1996 to require foreign carriers flying in or out of the United States to file family assistance plans and fulfill the same family support requirements as U.S. air carriers.

On September 28 and 29, 1998, the Safety Board will host an international symposium in Washington, D.C. for industry, government, and community officials to promote a better understanding of the federal government's family assistance role after a transportation disaster. It will also allow individuals and organizations to discuss their experiences and learn new techniques in disaster resource management. I invite all of you to attend what will be the first international gathering of this kind. Information on the conference will be available this Spring on our Internet home page, www.nts.gov.

In closing, I am reminded that my predecessor, Carl Vogt, spoke before this Congress in 1992 and urged closer ties with other independent agencies and expressed his belief that there needs to be more such agencies, preferably inter-modal, because our experience testifies to their efficiency and economy.

I strongly believe that since the First World Congress six years ago, we have seen the benefits of working closely together. Since that time, the International Transportation Safety Association (ITSA) has been founded and joined by 7 independent investigation

authorities. We now meet annually to share information, discuss common concerns, and look for ways to refine and enhance the information sharing between our agencies.

Globally, all of our citizens board airplanes, buses, ships and trains in pursuit of recreation and business. It is our mission and duty to maintain a constant and vigilant effort to keep transportation safe for all of the world's travelers. This task will be much easier if we work together to achieve this end.

In closing, let me state that one of the founders of my nation, Thomas Jefferson, said, "The care of human life and happiness is the first and only legitimate object of good government." I believe it is this simple phrase that describes the mission and goals of the National Transportation Safety Board and independent accident investigation agencies worldwide.

The Appraisal of Safety in the Channel Tunnel

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1. Introduction

This paper considers the appraisal of safety of a high-profile transport facility: the Channel Tunnel. We consider a brief description of the tunnel; safety regulation; criteria for safety in the tunnel; the estimated risks; and a comparison of the estimated risks and the criteria. The paper concludes with some comments.

The main technical reference for this paper is Eurotunnel's Safety Case. The original version was produced and published (Eurotunnel, 1994) before there was any experience of operating the tunnel, so it is now in the process of being reviewed and updated. There have also been two British parliamentary inquiries into safety aspects of the tunnel; one was by the Home Affairs Committee (1991) on fire safety and policing; the other was by the Transport Committee (1995), aimed at comparing safety on the ferries with that in the tunnel. Finally, Sir Alastair Morton (1995), then co-Chairman of Eurotunnel, has made some interesting comments on the process by which safety requirements were determined for the tunnel. These together provide much information relating to safety appraisal, but there are still gaps, particularly on the economics of the relevant safety measures, and the risks themselves remain uncertain.

2. A brief description of the Channel Tunnel system

The Channel Tunnel is a railway system linking Folkestone, Britain, and Coquelles, near Calais in France. There are three tunnels, each about 50 kilometres in length: two railway running tunnels with an internal diameter of 7.6 metres, and a service tunnel with an internal diameter of 4.8 metres. (For comparison, the standard diameter of the London tube lines is 3.7 metres.) There are cross-passages every 375 metres linking the three tunnels, and piston relief ducts directly linking the running tunnels every 250 metres. The two running tunnels are normally used by trains running in opposite directions. There are two undersea crossovers by which trains can switch from one running tunnel to the other. These are used when part of one of the running tunnels is closed for maintenance, and the other is used to carry trains successively in both directions; they are also available for emergencies, and were in regular use when part of the tunnel was closed for several months after the fire on 18 November 1996. There are major tunnel ventilation systems above the tunnel at

Shakespeare Cliff in England (9 kilometres from the portal) and at Sangatte in France (3 kilometres from the portal). Railway traction within the tunnel is electric at 25 kv AC (the same as in France, and elsewhere in Britain, though not south of London), and automatic train protection is provided.

Outside the two portals there are extensive terminals for loading and unloading cars, coaches and freight vehicles transported through the tunnel, and there are loop tracks so that the road vehicle "shuttle" trains simply complete a circuit to return to the tunnel. The tunnel railway is also linked to the British and French national railway networks, so that national railway trains can travel through the tunnel (though all the rolling stock used for this so far has been purpose-built). In France, the tunnel is directly linked to the high speed lines to Lille, Paris and Brussels, as well as to local lines. Outside the tunnel boundary, there is a large national rail freight terminal near Calais, and there is a freight locomotive exchange and holding siding facility near Folkestone.

Four types of train use the tunnel:

1. Car-carrying shuttle trains;
2. Goods-vehicle shuttle trains;
3. National passenger trains (at present, only the London-Paris and London-Brussels "Eurostar" trains); and
4. National freight trains, with a variety of origins and destinations on both sides of the Channel.

All passenger trains have two locomotives, either of which are capable of moving the train in the event of a failure of the other.

3. Regulation of tunnel safety

The British and French governments invited proposals for a fixed link between two countries in April 1985. A variety of proposals were submitted, of which Eurotunnel's rail-only tunnel was selected, and formally adopted at the Treaty of Canterbury in 1986. Eurotunnel was awarded the concession to build and operate the tunnel for 55 years, subsequently extended, after which ownership of the fixed link reverts to the two governments. The tunnel began operation in 1994.

Because the two governments will ultimately own the tunnel, they have overseen its construction, and will oversee its operation and maintenance for its entire life. A special bi-national body, the Inter-Governmental Commission (IGC) with equal representation from the two governments has been set up for this purpose. That in turn has set up the Channel Tunnel Safety Authority (CTSA), which effectively became the safety regulator for the tunnel during its development and construction phase. Since the tunnel became an operational railway, the CTSA remains the principal regulator at the working level, but HM Railway Inspectorate and its French equivalent are also involved in various ways. HMRI has always been represented on the CTSA, along with the other professionals.

It may be noted that, quite apart from any requirements of regulation, Eurotunnel has a strong commercial incentive to safety, because the indirect costs of accidents, in the form of disruption and loss of demand, are high.

Before the tunnel opened, the CTSA required Eurotunnel to prepare a safety case assessing all risks in the tunnel, and to state how they were being controlled and managed. The CTSA's requirement was made before the requirement was established for all domestic railway operators in Britain to prepare safety cases. Eurotunnel's original safety case did not comply in all respects with the new domestic requirements, but the updated version does so.

4. Criteria for safety in the tunnel

4.1 *The general criterion*

Safety has always been a very important consideration in the design and operation of the Channel Tunnel, for the obvious reason that a 50-kilometre tunnel is bound to present special hazards. Therefore, both Eurotunnel and the CTSA were determined to ensure a high standard of safety from the start. Indeed, one of the major reasons for the acceptance of the Eurotunnel's 3-tunnel bid was that it appeared to offer lower risk than the alternatives.

However, at the start of the Channel Tunnel project, there were no clear criteria for what level of safety was tolerable in the tunnel, and no criteria for decisions concerning what safety measures should be incorporated. This was partly because the tunnel was an entirely new project, and during its development phase it was not clear what level of safety could be achieved. It was also because, in Morton's (1995) words, the IGC and the CTSA comprised:

"professional people...doing their best with a job tossed their way with inadequate terms of reference - all of them knowing that fame would come only from failure" (p7).

As a result, the safety systems were largely determined not by quantifying risk, but on the basis of best-practice professional judgements made by several different professional groups - police, fire, railway operation, civil engineering. They were made more stringent by the fact that two sets of professionals were involved - French and British - so if either set required a safety measure, there was a tendency for the CTSA to require it. It was only after all the principal decisions had been made that a quantified risk assessment was made.

The first statement of a quantified safety criterion for the tunnel was made by Bryan Martin, British co-Chairman of the CTSA, who said in response to a question from a member of the House of Commons Home Affairs Committee on 6 November 1991:

"my own view, and it is not yet the Safety Authority's view, because we have not discussed this in detail, is that a passenger travelling by train from London to Paris should be in the part of the journey through the tunnel as least as safe as in the equivalent length of the journey from either Waterloo to Folkestone or from Sangatte to Paris." (Home Affairs Committee, 1991, Volume 2, page 77.)

This criterion was later adopted by the CTSA itself, because it is subsequently quoted in Eurotunnel's Safety Case (1994) as one of the criteria by which the safety of the tunnel was to be judged.

With the benefit of hindsight, one can comment that at the time that the statement was made, the tunnel had been under construction for more than five years, and presumably all the main design decisions, and many of the operational decisions had then been made.

It seems remarkable that the CTSA had not by then decided what its safety criteria should be. Hence Morton's advice:

"Set your Philosophy of Safety in stone at the start of the design and procurement process, and do not change it. Decide how safe you intend to keep users and stick to that decision." (Morton, 1995, page 9.)

The criterion that the Channel Tunnel should be as safe for passengers as comparable surface railways was used in Eurotunnel's Safety Case (1994) to determine tolerability limits for individual risks to passengers and an FN-criterion line to be compared with the tunnel's FN-curve. The only tolerability limits that were not based on the criterion of comparability with existing railways are those for staff, which are based on the standard Health and Safety Executive (HSE) individual risk criterion for employees of a risk of death of 1 in 1,000 per year (see for example, HSE, 1992).

4.2 Individual risk criteria

Eurotunnel has interpreted the criterion above to mean that the upper tolerable limit to the risk of death for a passenger travelling through the tunnel should be the average risk of death on a comparable 50-kilometre journey on British Rail (BR) (It was estimated that the risk on SNCF was not very different). For through journeys on the Eurostar trains, they calculate this to be 4.7 deaths per 100 million transits. For the vehicle-carrying shuttle trains, the tolerable risk limit is somewhat higher, 5.6 deaths per 100 million transits, because there is some risk in embarking and disembarking from the shuttle trains at the terminals, whereas there is no such risk on the Eurostar trains, which pass non-stop through the terminal areas.

In the case of Eurostar and freight train staff, Eurotunnel has converted the HSE's general limit for the risk of death of 1 in 1,000 per year into a risk per hour, which is then converted into a upper limit for the risk per tunnel transit. Finally, Eurotunnel has adopted without amendment the HSE limit of 1 in 1,000 for its own staff. The resulting individual risk limits are as follows:

- Road-vehicle "shuttle" passengers: 5.6 per 100 million transits;
- Eurostar passengers: 4.7 per 100 million transits;
- Eurostar train crew: 26 per 100 million transits;
- Freight train crew: 31 per 100 million transits;
- Eurotunnel staff: 1 in 1,000 per year.

4.3 Societal risk criteria

For societal risk, Eurotunnel adopted the standard approach used in industrial risk assessment, using an FN-graph. Eurotunnel derived its upper criterion line from the criterion above, based on comparability with BR. They first plotted BR's empirical FN-curve for accidents with two or more fatalities over the period over the period 1971-1989: this is similar to that shown in Figure 1, but for a shorter period. Next, they fitted a straight line through the empirical data (in the usual logarithmic scales), which happens to have a slope of -1.1.

Finally, they noted that the scale of Eurotunnel's activity, as measured by passenger-kilometres, was about 1/18 of that of BR, so they reduced the fitted line by a factor of 18,

which means simply shifting it downwards in logarithmic scales. All this is shown in Figure 1.

The resulting upper FN-criterion line is that labelled the "intolerable line" in Figure 1 and reproduced with a different scale on the y-axis in Figure 2. The "negligible line" in Figure 2 is simply the line which is a factor of 1,000 below the intolerable line, because a factor of 1,000 is commonly used for that interval in individual risk criteria.

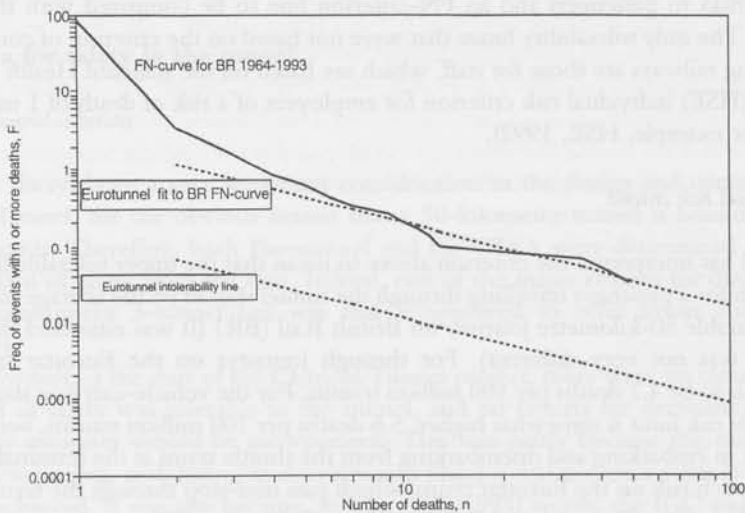


Figure 1. British Rail FN-curve 1964-1993 and Eurotunnel intolerability criterion.

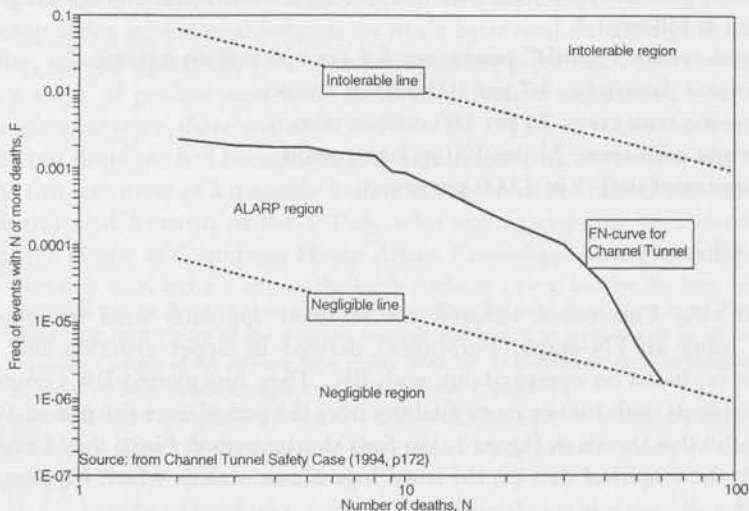


Figure 2. FN-curve and criterion lines Channeltunnel.

5. Risk estimation

Having been determined these risk criteria, before operation began Eurotunnel made estimates of the risks to see whether the criteria were met. In terms of the time scale of whole project, both the criteria setting and the risk estimation were carried out far too late to have much influence on the design and operation of the tunnel, but presumably if the risk estimation had shown that the criteria were not met, the CTSA would have required further safety measures.

5.1 Hazards

The major categories of hazard identified in the safety case (page 68) are the following:

1. Derailment
2. Collision
3. Fire
4. Pollution causing an immediate threat to people, such as a toxic release
5. Flooding
6. Suffocation - asphyxia
7. Explosion
8. Earthquake
9. Abnormal acceleration or deceleration
10. Movement and non-movement accidents
11. Electrocution
12. Total power failure.

5.2 Multiple-fatality hazards

Given the design of the system, which includes duplication or further replication of all critical services, with control rooms, electricity supplies, and ventilation on both sides of the Channel, the major risks of multiple-fatalities accidents were deduced to be (1) to (3) in the list above, namely derailment, collision and fire. Even derailment and collision have low risk compared with most comparable-length railways, because of the simple track layout (only two crossovers in the 50 kilometres between the terminals) and automatic train protection.

The largest single contributor to the risk of multiple-fatality accidents was estimated to be fire, though again there are elaborate safety measures in place to manage this risk, which were tested to the full in the fire of 18 November 1996 (see CTSA, 1997). In the original plan for managing train fires, the first priority was to move the train out of the tunnel to specially protected sidings at each end, where evacuation is easier and the fire can be more easily fought; one reason for the provision of two locomotives was to enable trains to be moved even if one locomotive became disabled. However, following the fire of 18 November 1996, the first priority has been changed to the immediate evacuation of the train occupants: they are to reach a cross-passage by walking either through the train or along the continuous walkway, and then go through the passage into the service tunnel, in which the air pressure is maintained at a higher level than in the running tunnels, so as to

prevent smoke entering and to provide a continuous supply of fresh air. People are then evacuated by a train stopped opposite them in the other running tunnel. Fire fighters, rescue equipment and ambulances are brought to the scene using purpose-built service vehicles in the service tunnel, and seriously injured people are evacuated that way.

The reason for the change of plan is a re-estimation of the probability that a train with a fire would be able to drive through without having to stop, either because of a fault on the train itself, or because of the presence of other traffic. In the fire of 18 November 1996 the train developed a fault which required it to be brought to a controlled stop; the traction current was then quickly lost, so the train could not be moved.

None of the other risks listed above are estimated to make a substantial contribution to multiple-fatality accidents. The risks associated with the first three were estimated in Eurotunnel's safety case using a quantified risk model.

5.3 Single-fatality hazards

The major contributor to single-fatality accidents is estimated to be item (10) in the list above: movement and non-movement accidents, that is injuries to individuals, either from the movement of trains or from mishaps not involving trains. The frequency of such accidents was estimated from the past record of such accidents on BR. However, rather than include all such accidents on BR, only accidents of the kind that could occur on Eurotunnel were included. The reason for excluding certain types of accidents is that many single-fatality accidents that occur on BR could not happen in the Channel Tunnel, because they have been "designed out", such as level crossing accidents (there are no public level crossings in the Eurotunnel system); passenger falls from trains (all trains doors are automatically locked); track maintenance staff struck by service trains (there is no track maintenance while service trains are running alongside).

6. Comparing the estimated risks with the criteria

Eurotunnel's safety case (1994, page 169) estimates the overall risk to passengers and staff in the Channel Tunnel system to be about 6% of the risk on an equivalent size of British or French national railway system. The BR data used by Eurotunnel for calculating individual risk was 1984-1990, during which the average annual number of fatalities (excluding trespassers) on the whole of the British railway system was 81.4. (In passing, it might be mentioned that safety on the ex-BR system has improved greatly since then.) Assuming that the Channel Tunnel system is 1/18 of the size of the British national system (see above), the fatality rate on a national system the size of the Channel Tunnel would be $81.4/18 = 4.5$ fatalities per year. The actual Eurotunnel rate is estimated to be 6% of this, or 0.27 year, that is about 1 fatality every four years on average. This is an extremely low rate. The major contributor to this is "movement/non-movement" accidents, that is individual accidents; this is also true of the national systems.

Because the performance of the national systems provides the criteria for the tolerable passenger risks, it follows from the fact that the estimated actual risks on

Eurotunnel are a small fraction of the risk on the equivalent national systems that they must also be a small fraction of the tolerable limits. The actual fractions vary between categories of passenger, but they are all only a few percent of the criterion risk: for example, the risk for Eurostar passengers is estimated to be 2.0% of the tolerable limit (Eurotunnel, 1994, page 171). The staff risks are generally a higher fraction of the criterion value than passenger risks: the worst is for maintenance workers at about 10 per cent of the tolerable limit, implying an individual risk of 1 in 10,000 per year. This risk is about equal to Railtrack's target for such workers.

It may be noted that if the risk to passengers on Eurostars in the tunnel is really only 2% of the average railway passenger risk per kilometre, it would follow that passengers are at lower risk than on any mode of transport, and lower than being at home or at work in any large occupational group.

Figure 2 shows Eurotunnel's original FN-curve for accidents with two or more fatalities, based on the modelled QRAs for derailments, collisions and fires. The graph also shows the criterion lines discussed above. It can be seen that the estimated frequency of accidents with two or more fatalities is about 0.0025 per year, or about 1 in 400 years. The FN-curve is well below the upper criterion line throughout its length; at worst, it is a factor of about 10 below the criterion line. The fire of 18 November 1996 may lead to a revision of this FN-curve, but it does not in itself disprove it.

7. Comments on the appraisal

7.1 Risk estimation

The main difficulty of estimating risks in new and unique transport facilities like the Channel Tunnel is the absence of statistical data on several of the important risks. It is sensible to have used data from other railways to estimate risks that are common to the Channel Tunnel and other railways, such as certain types of single-person risks, but this approach does not work for the risks that are unique to the tunnel, notably fire risks. In the absence of statistical data, there is no alternative to using risk models, but it is almost impossible to test such models.

It is because of this difficulty that safety remains a controversial issue in the tunnel. If the results of the risk models are correct, the tunnel is exceptionally safe, but it is clear that many people, including some experts, are not convinced that the results are correct.

7.2 The "comparability criterion" for risk

The key formal risk criterion for passengers adopted by the CTSA is the requirement that passenger risks in the 50 kilometres of the tunnel should be no higher than on 50 kilometres of surface main-line railway. While it is easy to see how this criterion became established, it is not easy to justify, and it is quite different from the "ALARP Principle" which applies to domestic railways in Britain, and to industrial risks.

The ALARP Principle requires first that risks to individual passengers (for example,

frequent users) should be less than some upper limit of tolerability, and secondly that, once this condition has been met, risks should be further reduced to a level that is "as low as reasonably practicable" (ALARP). The upper limit of tolerability for passengers in Britain is taken to be a risk of death of 1 in 10,000 per year. In practice risks on all railways are much less than this, so the limit does not bind. Therefore the level of railway safety is effectively determined by what is reasonably practicable.

The interpretation of what is reasonable practicable is subject to continuing discussion: the two elements in it are "good practice" and "value for money" in safety measures. Value for money is determined by a comparison between the costs of safety measures and the safety benefits, of which an important component is savings in fatalities and injuries, which are assigned monetary values. (In 1997, the monetary values for the prevention of a fatality on the ex-BR network were £0.89 or £2.49, depending on the circumstances (Railtrack, 1997).)

The key difference between the "comparability criterion" above and the ALARP Principle is that the "comparability criterion" makes no explicit reference either to good practice or to value for money. It could be that the application of the ALARP Principle to a brand-new railway system like the tunnel would lead to safety levels that are better than on existing railways; on the other hand, it could be that the unique hazards of the tunnel mean that it was not reasonably practicable to achieve the same levels of safety as on existing railways. Either way, differences between the levels of safety in the tunnel and on existing railways would seem rather poor reasons for decisions concerning safety measures in the tunnel.

7.3 Use of the "comparability criterion"

In fact, as discussed in section 4, the "comparability criterion" was established only after all the key design decisions concerning the tunnel had been made. Moreover, as discussed in section 6, when the estimated risks were compared with the criterion, they were found to meet it by wide margins.

It follows that most the operational decisions must have been made on the basis of good professional practice, rather than by quantifying the risks.

8. Conclusion

While the apparent high level of safety in the Channel Tunnel is an obvious matter for congratulation, the obvious criticism of the process for determining the safety systems in the tunnel is the absence of a convincing rationale for the particular levels of safety that emerged. Domestic railways in Britain now do have a rationale, in the ALARP Principle. The "comparability criterion" was established late in the day; this criterion lacks a rationale itself; and in any case does not appear to have been binding in practice.

This conclusion echoes a comment of Sir Alastair Morton, who said that in the absence of a clear philosophy of safety,

"...you end up piling up a lot of requirements, one on top of another, Pelion upon Ossa¹ - and grief all the way for the client - who pays. You aggregate, rather than optimise: you create, as we have, a tunnel system designed and built to a standard of safety provision so high that it would exclude the equipment long in use in tunnels everywhere else with an excellent safety record" (Morton, 1995, page 9).

However, the Achilles Heel of this conclusion is the uncertainty about the level of the risks, particularly those unique to the tunnel. In the absence of statistical evidence, it is natural to err on the side of caution.

References

- Channel Tunnel Safety Authority (1997). Inquiry into the fire on heavy goods vehicle shuttle 7539 on 18 November 1966. CTSA.
- Eurotunnel (1994). The Channel Tunnel: A Safety Case. Folkestone, Eurotunnel.
- Health and Safety Executive (1992). The tolerability of risk from nuclear power stations. HMSO, London.
- House of Commons Home Affairs Committee (1991). Fire safety and policing of the Channel Tunnel. Viols I and II, 23-I and 23-II. London, HMSO.
- House of Commons Transport Committee (1995). Cross channel safety. Viols I and II, 352-I and 352-II. London, HMSO.
- Morton, Sir A (1995). Eliminating risks for the travelling public. London, Royal Academy of Engineering.
- Railtrack (1997). Railway Group Safety Plan 1997/98. Railtrack, London.

¹ In Greek mythology, the Giants heaped the mountain Ossa upon the mountain Pelion in an attempt to reach heaven. The metaphor seems remarkably appropriate. However, Sir Alastair Morton has transposed the mountains: Pelion was the one underneath and Ossa on top.

A Multi-Static Doppler Weather Radar to Measure Severe Weather

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Abstract. Airport operations and capacity are heavily influenced by the prevailing weather situation. Abrupt changes in the wind near the ground pose serious hazards to an aircraft during approach for landing or departure. The aircraft pilot and traffic controller may perceive different environment conditions. Inconsistent information between pilot and controller increases voice communications. Ad hoc decisions are the result, often accompanied by negotiations. These will lead to delay and higher workload, especially in critical time periods of bad weather. One of the most dangerous weather hazards is wind shear. The hazard from wind shear is the resultant change in the lift of an aircraft. When sustained for a significant duration, the loss or gain in lift can lead to performance problems, especially hazardous at low altitudes. In this paper we propose to detect wind shear in the terminal area of an airport, by means of a cost-effective radar network. By advanced technology it is possible to warn the pilot well before a possible encounter.

1. Introduction

At Christmas Eve (25 December 1997) an airplane accident just missed to happen at Amsterdam airport. A Boeing 757, owned by the Dutch airliner "Transavia", broke its nose wheel and ended alongside the runway. The landing of the airplane took place in severe weather with wind from south-west, accompanied by strong wind shear. The near-accident triggered discussions about choosing the right runway for bad weather conditions. The north-south runway (Zwanenburgbaan) was chosen instead of the north-east runway (Buitenveldertbaan). Under given conditions the last one has a headwind approach that used to be safer. The other runway was chosen because of environment claims: inconvenience of noise pollution for the dense population under the approach. The matter is under investigation by the office of the Dutch Department of Civil Aviation.

However, the near-accident, once more, urged for a more detailed a-priori information about the local weather conditions on an airport. The wind regime on the ground level is known by results of an extensive wind measurement network of wind vanes and anemometers, at and around the airport. Generally the upper air is sensed in a coarser way: at distance, the National Weather Service performs specific measurements, using Doppler weather radars, radio sondes and windprofilers. In case of the Faro aviation accident (Portugal, 1992 [1]) the upper air data were retrieved at a distance of about 300 km (at the Meteorological Office in Lisbon). It may be clear that it is more effective to

measure the windfield as close as possible to the runways at an airport.

A Doppler radar can detect the wind velocity in only one direction (radial, alongside the radar ray). To measure the three-dimensional wind field a network of at least three weather radars is needed. However, this is very expensive. Using a bi-static radar concept, three dimensional wind fields can be measured with reduced cost. We propose to apply multi-static radar systems, compromising one transmitter and three or more receivers. In this paper we describe such a special radar system, for the measurement of severe weather phenomena for aviation.

2. Severe weather in relation to the safety of aviation

Wind shear is a generic term referring to a wind change, direction and/or speed, over a small distance or in a little time difference. It is not a serious hazard for aircraft en-route between airports at normal cruising altitudes. But in the terminal area low-altitude wind shear can be deadly for an aircraft, especially during take off or approach for landing. There are a number of sources of wind shear: temperature inversions, surface obstructions and thunderstorms. Two special forms of low-altitude wind shear in relation to thunderstorms are: the "downburst" and the "gustfront". We will start our explanation with wind shear related to these hazardous meteorological phenomena.

The downburst is a strong short-lived outflow produced by strong thunderstorms. When this cold downward rushes of air reach the ground, they spread out, or burst, horizontally in all directions. Thus the downburst creates a locally intense divergent wind shear, illustrated in Figure 1. Such a downburst can be imbedded in the thunderstorm heavy precipitation, but also within a benign-appearing virga. Those are wisps of precipitation streaming from the cloud but evaporates before reaching the ground. This makes a "dry"-downburst more difficult to observe.

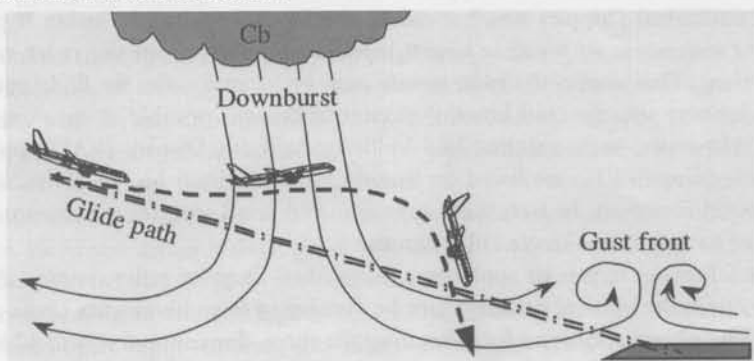


Figure 1. Downburst and gustfront produced by a powerful Cumulonimbus and the impact on aviation

Figure 1 illustrates a potentially hazardous encounter of a downburst by an aircraft on its final approach. Upon entering the downburst, an aircraft first experiences an increase in head wind. This increase causes the aircraft to fly above the glide slope. The pilot, who is

unaware of the downburst, may attempt to return to the glide slope by reducing air speed and angle of attack. As the aircraft continues through the downburst, it encounters a strong downdraft and then a tailwind, which results in a loss of lift acting on the wings. The airplane falls beneath the glide slope and the pilot must increase power and angle of attack to bring the plane back to the glide slope. The aircraft, which requires a finite amount of time to respond to the controls, crashes if it is too close to the ground to recover. The lack of lift may cause a crash, even if maximum control and maximum power is used. The same mechanism can be applied to a take-off.

Another wind problem mentioned earlier, the "gustfront", is also downdraft-related, as illustrated on the right hand side of Figure 1. A gustfront is formed at the leading edge of the outflow, where the cooler air from the downdraft meets the warmer air of the environment. Convergent wind shear pattern and very strong low altitude updrafts characterize them. An unsuspecting pilot descending into the outflow will find his airspeed suddenly falls as he comes down into a tail wind during the last few hundred meters. Moreover gustfronts are mostly accompanied by severe turbulence, and that can cause fatal accidents. They do often cause a change of wind direction, necessitating a change of the runway in use. While downbursts are short in duration and occur with little warning a gustfront can last for hours as they travel away from the generating storm system.

3. Detection of wind shear

For the safety of aviation it is important to know the wind shear nearby the runway in an area of about 10 km. The horizontal surface wind is measured with a network of anemometers and windvanes. These instruments, which are mounted on 10-meter-high masts, can analyze the wind regime near the surface. However, airplanes are flying at a higher level. Thus the wind in the upper air (0-1 km) must be measured too. This can be done with traditional Doppler weather radars: the Doppler principle makes it possible to measure the movement of weather targets towards and away from the radar antenna (in radial direction). That implies the radar system must be located under the flight path looking across. Under very specific (and known) circumstances it is possible to measure the wind field aloft. However, such systems, like Velocity Azimuth Display (VAD) and Volume Velocity Processing (VVP), are based on linearly varying windfields. In convective storms this assumption is suspect. In fact, these approximated wind analyses are grown out of the restriction of having only a single radar system.

The following step is to apply two radars: dual Doppler radar systems. Again, this forms estimation: the vertical velocity must be computed from kinematics (mass continuity equation). The ultimate solution for measuring the three-dimensional windfield is applying consequently three Doppler radars.

The National Center for Atmospheric Research (NCAR, Boulder, CO, USA) and the University of Chicago (Prof. Fujita) has conducted such a research project, in a Joint Airport Weather Studies (JAWS) project low-level windshear effects on aircraft performance. The fine structure of thunderstorm kinematics in the vicinity of the Denver (CO, USA) airport was examined. In this specific research project three independent

scanning weather radars were used. Deploying two or more conventional weather radar systems is very expensive in purchase and maintenance. Moreover, synchronizing the scan strategies of the individual radars is very complex, if possible [3].

4. Proposal for a multi-static weather radar to detect wind shear

The radar systems we mentioned before are of mono-static character, which means they have the same path for transmit and receive. By leaving this mono-static principle a considerable reduction in cost can be achieved. We propose to introduce the multi-static radar system, defined by the separation of transmit-axis and receive-axis. In Figure 2 an example of such a radar system: one transmitter only and three receivers at different locations.

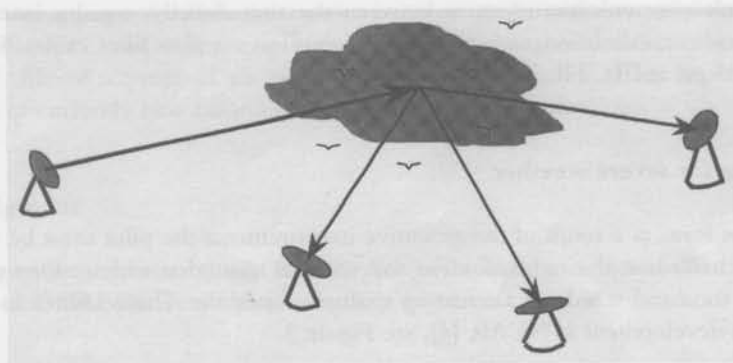


Figure 2. A multi-static weather radar system for the detection of the three-dimensional windfield.

The transmitter must operate within a very small beam width (pencil beam, $\sim 1^\circ$) to retrieve the exact location of reflection. In contrary the receiver's antennas may have wide angles. That means wide in azimuth direction (60°), but limited in elevation direction ($1^\circ \sim 30^\circ$). However, the low gain receive antennas will be highly contaminated by reflected radiation from the sidelobes of the transmit antenna. These adverse effects are reduced by introduction of more advanced radar technology: wide angle antennas with higher gain. Moreover, electronic arrays make it possible to divide the receive antenna into several small angle ones. Coordination with the scanning transmit antenna can be controlled by electronic switching of the corresponding receive antenna sections. Electronic switching put into hand more rapid scanning scenarios as is the case with the traditional mechanical rotation of the radar antenna. This implies an important issue for detecting the fast changing weather situation. Within minutes a dangerous hazard may arise and rage itself out. Again, downbursts are very local and have a short lifetime.

Modulation of the transmitter pulse yields specific improvements: high range resolution (~ 20 m.), low minimum range (~ 200 m.), accompanied by a reduction in transmit power (~ 100 W). This principle of pulse modulation reduces the maximum range

(~ 50km), but that is not a handicap for measuring in the terminal area of an airport.

In the extreme case hundred percent modulation results in a FM-CW (Frequency Modulation-Continues Wave) radar. At the Delft University of Technology we have an outstanding experience in this radar principle [2], as well as with multi-static radar systems (in anti-collision systems, with electronic arrays). The major disadvantage of FM-CW radar requiring two separate antennas (Tx and Rx) is eliminated gracefully in this proposal. The sensitive FM-CW principle makes it possible to detect and warn for bird's migration in the terminal area of an airport.

The installation of the multi-static receivers at different locations (and separated from the transmit antenna) demands for specific technical solutions of synchronization. Locking the (highly stable) frequency sources, of transmitter and receivers, makes it possible to maintain the necessary coherence. This can be done by linking the sites to the Global Position Satellite (GPS) system. A more accurate solution may be found in applying advanced telecommunication systems between the sites directly; e.g. by extremely high frequency radio transmission or by optical transmission via glass fiber cables. Research in this field is done at IRCTR.

5. Warning for severe weather

Last but not least, as a result of the extensive measurements the pilot must be warned for wind shear hazards at the right moment and without misunderstanding. One picture says more then thousand words. A fascinating example forms the Three Dimensional Viewer (3DTV), in development at NCAR [4], see Figure 3.

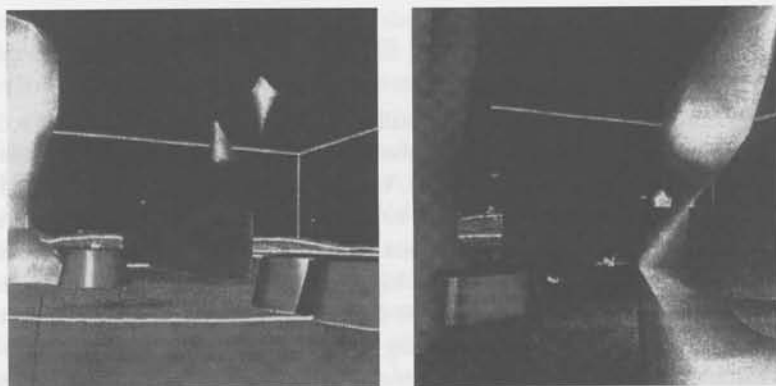


Figure 3. Approach to runway with precipitation (white), microburst (red) and gust fronts (blue).

It enables an intuitive understanding of dynamic weather phenomena, better communications among users (especially flightcrew and ATC), and its impact on a terminal area or en route airspace. It integrates topographical data from LANDSat imagery with ATC radar data and information from a variety of weather sensors. The result is displayed in high-

resolution images and in real time. The virtual environment can be viewed from approach or departure end of the selected runway. By transmitting the image to the cockpit, a pilot could find himself immersed into the virtual environment of the terminal area.

6. Conclusions

Three-dimensional measurement and display of wind shear would minimize traffic disruption and supervisor workload by providing advance-warning capability. This would permit air traffic supervisors to reroute before the severe weather takes place with attendant workload reduction and capacity benefits.

The improvement of the safety of aviation, in relation to the weather conditions, is not a one-party problem but of all world urgency, so cooperation between the authorities of airports and airlines of different countries is necessary. In order to meet future airport capacity, efficiency, and safety requirements, new techniques and systems had to be introduced. Above a proposal to measure local severe weather at an airport with the application of currently new radar and telecommunications technology.

Acknowledgment

The authors would like to thank Bill Meyers of NCAR and Joshua Wurman of the University of Oklahoma for carrying over their experience.

References

- [1] Van Gorp, J.J. and Lighthart, L.P. 1994: To be or not to be a microburst, that is the question. 27th International Conference on Radar Meteorology, Vail, USA, AMS, 536-538.
- [2] Van Gorp, J.J. and Lighthart, L.P. 1994: An operational weather radar network based on FM-CW. COST-75 International seminar on advanced weather radar Systems, Brussels.
- [3] Wurman, J., 1994: Vector Winds from a Single-Transmitter Bistatic Dual-Doppler Radar Network. Bulletin of the American Meteorological Society, Vol.75, No.6, June 1994.
- [4] Annual Report - 1992, National Center for Atmospheric Research, Boulder CO, USA.

Risky Carrier Identification, a Step in Aviation Safety Improvement

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1. Introduction

Air transport is one of the safest modes of transportation. After a historic substantial decline, the past ten years accident rate trends seem to level off. Further reduction of this rate is required to limit the total number of accidents in view of the increasing number of flights. The interest for aviation safety is increasing both from aviation industry and the general public. The general public is starting to ask questions about safety aspects of the operators they travel with and the media exposure of aviation safety is high. In order to promote aviation safety, authorities are developing measures. One step in this field is the program for the detection of risky carriers that is presented here.

International air transport is based on arrangements made by the Chicago Convention (1944). This ICAO (International Civil Aviation Organization) Convention sets, amongst others, safety standards for international flights. It is the duty of each contracting State to ensure that these standards are followed by their countries' operators. The civil aviation authorities are given the task to, amongst others, oversee the safety performance of the operators.

The increasing competition puts pressure on the aspect safety as ensuring safety is a cost-factor. It is cost-reducing to follow safety regulations only partly, thus reducing the safety level of the operation. Increased risk will show in the number of accidents in a statistical way only: there is no direct visible effect of a safety measure: disregarding safety rules will not necessarily lead to an accident or incident. In view of this, as aviation is important for the economy of most countries, a higher risk is more easily accepted.

Another contributing factor in the existence of risky carriers is the fact that Civil Aviation Authorities in developing countries lack resources leading to limitations in staffing, both quantitatively as qualitatively. It is not always possible to have the experts available and keep them current on the developments in modern aviation. This limits the effectiveness of the oversight function of the authority.

2. Safety assessment programs

The assumption made in the Chicago convention: every State fulfills its obligations (or mentions to ICAO that the State is not able to do this) appeared to hold for several decades. In the last few years however it became clear that the Standards were not always adhered

to. The accident rate gave rise to a growing concern. Various organizations took different approaches to solve the problem.

In 1991 the United States' Federal Aviation Administration (FAA) launched the International Aviation Safety Assessment (IASA) program. This program focuses on the capability of civil aviation authorities of countries from which operators fly into the United States. Taking ICAO standards as reference, authorities are assessed and as a result, the well known rating list is drawn. The ratings are: acceptable, conditional and not acceptable. Operators from countries that are categorized as unacceptable are banned from flights into the U.S.A.

ICAO undertook the initiative to start the Safety Oversight Program (ICAO-SOP). The program was approved in 1995 by the Council. States are invited to ask for an assessment on the application of safety-related standards. The assessment is done by an ICAO expert-team. The State is committed, through the signing of a Memorandum Of Understanding, to take measures in order to get into compliance again, by developing an action plan. It is in principle a voluntary program. Like the FAA-IASA program, ICAO-SOP focuses on the aviation authorities of the different states.

In the Asian region the problem of safety standards is also addressed by the Group of Experts on Aviation Safety and Assistance. The assessment programs are basically aimed at promoting aviation safety. Following the identification of weak points help is offered. This help includes expertise on certain fields or training of personnel.

Beginning 1996, the European Parliament adopted a Resolution as a result of which the European Civil Aviation Conference (ECAC) started the development of the Safety Assessment of Foreign Aircraft (SAFA) program. This program will be introduced in this presentation.

All programs mentioned above have the objective of identifying operators that have a safety standard that is lower than generally accepted. Both ICAO- and FAA programs focus on the oversight function of the aviation authority, the ECAC program however focuses on the detection of "risky carriers" directly. In this paper we will be explaining the ECAC-SAFA system as a means to help improving aviation safety.

3. The European approach

ECAC (European Civil Aviation Conference) is an organization in which authorities cooperate in order to harmonize their approach. At this moment 36 countries are ECAC member states.

The JAA (Joint Aviation Authorities) is set up by ECAC as its executive body. It has the task to develop a common set of regulations for the ECAC countries. These regulations are adopted by the European Community and are binding for EC countries.

The SAFA program can be seen as the bottom-up complement of the ICAO program. The program is not primarily aiming at assessing oversight of authorities but at the safety of visiting operators by checking their aircraft and operation. In the view of ECAC, it is of concern that aircraft that fly over ECAC-states territory or carry passengers from their countries are safe. That does not only apply to the technical condition of the aircraft

itself but also the way the aircraft is operated. In order to get a clear and complete picture of its performance, the quality of the airline operator has to be assessed. It is primarily the responsibility of its own authority to oversee this. The ECAC-SAFA program does not take over this responsibility.

The program is still in the development stage, which means that certain parts of the program are already standardized, while other parts are left to the discretion of the authority involved. As the situation around information exchange between the various sources will be different in each country, arrangements will differ. Through the JAA, standardization is reached for the way the ramp-checks are performed and how the information obtained is spread to other countries. Special forms are used throughout Europe and regular meetings are held to share experiences and update the program. In the following the situation in the Netherlands will be described.

The SAFA program can be divided into two parts: information exchange and ramp inspections. The latter generates safety information from a monitoring function: checking on the ramp. The first function gathers, exchanges and analyses safety data and makes safety data available for policy-making.

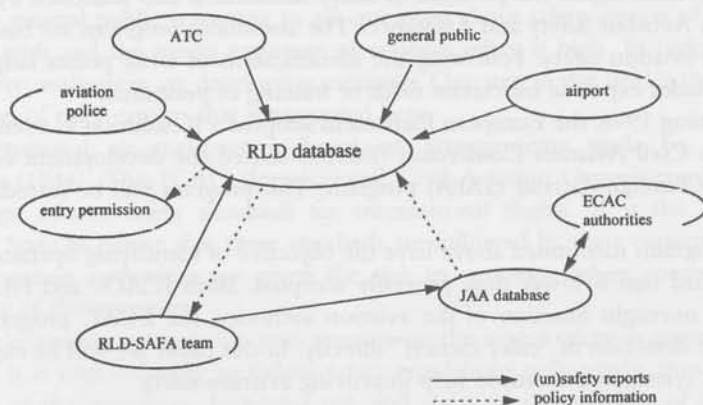


Figure 1.

Information on the safety of air carriers is available through a large number of sources (see Figure 1). At the moment various countries use different sets of sources. In the Netherlands sources include Air Traffic Control, airport authorities, people working on the ramp, police and even the general public as they also will be aware of safety items. In addition, the safety aspects of an operation can be judged from the results of investigations at the ramp. Links are established between all sources and the RLD-SAFA team. The information gathered is used locally for policy making in various fields: entry permits for flights, Ramp Inspection targeting, contacts to affected authorities, assistance programs or other corrective actions towards the operator. In the international SAFA cooperation the results of all ramp-checks, together with other safety-related information is exchanged through JAA. The JAA database is the coordinated core of ramp inspection reports and subsequent corrective actions that are taken. Every ECAC State fills the database and has access to the information stored at

JAA. Procedures are established for the information exchange. The JAA data can be seen as the international source of information whereas the additional, other sources are reporting systems of national organizations.

The most important step taken in the SAFA program in the establishment of dedicated ramp-check teams. In the past it was left to the authority of the home country to inspect the operator. Awareness of lacking oversight forced other authorities to take the initiative and inspect visiting operators. The ramp-check has the following elements: paperwork of crew and aircraft, general and technical condition of the aircraft, (cabin)safety items (including emergency equipment), operational matters (e.g. flight planning, load sheet) etc. The inspection follows the JAA developed checklist thus ensuring a common approach at every SAFA ramp-check. As the inspection is performed during turn-around, time is limited, and the inspection is non-disturbing, much effort is put in developing an efficient method. Typically, it takes about 20 minutes for a standard ramp-check. The result of the check is put into the national database and sent in to the JAA. Also a copy is sent to the operator for information.

As the bases for the ramp check ICAO standards are used, as these cover international aviation rules. These are the minimum requirements, although much countries have developed additional rules that go beyond the ICAO standards (e.g. JAR and FAR regulations). There is a clear link between the ICAO standards and the checklist used.

Which operator is due for inspection is based on all available information. A priority scheme is used which ensures a closer and more frequent look at operators which come out of the program less favourable. Being a non-discriminatory program, all foreign aircraft are subject to ramp inspections, including those from other ECAC and/or EU countries.

4. Follow-up

The SAFA program is set up in order to identify operators that do not meet the standards of ICAO. Once weak operators are identified various options for follow-up are available including banning all suspect operators. Every approach has advantages and disadvantages: banning of operators will possibly lead to retaliation action from the other country involved and little chance of improving the safety situation at the operator, thus for the aviation community as a whole. However, it prevents possible unsafe aircraft from flying over the country.

Assisting and stimulating operators or their authorities is another approach. Assistance programs, however, have a long term character are not normally accompanied by measures against the third country. All ECAC countries have their own responsibility in taking the appropriate measures. In SAFA coordination meetings a coordinated approach is sought and experiences are shared between the member states. As the program just has started and not too many risky carriers have been identified, the approach towards them is not yet mature, and will need further development. Attitudes from both operators and authorities differ and the need for specific measures differ accordingly. In general however, the SAFA program is well accepted in most countries and by most operators. This has been confirmed in the recent ICAO Conference on Safety strategy.

Experience of RLD has shown that both operators and corresponding authorities act positively on the deficiencies found at ramp-checks or otherwise. Immediate actions were taken which prevented re-occurrence. Communication between concerned authorities is enhanced, which in itself is a positive contribution to aviation safety improvement.

The approach of the Dutch government in this field is that the most positive effect on aviation safety can be obtained by giving assistance to other authorities in fulfilling their safety oversight function. Furthermore RLD will investigate the possibilities for Dutch industry to establish links with their foreign counterparts would the need arise for this. Basic requirements for this assistance would be: mutual benefit, voluntary basis, mutual contribution of resources.

Notwithstanding the aforementioned long term approach, the RLD SAFA team will monitor the safety standard of the operators visiting our country and will take appropriate action in case the safe operation of the aircraft is not ensured.

5. Conclusion

Identification of risky carriers is a contribution to the improvement of aviation safety. Improvement of safety is necessary in the light of the continuous growth of air transport. The European SAFA-program focuses directly on the safety aspects of foreign air-operators and gives a direct indication where assistance programs would be helpful.

Evacuation from Ships: Account for Ship Motion

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Abstract. A transnational BriteEuram programme on evacuation of passengers from ships is presented. Recent disasters on ferries of the roll-on/roll-off type have led to higher requirements for safety. These requirements are formulated in terms of overall performance rather than performance of a number of isolated components. This brings human behaviour high on the agenda because human behaviour is an important component of overall safety. Computer models provide excellent opportunities for predicting the overall performance as they can integrate human factors and equipment factors. Current computer models are inadequate for the maritime situation, because they omit important factors. A significant omission is the failure to address the effects of dynamic ship motion and the effects of heel/list (ship leans to one side) on passengers behaviour. One of the aims of the BriteEuram programme is to address these effects. The programme starts with considering new design features like "intuitive" guiding systems and corridors with special features. The effects these design features have in tilted and moving environments will be investigated in experimental studies with human participants. In the year 2000, the results of these studies will be incorporated in new computer models. The new results can have profound implications on the maritime industry. For example, given a ship's layout, estimates can be made under what sea states evacuation can still be done safely (that is, within the legal time limit); and what increases in safety are likely when (re)designing a ship.

1. Introduction

In case of an emergency aboard ships, passengers and crew must assemble at their muster stations. Muster stations, also called assembly areas, are relative safe areas where lifeboats or other life-saving equipment are within reach. People abandon the ship from the muster stations. The whole process, called mustering and evacuation (M&E), should proceed in a fast and orderly fashion. This will limit the consequences of an emergency as much as possible. How to make M&E an orderly process is the core of the project "Mustering and Evacuation of Passengers: Scientific Basis for design", called MEPdesign for short.

Due to recent disasters, the maritime sector is pressed hard to comply with new and stricter standards concerning M&E. Disasters such as the ones with the *Herald of Free Enterprise* and the *Estonia* have shocked the world and have made policy makers more aware of the need for improved regulations. An example is the SOLAS regulation for an evacuation analysis in the ship's early design phase. The regulation comes into force in the year 1999 for newly built ships (SOLAS 1995, Chapter 2-2, Regulation 28-1).

Regulations are not only becoming more strict - they are also formulated increasingly more in terms of total performance rather than the performance of isolated

parts of the M&E system. An example of a total performance requirement is an allowable time of 60 minutes for M&E. Total performance is clearly a better index of safety than performance of isolated parts. The consequence of a total performance requirement is that behavioural aspects are high on the agenda. Human performance is a major determinant of total performance. Hence, technical experts have to join hands with behavioural experts to assess overall evacuation safety.

How to make ships safer is not as easy as it looks. Exercises with volunteers are an excellent means to assess overall M&E safety, but the costs of such exercises are excessive. Wood estimated the costs of a recent exercise in excess of 70,000 U.K. pounds (Wood, 1996). The ship was in harbour during the event so the ship was as stable and level as a building in the city. Doing the exercise at sea to include the effects of ship motion on the behaviour of the passengers would further increase the costs of the exercise. Finally, it is far from clear what the shipowner or designer has to do should the ship fail meeting the regulation. This makes the demand for computer tools for the prediction of M&E performance very urgent. The potential of such tools includes early application - when the ship is under design, long before an exercise would be possible. Existing tools for the simulation of evacuations are based on the statistical approach to account for the large variability in human behaviour. For small groups, completely different evacuation times can be expected for different runs of the computer tool. However, when groups of 300 or more people are modelled, the statistical approach can better describe the likely overall M&E performance. With large groups, as is typical on many passengers ferries, the statistical tools can model the M&E process far better than purely physical models based on walking speed alone and no further human behaviour modelled.

The promise of computer tools for ship evacuation has to be realized to its full extent. Current tools are developed for other areas such as the chemical process industry, nuclear power plants, and offshore installations. In consequence, there is no representation of the special features of the ship environment. Even in "ship" models, there are surprising omissions like the failure to take into account passengers behaviours in a nonlevel and unsteady environment. Nevertheless, heel/list is a predominant scenario of a damaged ship (i.e., the ship leaning to one side, see Brumley & Koss, 1997). Nevertheless, sea and swell will very often rock and roll the ship. Moreover, it is obvious and has been demonstrated experimentally (Boer, 1993) that both list/heel and ship motion have strong effects on walking behaviour (see also Wertheim et al., 1994). In addition, the extremes of an unsteady environment have also indirect effects because they disorient, stress, or even panic the passengers. The consequence of stress can be described as "narrowing of attention" or "regression towards more primitive levels of functioning" which, in turn, means that guidance should be provided to the passengers in a way that is self-explaining or intuitively clear.

2. Theoretical framework

Figure 1 shows the processes of mustering and evacuation as influenced by human and physical factors. Design of escape routes (lower left) has to do with the layout of the ship;

in particular, the length and the capacity of the escape routes. Maintenance has to do with such elements as blocking escape routes by furniture. Safety inspections can be used to guarantee adequate maintenance. Guidance (upper left) has to do with informing the passengers about what route to follow. Individual interests has to do with private goals of the passengers such as to search first for relatives (children). Individual capability has to do with physical ability. Environmental conditions is a very broad category. It includes ship list/heel and ship motion.

For evacuation, the same factors apply in a different way. DESIGN has to do with the particular life-saving equipment; GUIDANCE with the instructions of the crew to the passengers and the complexity of those instructions; etc.

The project MEPdesign will address design, guidance, individual interests, individual capability, and environmental conditions. Failing to take these factors into account means that nonmoving and perfectly horizontal ships with perfect guidance systems are assumed - all very optimistic assumptions. As said before, an experimental study showed that walking was worse than normal in a ship motion simulator; moreover, volunteers who relied on the mustering signs exclusively needed twice as long as normal to reach the muster station (Boer, 1993).

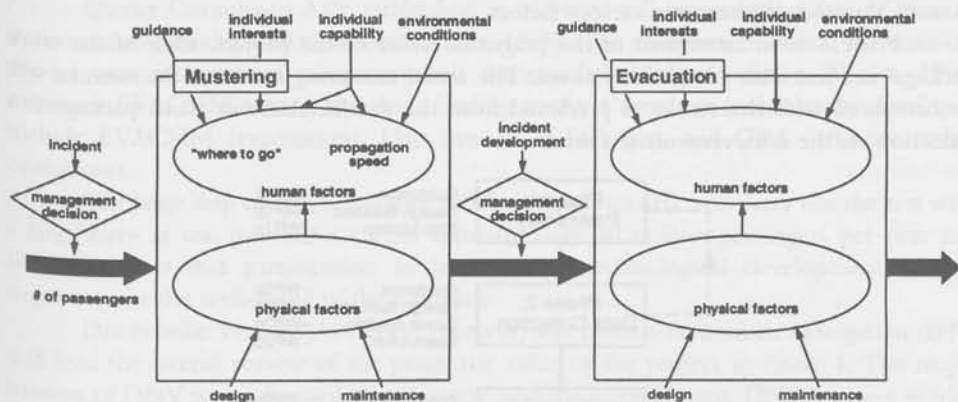


Figure 1. Factors influencing mustering (assembly) and evacuation.

3. Approach

The work of the Basic Research Project consists of four phases, as shown in Figure 2. The preliminary Phase 1 is definition. Guidance systems will be studied and new systems will be proposed such as systems that can be adapted to the emergency and systems that are intuitively understood. Also, the design of corridors and stairs will be studied and proposals will be made to adapt the design to help passengers to proceed in an unsteady and listed environment. Finally, ship motions and ship list will be studied to provide a representative scenario for emergencies.

Phase 2 is data collection. Under the environmental conditions specified in Phase 1, guidance systems, design features, group binding, and evacuation equipment will be tested

experimentally. The efficacy of different guidance systems will be tested in a life-size mockup of a ship's interior. The mockup can lean to one side. Large numbers of people will be asked to find their way in the mockup. The efficacy of different design features will be tested in a similar mockup. That is, it is recorded how fast people are following a route given particular design features. This time, "ship" motion will be added to the list/heel. The effects of group binding will be assessed by studying actual passengers during ferry trips. Groups binding refers to the tendency to unite the group first before commencing mustering. The efficacy of different life-saving equipment will be tested in a wave basin using scale models. The "mother ship" will lean to one side during the tests.

Phase 3 is very important for integration. In this phase, the heterogeneous "data banks" collected in Phase 2 are integrated into a computer tool for the prediction of total performance. There will be a tool for mustering only, a tool for evacuation only, and a tool in which the two are combined. These tools will bring to light whether or not improvements at a certain level will show up in total performance. For example, at the design level, newly designed corridors may permit 20% faster walking under unimpeded conditions, but due to congestion along the escape routes, this improvement can be lost completely. This example illustrates the potential of integrated tools: the tools permit users to study the tradeoffs between various factors.

Phase 4 is an assessment of the pragmatic value of the project. One of the work packages is a test with a large ferry at sea. The actual mustering results of the exercise will be compared with the results as predicted from the model. Another work package is a reflection on the achievements as a whole.

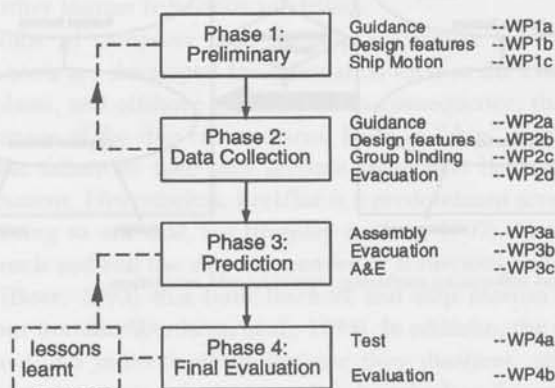


Figure 2. The work packages (WPs) and their relationship.

4. European consortium

A major financial contribution to the project comes from the European Commission as a grant within the European Industrial and Materials Technologies Research and Development Programme. The grant goes to a consortium of seven partners.

Partner 1 - also the coordinator of the project - is TNO Human Factors Research Institute. The institute is specialized in human behaviour and applies this knowledge to the design of human work and technical aids. TNO will lead the behavioural data-collection studies of Phase 2 using its ship-motion simulator and its facilities to construct life-size mockups.

The Danish Maritime Institute (DMI), a nonprofit, self-supporting R&D institute affiliated with the Danish Academy of Technical Sciences will lead the definition studies of Phase 1. DMI offers consultancy in the fields of hydro- and aerodynamics with special reference to the maritime, offshore, and construction industries. In order to maintain its position at the forefront of technology, DMI carries out a range of applied research programmes.

K ngliga Tekniska H gskolan (KTH), one of the largest technical universities of Northern Europe, established in Sweden will study evacuation equipment, thus adding the "abandon ship" knowledge to the project. KTH's Division of Naval Architecture will carry out the pertinent data-collection work using its wave basin and time-domain simulation tools for numerical modelling of the physical behaviour of ships in waves (e.g. Hua & Rutger sson, 1994).

Quasar Consultants A/S, established in Norway will integrate the data of Phase 2 into computer models and tools (see Quasar, 1996). The company is among the state-of-the-art manufacturers of computer tools for simulation of evacuation (Wood, 1996, mentions EVACSIM among the three leading tools). Computer tools already developed include EVACSIM (evacuation), LBL (launch of lifeboats), and ORS (offshore rescue operations).

The large ship owner Scandlines A/S based in Denmark will carry out the test with a large ferry at sea. Scandlines carries approximately 30 million passengers per year and firmly believes that participation in leading-edge technological development is very important for the well-being of the company.

Det Norske Veritas A/S (DNV, Norway) and Institut Fran ais de Navigation (IFN) will lead the overall review of the pragmatic value of the project in Phase 4. The major mission of DNV is to safeguard life, property, and the environment. DNV is active worldwide in maritime classification, and certification of management systems, products, and personnel (e.g. see DNV, 1996; Mathisen & Skjong (1996). As a leading classification society, DNV is in a unique position to implement results of research projects in Rules for the Design of New Ships and in prioritizing inspections of the existing fleet. The French IFN is a nonprofit organisation aiming to promote the sciences and technologies of navigation at large. The institute has close relationships with administrations, designers, and manufacturers of marine systems.

Contacts with Southern European countries are established through the Thematic Network SAFER-EURORO ("Design for Safety: An Integrated Approach to Safe European RoRo Ferry Design") led by Dracos Vassalos from Strathclyde University, Scotland. The thematic network unites almost 40 partners from all over Europe. It is intended as a platform for overall coordination and dialogue.

5. Expected results

A first achievement of the project will be computer tools that give realistic predictions for evacuation of passenger ships. The tools take into account human behaviour in a nonlevel and also an unsteady environment. The tools may have profound effects on ship design precisely because of the realism. Designers, ship builders, and ship owners can use the tool to explore the evacuation performance of a given ship. For example, they can find out what an improved ballasting system could mean for evacuation safety. What makes the tools so attractive is that they can be applied long before the final design. It will be possible to explore and to compare several designs and design variants ship before deciding on a final design. The tools will be accessible through the internet.

Another achievement of the project will be the recommendation of new design concepts. These concepts are aimed at making evacuation 20% faster in an unsteady and nonlevel maritime environment. The new design concepts address (a) guidance systems, (b) features of the ship's interior that enable the passengers to walk better, and (c) life-saving equipment. Designers, ship builders, and ship owners can trade-off the various design features because all features are integrated into the computer tool.

A final achievement could be the definition of new rules and regulations. The results of MEPdesign could be used to develop international regulations, justified by a Formal Safety Assessment, or to improve safety beyond international requirements.

References

- Boer, L.C. (1993). Ship listing: Reactions of passengers, TNO HFRI C-26. Soesterberg NL: TNO Human Factors Research Institute.
- Brumley, A.T. & Koss, L.L. (1997). The need for statistics on the human behaviour of passenger during the evacuation of high speed craft. Sydney: FAST'97.
- DNV (1996). Risk assessment of passenger ro ro vessels. DNV Technica Project C 6185. Høevik NO: DNV.
- Hua J., & Rutgeresson, O. (1994). A study of the dynamic stability of a RoRo-Ship in waves, STAB 94, Florida.
- Mathisen, T-C. & Skjong, R. (1996). Towards a rational approach to maritime safety and environmental protection regulations. In: Market Mechanisms for Safer Shipping and Cleaner Oceans. Rotterdam NL: ERASMUS UNIVERSITY.
- Quasar (1996). Evacuation models: State of the art. Oslo NO: Quasar.
- Wertheim, A.H., Heus, R. & Vrijkotte, T.G.M. (1994). Energy expenditure, physical work load and postural control during walking on a moving platform, B-8. Soesterberg NL: TNO Human Factors Research Institute.
- Wood, A.G. (1996). Validating ferry evacuation standards. In: Escape, evacuation & rescue: Design for the future. London: RINA.

Experience with the Usage of "Large Scale ECDIS"

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Ship bridges have seen a lot of equipment arrive since the 50's: radar, autopilot, echo sounder, (Doppler) log, etc.. During manoeuvres in narrow fairways, harbour basins, through bridges, etc. pilots and captains still rely almost entirely on visual observation of the outside world, in many cases assisted by officers on forecandle and/or stern. The reason is quite simple until now the equipment most of the time did not provide the same accuracy, reliability and information content that visual observation does. Also in most cases the information obtained by visual observation was sufficient taking into account the margins that ships and fairways provided.

Since the 70's ships' sizes have increased dramatically. However the fairway dimensions have not followed suit. The resulting smaller margins required additional information to visual observation. In a number of ports electronic navigation systems were introduced to assist piloting large vessels in the approach channels. An example is the Decca based "Brown Box" that was used for the approaches to Europort. These systems in general required a paper chart to interpret the ship's position. The increasing computing power of PC's led to the introduction of electronic chart systems for navigation. The name for these systems is ECDIS. ECDIS stands for "Electronic Chart Display and Information Systems". An ECDIS system does not only consist of a computer with a software for displaying the chart, it involves a lot of other components. Examples of these components are positioning system and functions to log information about course, speed, position and imported data. Examples on other components that can be incorporated are radar, echo sounder and compass.

The continuing miniaturisation of both PC's and (D)GPS receivers made it possible to use electronic chart systems in combination with standard DGPS for piloting. In a number of ports throughout the world pilot services are starting to use such systems in approach channels. Most harbour basins still provide sufficient margins to manoeuvre by visual observation even though the approach channel to these basins may be navigated with an electronic chart system. Optimisation however continues and also in harbour basins, bridges, etc. margins tend to decrease to a point where visual observation no longer provides sufficient cues to the navigator.

The importance of safety in modern shipping operations has reinforced the need to provide the mariner with timely, accurate information about ship status and position. ECDIS satisfies this need by integrating the information so far provided by the traditional

paper chart and the DGPS in a single display that is continuously updated. To ensure consistent encoding of information across different systems, standards are issued by the International Hydrographic Organisation (IHO).

One of the most successful builders of large, highly sophisticated cruise-vessels is Jos L. Meyer shipyard in Papenburg, Germany. Well-known ships that stem from this yard are P&O's Oriana and last summer Celebrity's Mercury. The yard is located some 40 miles from sea along the narrow and winding river Ems. The cruise-vessels that are built by Meyer nowadays have a length of about 270 m and a beam of about 32 m. The navigable width of the river is for a large part just 50 m. The radius of some of the bends is only 650 m. Also some very narrow bridges are passed.



Figure 1.

Complicating for the river navigation is the very high eye height - about 40 m - and the fact that the wheel houses of these vessels are located forward. Locating additional pilots on the bridge-wings and the stern provided insufficient accurate information both with regard to the present position and - equally important - with regard to the ship's movement, i.e. the future position. Adding pilots involves a mental translation of visually observed distances into numbers, e.g. meters, that can be communicated by mobile radio. The accuracy of this mental translation does not match the small margins. The conning pilot is confronted with distances that suggest that either the vessel's beam or the fairway width is fluid. Although so far all the ships built at the yard reached sea successfully, the yard aimed at maximum safety and reliability also with the increasing ship sizes while minimising infrastructural measures.

About five years ago Meyer Shipyard - from her experience with earlier deliveries of cruise-vessels - formed a special team consisting of the yard captain, the Technical Bureau

of the yard, KNC, SevenCs and STN-Atlas Elektronik GmbH to attain flawless transits for her vessels. This resulted in a commission to SevenCs and STN-Atlas Elektronik GmbH to realise the concepts developed by the yard captain, KNC and Meyer Shipyard.

The result of these efforts was a navigation system for tight manoeuvring situations that is basically a combination of radar and an ECDIS. In fact a special application of ECDIS, as it has to operate at large scales, that is a range of around 0.25 nautical mile or even smaller: the Large Scale ECDIS. The ECDIS shows the surroundings of the vessel with all the topography as well as the prevailing regulations and signals that are relevant for the transit. The chart is based on the Bundeswasserstrassenkarte, the official German chart, of the Bundeswasser-strassenverwaltung. Using a high-accuracy position measurement via the satellite based GPS in combination with other sensors, like for example gyro, position and heading of the vessel are continuously visible in her surroundings on the display of the navigation system. Before applying the system in real life it was extensively tested and compared to the previous transits in the full-mission simulator of MSCN in Wageningen, the Netherlands.



Figure 2.

The Large Scale ECDIS is a further development of the bird's-eye-view that was introduced by MSCN (at that time Delft Hydraulics) almost 10 years ago on board of Celebrity's Horizon and Zenith (also built by Jos L. Meyer) to assist master and pilots at St. George's, Bermuda and more recently on the Trident submarines of the Royal British Navy. These systems, however, used a rather primitive electronic chart.

The choice for ECDIS is largely based on the flexible object oriented structure of

the underlying databases and the ease of updating charts. The first provides the possibility to easily meet special needs, the latter takes into account the dynamic character of a fairway like the river Ems.

The river Ems is exposed to the tidal influence of the North Sea that leads to the permanent supply of sediments into the river bed. The fairway changes frequently. The importance of highly actual precise data for navigation purposes in river estuaries is obvious.

The internationally approved ECDIS standards ensure that various data sources can be used as the basis for an ECDIS chart data set.

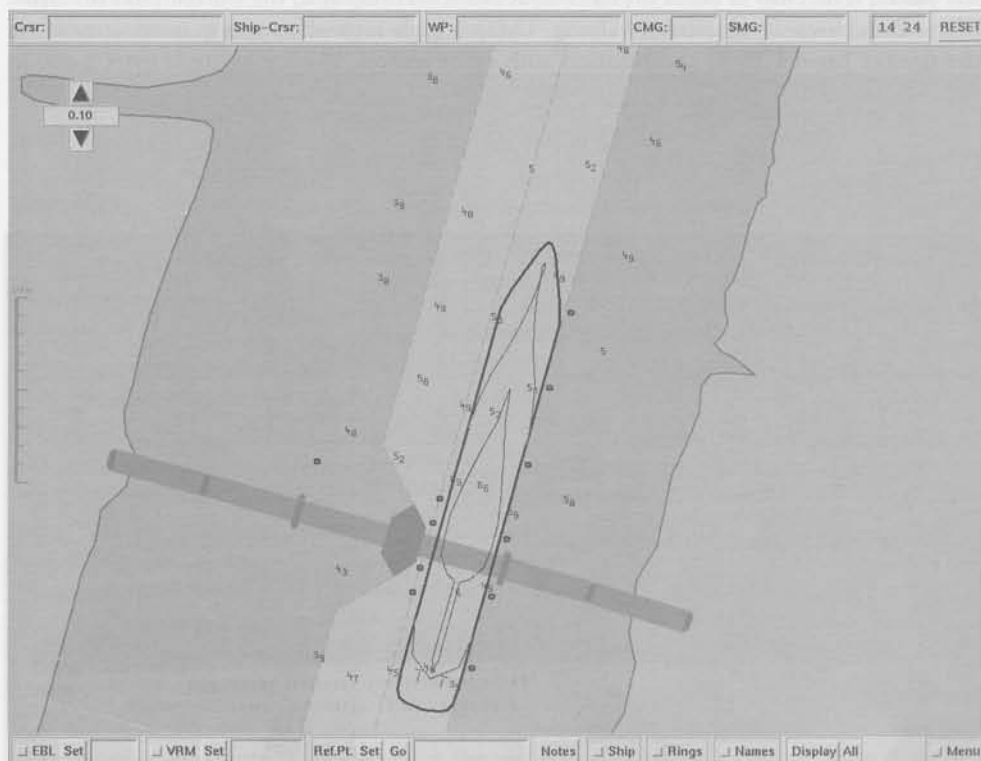


Figure 3.

Such data sets that are digitised from existing paper charts are already known and commonly used in standard ECDIS equipment. Anyway, the user has to bear in mind that paper chart based data sets include the resolution of information, the cartographic generalisation and the compilation of displayed items in the reality of the used paper chart! It should be evident that a paper chart at a printing scale of 1:25.000 should not be used to blow up the information in an ECDIS display at 1:10.000 or even larger. Following the ECDIS Performance Standards in such situation the chart display should be artificially cluttered by an overlaid pattern to warn the user of an "over-scale" situation.

For a Large Scale ECDIS operation equivalently large scale sources for the ECDIS data must be used. Meanwhile, it is proven that pre-processed survey data under the

responsibility of the local Federal Maritime Authority (Wasser- und Schifffahrtsamt Emden) provide the necessary source information. This data being supplied in digital form are converted to far extend automatically into ECDIS-compliant data. The fact that the survey is performed also using DGPS positioning guaranties the necessary precision and reliability. The automated, software based conversion of the data avoids an additional capturing error and mirrors the precision of the survey data in the ECDIS data.

Another requirement is the currentness of the data. A paper chart needs commonly at least several months for the production process until the publication of an actual edition. The deliveries of the Meyer Yard require up-to-date information based on the latest surveys that again can only be provided by the competent authority being directly responsible for the area. Within the delivery voyages, updates of depth information in the ECDIS data set based on surveys two days before could successfully be applied.

Further, large scale topographic charts and construction plans are used to add other necessary information, e.g. concerning the bridges. This guaranties that details like the beam between to bridge pillars are finally displayed in its real value at the ECDIS chart.

Thus, the displayed fairway area, shallow areas, river banks, groynes, bridges, locks, etc. shown at their correct position and true extension match perfectly with the ship's position derived from a high precision position sensor and assist to locate the ship with its huge dimensions correctly in the confined environment.

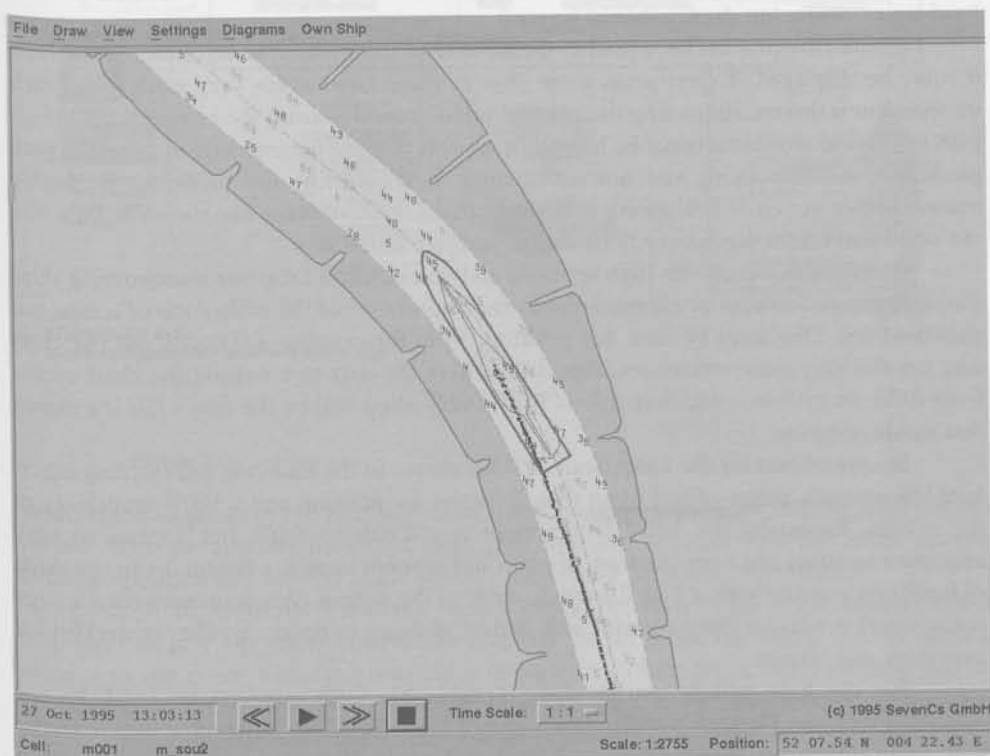


Figure 4.

A further important requirement deals with the presentation of the own ship's position. In an approach channel it may suffice to represent the ship on the ECDIS display by a generic point marker or a simple contour. Given the ornate line of cruise-vessels and the margins on the Ems, it is necessary to show the (very) different dimensions of the vessel at deck, waterline and bottom level. Usually the height of the shore is such that there is no harm in it when the bow reaches out over the shore.

The work-load of master and pilots during the transit is considerable, therefore a high degree of "hands free" operation of the ECDIS is required. In this regard the "re-centering" routine that is used by the ECDIS, is important. In general to reduce PC-processor load ECDIS operate in "true-motion" mode, i.e. the ship's representation travels over the display, usually in a limited area around the display centre. Whenever the pre-set limit is reached, the chart is redrawn and the ship's representation is re-centered. With standard ECDIS however just before re-centering most of the displayed area is behind the vessel and little ahead of it. To have sufficient view ahead of him the master/ pilot is forced to choose a smaller scale. Therefore a re-centeringrecentering option, where the ship travels from an off-centre position towards the display centre, is necessary. With the cruise-vessels of the Meyer yard the transit is only made more or less from South to North. In this case the north-up display of standard ECDIS is sufficient. For transits the other way around such a display mode requires a mental translation from left and right on the display to starboard and port in real life. In cases of a high work load this will inevitably lead to errors and a head-up or course-up display should be used.

Much attention has been paid to the amount of information to be displayed and how it must be displayed. Experiments show that at these large scales very easily too much information is shown, distracting the master/ pilots' attention from the essentials. Although path prediction would certainly be helpful, it appears that the present state of the art of path prediction is extrapolating and not anticipating. It is therefore not proficient for highly manoeuvrable vessels at low speeds in a very variable environment like the river Ems. On the other hand showing history does help to indicate tendencies.

A system that connects high accuracy and currentness of data for manoeuvring ships through narrow fairways or channels shows the importance of the calibration of sensor and data-modules. One must be sure that positions from for example a (D)GPS and the chart data use the very same references. Especially where the data to construct the chart comes from different sources - which in inland waters very often will be the case - this is a matter that needs attention.

Requirements for the Large Scale ECDIS system in the Ems case were among others a 99.5% accuracy radius of not more than 2 meters for position and a 100% availability of the system. Especially the latter requirement is difficult to fulfil, but appears to very important to attain and keep the trust of pilots and captains in such a system. In an approach channel one can live with a 1 or 2 seconds' drop of the system. When manoeuvring a large cruise vessel in a bridge opening with only meters' distance to concrete pillars or steel bridge structures one cannot.

For the Ems transits two geodetic Trimble SSi GPS receivers are used. In cooperation with the German Satellite Positioning Office (SAPOS) differential data from the permanent differential stations Leer and Emden (Knock) are available via a 2 meter band

radio link. Standby is a GSM telephone link in case the normal radio link is hampered. For the previous two transits the ECDIS was incorporated in the STN Atlas NACOS system that was available on board of the vessels. This will also be the case on the vessels for Star Cruises that are presently under construction.

So far the second GPS receiver has only been used as a back-up. However it is planned to apply Kalman filter techniques for future transits to avoid "position jumps" in case one of the receivers fails. Even without the Kalman filtering a very stable, highly accurate and reliable position information has been realised. A demonstration of this is the fact that the DGPS signal proved to be sufficiently accurate and stable to allow the making of a reliable graphic of forward and drift velocities of bow and stern on the Conning Pilot display. This is a very helpful add-on as the standard Doppler log does not operate with the available under-keel-clearances of just a few decimetres.

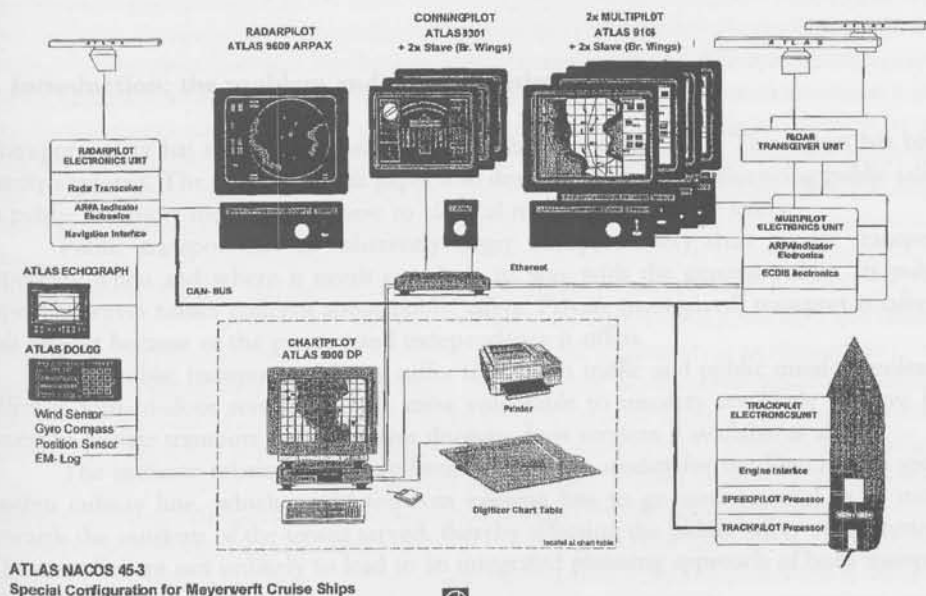


Figure 5. Radar and position display

With regard to accuracy the next step to be taken is compensation for heeling angles of the vessels. With an antenna height of over 50m one can imagine that the effect on the displayed position of a heeling angle of the vessel of just 1° is very significant.

Not to be neglected is the large mental step to be taken by pilots and captains when they have to give up visual observation and rely on an electronic chart at such small a distance to the shore. Simulator training is imperative to help them make this step and to get familiar with the different way of observation that is necessary when using such a system. Half of the job of manoeuvring is observation of the ship's position and movement. It is therefore evident that paying a great deal of attention to the development of and training

of adapted observation techniques is imperative. The successful acceptance by pilots and captains of a Large Scale ECDIS in reality on the other hand depends mainly on a high accuracy and a 100% availability from the very beginning.

The transits are made only once a year and the pilots handle much smaller vessels the rest of the time and without Large Scale ECDIS. Therefore the yard has the captain and pilots do a refresher training in the ship manoeuvring simulator shortly before every transit.



Transport Safety, Public Safety and Public Transport

Exploring an intricate relationship

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1. Introduction: the problem and its explanation

Transport safety has several dimensions. One is that of public safety. This aspect has been hardly explored. The purpose of this paper is to describe the factors influencing public safety in public transport and to relate these to classical transport and traffic safety.

Public transport has an inherently larger transport safety than private transport, especially when and where it needs not share its way with the general public. Its public aspect however causes concern about public safety. Private (motorized) transport is safer in this respect because of the privacy and independence it offers.

The public transport user may suffer from both traffic and public unsafety unless it offers a door-to-door service. People most vulnerable to unsafety are likely to have less access to private transport and expensive door-to-door services if available at all.

The intricate relationships have been explored in studies for the Dutch high speed eastern railway line, which might force an existing line to go underground or to move towards the outskirts of the towns served, thereby affecting the public safety of the system. These studies are not unlikely to lead to an integrated planning approach of both transport and public safety.

2. Transport safety and public safety

In the past transport safety was more or less synonymous with traffic safety or internal safety of the transport system: the chance to participate in traffic without damage resulting from human, vehicle or infrastructure failures. This chance is dependent on the subsystem one is utilizing, the technologically more advanced (separated, professionalized, automated) systems being the safest ones. Safety perhaps is threatened most where less advanced systems meet in public space, intended for human interaction but permitting rapid vehicle movement.

External safety, the chance of damage to the environment resulting from transport incidents, has received more attention in recent years especially because of the danger

inherent in chemical transports. In The Netherlands it lead a.o. to a dispute on the acceptability of building an office near Dordrecht station, with its important transports of Dupont chemical industries. The danger for approximately 100 additional office workers was regarded to be a problem, the fate of tens of thousands of passengers, already present on platforms and on board of trains, was disregarded. It might be called internal safety, but that can hardly be a reason for disneglect.

External safety too is likely to be best in technologically more advanced systems. Railway stations with mixed operations constitute a problem because of the confrontation of externally dangerous freight operations with large numbers of persons.

Public safety might be called the freedom from harm caused by deliberate human action. A logical question is whether this type of safety should be regarded as external or as internal instead.

Two hypotheses seem to be plausible:

- public unsafety may add considerably to both external and external unsafety
- public unsafety is a dimension of both internal and external safety

The plausibility of the first hypothesis is easily shown by two extreme examples: suicide and terrorism, which again may imply suicide. Transport means may be used to commit suicide. Throwing oneself before a train is a traditional and effective technique. It is an important cause of disruption of Dutch railway schedules with several hundreds of incidents a year. For passenger safety it is rather irrelevant though: the train is hardly receiving any impact at all. More problematic is the use of the motor car as an instrument for suicide, especially when a collision with another vehicle is sought. Some of the "ghost riders", using a highway lane in the wrong direction, have this in mind.

Terrorism in the transport system no doubt has an impact on internal traffic safety too, but it is more than suicidal actions likely to have an impact on external safety, simply because (potentially) excessive harm is the goal of terrorism. The Lockerby disaster is only one example. It shows that technologically more developed systems that are subjected to terrorism may have more disastrous external effects.

The second hypothesis implies in fact that public unsafety is internal to the transport systems themselves. The traditional distinction between internal and external safety of transport systems is in fact only one between victims on the road and off the road. External safety might just as well be conceived as safety outside the system. As a threat from outside this may have have transport internal effects, which may have to be mitigated. Therefore the Dutch high speed link to Belgium is guided by a concrete wall where it bundles closely with an existing highway: to be protected from collisions with lorries.

Transport systems do not exist in splendid isolation. They are intended to maintain communications between different geographic parts of society. Certainly the movement of persons and especially public transport, in which these persons get into direct contact, is likely to be a mirror of society in general.

Unsafety may deter people from using the or a transport system thereby threatening its essential function. Traffic unsafety may discourage participation with private means of transport, but public unsafety might reinforce this effect on the one hand (affecting walking and cycling especially) and affect the safety of public transport on the other hand.

3. Tunneling as a threat to public safety

Traditionally tunnels were built for economy. In designing railways and roads other infrastructure, like navigable rivers, have to be crossed and difficult territory (mountains or conurbanisations) traversed. Tunnels were constructed to avoid large horizontal or vertical detours or the great cost of adapting land- and townscape.

In The Netherlands, but in other countries as well, there seems to reign a tunnel mania, possessing the general public and local authorities and fueled by the construction industry. People are demanding tunnels in new infrastructure in circumstances which on the basis of cost or accepted values would allow for elevated or even surface constructions. Strict noise regulations make these more costly than they used to be, but as a rule insufficiently so as to justify tunnel construction, in spite of better (more profitable) development opportunities in the zone of the line.

Especially in the case of railway widening (doubling the number of tracks) there is an urge to put the entire line in a tunnel within built up areas. With the line the railway station goes down as well. The underground situation, out of sight, might create public unsafety though. Even if the objective safety (the number of incidents) would not deteriorate, subjective safety (people's perception of the chance of an incident) might turn more negative. Even if it is perceived only as a loss of amenity it might distract passengers from using the train, especially during off peak periods. It could be even fatal for the exploitation of less used stations. This is the problem as it was perceived by the project management of the Dutch High Speed Project Southeast.

4. A research programme for the High Speed Train Southeast

Dutch government is working at high speed rail connections to its neighbouring countries, Belgium and Germany. To Belgium an entirely new line for 300km/h is built from Amsterdam Airport to the Belgian port of Antwerp: the HSL-South for which construction is expected to start before the year 2000.

After some debate the idea of a new line to Germany was dropped. Instead the Amsterdam - Utrecht - Arnhem - Emmerich line to Germany will be doubled and adapted for 200km/h operations. The first stretch, to the town of Utrecht has been agreed upon, except the part within the municipality of Abcoude, which demands a tunnel supported by national parliament. Planning for the Utrecht - German border stretch is still in its beginnings, but several municipalities are demanding tunnels for the passage of the HST-east through towns like Ede and Maarn.

As part of the planning process a series of studies into public safety was undertaken, with the ambitious goal of assessing the contribution to public safety made by depressing stations and the impact it might have on travel behaviour.

During 1996 and 1997 four studies were undertaken in the following order:

- a literature survey by Holland Railconsult (an NS company),
- an effort to construct a theory on public safety of railway stations by TU Delft,
- a "quick scan" on the basis of existing railway data to estimate the potential number

of passengers lost at stations that might be depressed, by several parties lead by Heidemij Consultants (now Arcadis),

- a design oriented study of the most important HST-east case: Ede station by Holland Railconsult and TU Delft.

In this paper the emphasis is on the theoretical study by the present author, but some outcomes of the other studies will be discussed. In the studies public safety was only loosely connected to other types of safety.

5. Public transport tunnels and public safety in literature and sources

An extensive literature survey produced several general sources on public safety as related to the physical environment, but hardly any source on public transport let alone railway stations. Inquiries amongst foreign railway companies were completely unproductive. One might think that the problem is nonexistent. The existence of railway police and the presence of a multitude of surveillance cameras on stations (at Amsterdam CS at least 120) are proof of the contrary.

Social safety proves to be a multi-faceted problem: it can be identified with certain areas, times and population categories both in an active and passive way. Areas with little social control but some shelter for assailants are most problematic, especially after dark. The potential victims, relative defenceless women and elderly tend to avoid these circumstances.

A Dutch survey showed that people felt most unsafe in the most segregated public system, the underground, and least so in the most integrated one, the bus. The variables responsible for this distinction were not identified. For Dutch railway stations regular surveys and incident registration give a relatively reliable picture of social safety and its causation but only in general terms. During the day(light) there is hardly any public safety perceived. Only border stations with foreign drug abuse are scoring higher than 10%, the notorious station of Heerlen on the German border ranking highest. Platform tunnels and empty platforms are mentioned as unsafe places. Crime on railway stations can be called petty: hardly a case of murder, no rape at all, and instead predominantly deviant, annoying behaviour, pickpocketing etc.

Depressed stations being the exceptions as yet (only two examples, at Rotterdam and Rijswijk respectively) the public safety of this type of station could not be assessed. A comparison of safety records of stations with and without platform tunnels respectively, showed no significant difference. This is hardly surprising given the large variety of stations, with differences in use, layout and environment.

An estimate of a potential decline in passenger numbers was rather difficult too. It requires detailed information on passenger sex, age and travel hours. This was available only crudely.

The efforts to grasp the substance of public unsafety and its contribution to a decline in passenger numbers did not yield very tangible results. Yet the risk to loose passengers during off peak hours, when they are of particular value for profitability, was a sufficient motive for both a theoretical and a practical exercise.

6. Theorizing on public safety and tunnelled stations

Looking for the impact of an underground location of a railway station, one is trying to assess the impact of only one of the causes of public safety. Besides physical variables social ones are important. Measures against unsafety should be based upon both categories. Preferable are measures that work "automatically", through "social control" or the physical conditions for it.

In traffic safety the tendency in Dutch policy is different: intensifying formal and physical control of behavior. In both internal and "external" safety problems we have to do with the control of machine-systems however, whereas public safety is essentially social. On the basis of the insights gained from literature one can distinguish four conditions for public safety of railway stations or of public places in general, disregarding the presence of potential attackers.

Two conditions are social in character: company and control (social and formal). The other conditions are physical in character: sight and escape. These conditions seem to consist of a number of subvariables, which will be mentioned briefly. Their relative importance is often uncertain, but do require attention in any case.

The most important condition no doubt is company: accompanying persons, fellow passengers, visitors of station facilities and passers by. Amongst people nothing much can happen. A second condition, more or less contrasting with the previous one, is escape: the possibility to retreat, either into an enclosed private space (like the motor car offers) or into an adjacent public space. The condition is important both objectively and subjectively: a possibility to avoid unwelcome company, and the feeling not to be pent up.

A third factor is sight: the possibility to look ahead, transparency, lighting. It makes avoidance not easier, but at least potential danger is visible, and for other people as well. In design and management of Dutch railway station this condition is optimized if not maximized: glass palaces bathing in light. The fourth condition is control or supervision, both formal and informal, with and without technology. It is served by sight of course.

In spite of the importance of social conditions, or maybe thanks to them, the physical factor of elevation, the position relative to the surface, is definitely relevant, because (simply stated) public life takes place at the surface. In fact an underground situation exerts a negative influence upon all four conditions. An elevated situation is less detrimental because the it allows for better sight and (social) control.

In an underground situation there is little (costly) room for facilities attracting outsiders, a smaller chance for passers by unless there is a pedestrian stream forced to pass through, it is difficult to create easy ways out or transparency etc. The contrast with the usual glass palaces makes the enclosed underground space all the more repulsive.

7. Conclusions: a comprehensive approach required

The research for the HST Southeast should be functional in moderating local authorities demands for depressed railways and ditto stations. It certainly made us clear, that in planning railway stations, in planning for a public transport that is attractive at any time and for

anyone, a comprehensive approach is necessary.

A maximum public safety of public transport can be achieved by putting a station in the centre of local life, with pedestrian and cycle routes passing along and through it and with activities around it. Of course this is necessary too for commercial success of the railway. The concentration of streams of "weak traffic participants" moreover enables the planner to provide them with separate facilities enhancing traffic safety.

Public safety predominantly is a problem of late hours and for relatively helpless people. Then offering help might be a solution: demand responsive transport from house door to train door, and not to station door, as is the case with the Dutch train taxi. An additional solution is reduction of the operating space of the station at night: using only a restricted area both at the roadside and at the railside and keeping it under continuous professional surveillance.

The Ede-Wageningen case-study showed that a comprehensive approach is no common practice as yet. The station was located at a railway crossing in the road between the towns of Ede and Wageningen. Ede gradually expanded to the station and across the line. About 15 years ago a new station was built and the road was led through a tunnel at a few hundred meters distance. Cyclists too were supposed to use that tunnel. For the inhabitants of the town quarter across the line it is a detour though and therefore they use the pedestrian tunnel of the station, often cycling through it in spite of threats with high fines. Pedestrian safety, or at least amenity, is threatened in the tunnel, which is the only access route to the intercity tracks. From the environment there is neither sight nor social control on the platform. Massive concrete walls, sharp curves and hidden corners spoil sight within the station as well. Both the road and the pedestrian tunnel are perceived as unsafe by the general public. The main entrance of the station is nearly hidden for passengers approaching the station, the waiting buses to Wageningen are hidden from the passengers leaving the station. The lighting of the station is continuously intensified, the station squares look all the more dark because of that.

Yet on the basis of registered incidents social safety is not a big problem at Ede-Wageningen, in spite of a number of tramps. One evening we counted passengers and observed behaviour in and around the station. To our surprise women were overrepresented, but elderly people were practically absent in spite of good light and weather.

The station has a frequent train service and it is well used, as the connection for two towns with higher education facilities. The squares at both entrances are under (informal) surveillance of local transport drivers long after the station personnel has gone home.

Chemical transports to nearby Akzo synthetic fibre factory are handled close to the platform. Really frightening are the Eurocities thundering along too narrow platforms at a speed of 140km/h. The station manager for the region thought it out of date: shouldn't platforms be sealed off from the tracks, to be opened only at the arrival of a train? At least it would save the waiting passengers from witnessing suicide. The only fixed design criterion for non-HST stations, no platforms along HST tracks (200km/h), may increase subjective safety but it will not prevent these incidents.

References

- E. de Boer, 1997, Sociaal veilige stations ondergronds? Naar een kader voor beoordeling en ontwerp, TU Delft on assignment of NS-RIB, Delft/Utrecht.
- F. van den Burg, 1997, Sociaal veilig op papier, literatuurstudie naar de relatie tussen sociale veiligheid op stations en het aantal reizigers, Holland Railconsult on assignment of NS-RIB, Utrecht.
- L. Molenkamp, G. Zijlema en E. de Boer, 1997, Quick scan mogelijk reizigersverlies door aanleg van ondergrondse stations, Heidemij e.a. on assignment of NS-RIB, Arnhem/Utrecht.

High Speed Trains and Safety in the Netherlands

Report of a national working group for disaster response

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Abstract. A working group installed by the Ministry of the Interior performed a safety study for the advent of high-speed trains to the Netherlands. The perspective of local disaster response agencies was chosen. The main objective was to incorporate considerations for disaster response in the design of the train and the track. Representative accident and response scenarios were drafted. It became evident that at some locations there is a discrepancy between the demands of a representative response and the actual response potential. Solutions have to be found for these locations, either by measures in the infrastructure, or by adding to the support facilities, or the response potential.

1. Introduction

Currently decision making on High Speed Trains (HST) is an issue in the Netherlands. The main issues are: the connection with the surrounding countries, spatial incorporation and environmental consequences. Safety is one of the factors for decision making.

Several approaches can be taken for safety considerations. The Dutch Ministries of Housing, Spatial Planning and the Environment respectively of Transport, Public Works and Watermanagement take a risk approach. A working group installed by the Ministry of the Interior took the perspective of disaster response instead¹. The results are presented in this paper.

It is relatively new to take the perspective of disaster response in safety studies for major projects regarding Dutch infrastructure. Hence its scope and significance are still to be determined.

¹ The working group resorts under a project team consisting of representatives from the Dutch Railways, several Ministries (the Interior; Transport, Public Works and Watermanagement; Social Affairs and Employment; Housing, Spatial Planning and the Environment), the operational services (Police, Fire Brigade, Public Health Services) and an independent advisor.

2. Objectives

The concept of safety only has meaning in a societal context. Inherent in the concept of safety is that a safety-level exists below which the remaining risks are accepted by society. Disaster response teams are instituted to deal with these remaining risks. The basic objective of the working group has been to rationalize the efforts and expenditures for dealing with the remaining risks of the HST. More matter of factly, the objective was to incorporate considerations for disaster response in the design of the high speed train and track in an early stage.

Early consideration of disaster response has several advantages. It creates a "win-win" situation where the designers as well as the disaster response organizations can benefit in terms of tailor-made plans. Most importantly it enables early incorporation of easily adaptable aspects in the design, e.g. the adjustment of maintenance-roads to allow for access by disaster response teams. In addition it facilitates a rational choice between preventive and preparative measures, e.g. between investments in the infrastructure, in supporting facilities or in disaster response.

3. Approach

A hazard and response assessment was performed. Both accident scenarios and response scenarios were drafted. Basic health-standards were adopted to develop operational testing criteria. This resulted in representative accident and response scenarios that served as guidelines for an adequate response. Finally local response agencies were asked to make an inventory of points along the track where the response capacity did not measure up to the representative response.

Overall the assessment consisted of five steps:

- inventory of potential accidents,
- selection of representative accidents,
- specification of representative effects and consequences,
- specification of representative response,

followed by:

- evaluation of actual response capacities, by local response agencies along the track.

4. Accident-types

With the aid of event trees a range of potential accidents was identified and characterized. Accident causes resulting in a similar accident were aggregated, e.g. derailment by sharp curves in, obstacles on, or dislocation of the track. Overall, seven types of accidents were distinguished (Table 1). These types of accidents will serve as checklist for (future) evaluations of design characteristics, e.g. the construction of stations such that individual accidents are not likely to occur upon entrance of the HST, or with (high speed) passage of the station.

Table 1. Types of accidents.

Derailment
Collision
Fire
Suicide attempt
Individual accident
Bomb threat

Subsequently, accidents with a potential for major loss of life were identified: derailment, collision, fire and bombing threat. From these, derailment and fire were selected as representative for a type of consequences and/or response. Derailment was chosen as representative for derailment and/or collision (with comparable consequences and response). Bombing threats were not considered within the working group for confidentiality reasons.

The next step was to choose the most relevant settings for the remaining types of accidents. For derailment an open field setting at full speed was chosen (soppy pastures), whereas for fire a standstill in a tunnel was deemed most relevant. Only derailment will be dealt with in this paper².

5. Derailment scenario

The drafting of scenarios is a creative rather than a scientific process. A more or less objective assessment is only partly possible. Consequently, expert opinion is of paramount importance. A(n unstructured) consensus approach was adopted to elicit expert opinions. A consensus approach was preferred over intersubjective weighing methods, because improvement of the current situation seemed of more interest than some "true value". Therefore the working group set themselves to the task of devising a scenario that was highly realistic and would form a challenge for local response teams for the first ten years or so to come.³

Derailment causes acute deceleration forces that result in the propelling of luggage and passengers, mechanical distortion of the train and fragmentation of glass. As a consequence a significant number of passengers will be killed or wounded, especially in the first two compartments. The types of lesions can be specified and grouped and numbers of victims can be estimated.

The lesions were grouped by level of severity into so called "triage-groups". Triage is the continuous process of determining the urgency of treatment for acute patients. In the Netherlands a uniform triage system has been adopted for mechanical lesions, such as occur with derailment of trains (Table 2). This system has been adapted to field circumstances. Triage groups presuppose free access to the patients.

² The tunnel-scenario is currently under investigation in the broader context of tunnel-studies.

³ The development time of the high speed track is almost ten years.

Table 2. Dutch triage system for mechanical lesions.

T1	Immediate threat to life, stabilization of vital functions needed within 1 hr
T2	Indirect threat to life, stabilization of vital functions needed within 8 hr
T3	No life threat

This system has been slightly adapted to allow for patients that cannot be readily rescued, because of the mechanical distortion of the train. In the moderate climate of the Netherlands the body temperature of victims may drop to dangerously low levels after about two hours during a large part of the year. This is even more true for patients with little or no body movement because they are seriously injured. If rescue is delayed for a longer period of time excess mortality is to be expected. The triage system has to take this into account (Table 3).

Table 3. Adapted triage system for situations with delayed rescue of victims.

T1	Immediate threat to life, stabilization of vital functions needed within 1 hr
T2	Indirect threat to life, stabilization of vital functions needed within 2 hr
T3	No life threat

For some types of accidents empirical data are available about the division of patients over the triage groups. No such data are available for HST's, however. As a matter of fact no valid data were found for train accidents. The accident-type with valid data most similar to HST-derailment was: start and landing accidents of airplanes. From these data a estimate was derived (Table 4).⁴

Table 4. Number of victims in scenario derailment.

Access	T1	T2	T3	TOTAL
Unhindered access	1	3	18	22
Hindered access	3	7	12	22
Entrapped victims	8	8	5	21
TOTAL	12	18	35	65

6. Response scenario

Major accidents and disasters require a coordinated effort of response agencies. Several interrelated processes and sub-processes can be distinguished. For the global purposes of drafting a representative response, however, it is sufficient to consider the overall response process. The response process can be divided into a number of phases (Table 5).

The phases can be characterized by the build-up of capacity over time and be related to the demands posed by the triage system. The demands that T1-victims have to be stabilized within one hour and T2-victims within two hours put a time limit to the "end

⁴ Modeling of lesions was not within the realm of the working group.

phases" of the response activities. Now it has become "only" a matter of counting back to the start of the accident to derive the representative response. Indeed, this exercise was performed, again by means of expert opinion (Figure 1/ Table 6).

Table 5. Phases in disaster response activities.

Phase	Short description
Detection	Time interval between start accident and its detection
Internal alarming	Time interval between detection and alarming passengers in train
Evacuation	Time interval between alarm and reaching a safe place outside train or tunnel
External alarming	Time interval between detection and alarming of rescue services
Attendance	Time interval between the first alarm and the arrival of the first rescue service unit at the deployment location
Deployment	Time interval between the arrival of the fire and rescue service units at the location of the incident and the operational deployment of the response agencies
Rescue	Time with elapses between the internal emergency officers/fire and rescue services being deployed and the moment when everybody has been evacuated from the imperiled area and if needed has got medical first aid
Aftercare	Period after rescue needed, for re-establishing of the normal functioning of the HST system

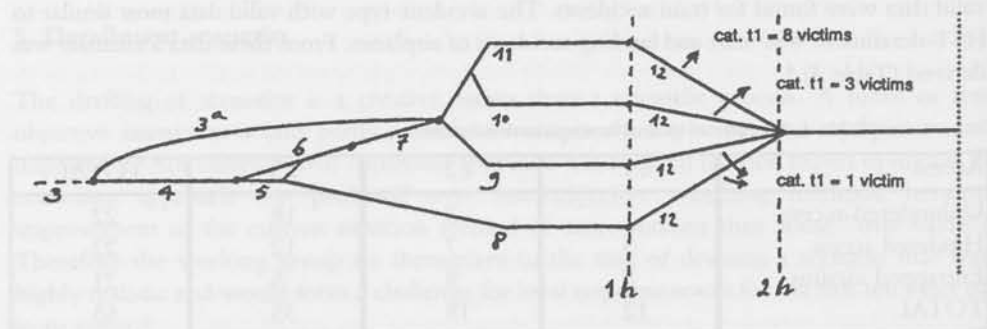


Figure 1. Time schedule for phases in disaster response activities.

With train accidents it is generally most troublesome to reach the accident site (through sappy pastures and over canals or sound barriers), to gain access to (the remains of) the train and/or to extricate entrapped patients. The time estimates for these activities are relatively uncertain. Especially the time required to reach the site can vary quite drastically, as it depends on the distance response workers have to go on foot. Further investigations showed that firemen can walk about ten minutes with the necessary equipment, e.g. for gaining access to the train. From these investigations it was further concluded that the maximum walking distance is 250 m and that there should be an access (incl. turning point and dispatchment area) for motorized vehicles, such as ambulances and fire fighting trucks, up to that distance all along the track.

Table 6. Time schedule for phases in disaster response activities.

Phase	Time (minutes)	Cumulated time (minutes)
(1) detection	0	0
(2) internal alarming	0	0
(3) external alarming	5	5
(3a) charge removal	2	(30)
(4) attendance	5	20
(5) first exploration	15	(25)
(6) accessibility of rail and train	5	45
(7) safe working conditions	25	45
(8) rescue of victims outside the train	0	(50)
(9) rescue of readily accessible victims in train	5	(55)
(10/11) make access to victims in closed train	5	60
(10/11) extricate trapped victims in train	15	60
(10/11) stabilize victims	15	60
(12) medical help to prevent supercooling	0	120

7. Evaluation of local bottlenecks

Local disaster response agencies have used the above guidelines to evaluate their potential response to accidents with high speed trains. Especially the maximum walking distance of 250 m was gratefully employed as testing criterion. Several exceedings of this maximum were noted. In some cases it is rather simple to correct these exceedings by extending or enlarging a road. In other cases, however, such measures are less feasible or simply impossible, e.g. restricted by waterways, and other solutions have to be sought.

8. Conclusion

The scenario method for incorporating considerations of local disaster response in an early stage of the design process proved to be useful in the case of the HST in the Netherlands. It resulted in the identification of local bottlenecks along the planned HST railroad.

Of course, this is only in contribution to a more general safety approach. With a more general approach it is possible to weigh the various solutions. Very often it is better to prevent accidents from happening than to create facilities for dealing with accidents. But it is very difficult to state that a certain accident, say derailment, can never occur. Only when a scenario can not occur, one can safely say that no measures are needed to cope with it. Usefulness of the described method in other cases will be investigated.

The Ergonomics of Traffic Signs

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1. Introduction

From the user's point of view, the road signs are understood as a whole, and at the same time, as a part of the driver's environment. The observation and analysis of their effective components allows us to say that the elements of the environment and the interpretation of the signs may be classified into two groups, endogenous, intra-individual and exogenous, coming from the environment wherein the user lives.

When used as a simple codified association between color and message signs do not assure user comprehension. The fact that a code works for its originator does not imply that it works in the same way for the user. In this case, the communication may be flawed.

An informative element is designated as a sign, which is composed of two elements: the significant, in this case the road sign and the meaning that it connotes, the concept or message. The road signs are at the same time code and language; sometimes the former, other times the latter. For example, a code in association with the colors and a language represented by a slash.

Lucet et al. (1975) divided the road signs in accordance with the way in which the object was represented. The first being manifested when the object is easily identified e.g. a bicycle. The second being a stylized representation, when the object is represented by a symbolic picture, as in the case of a straight road and the third being a conventional arbitrary representation. The reaction time of a verbal message is less than that of a symbolic sign (Dewar et al., 1976; Loo, 1978).

An analysis of the driver's task raises the question which is the available time in terms of mental load and perception. Which would be the actual readiness time for the road signs? Mourant (1969) studied the driver's eye movements during driving activity and proposed that the time spent in the reading of the road signs is less than 10% of the total time measured, with the remaining time distributed between looking at the vehicle in front, looking at the road, or glancing randomly. Shinar and Drury (1983) showed that the signs seen during the night were more easily recalled than those seen during the day. This result could be due to the fact that the perceptive field at night contains less visual distraction than the perceptive field during the day.

The recognition of the road signs is influenced by the visual angle in interaction with the environment and even in this case the vehicle's speed does not influence the perception (Ladan & Nelson, 1973). On the other hand, road signs placed in a position above the highway are seen more quickly than those placed by the roadside (Forbes, 1969).

Some studies indicated that there is a difficulty in relation to the visual record of the road signs, related to the interest of the road user or the importance of the sign for his behaviour. Initially the sign is detected at the sensorial level, but the information may be or may not be stored mnemonically. The storage process occurs when the road sign provides an important clue for the driver (Johansson & Backlund, 1970; Summala & Hietamäki, 1984). Road signs were placed along a highway in such a way that they may be well seen by the drivers. When questioned about the last road sign seen, it was found that speed limit signs and police warnings were more identified than pedestrian signs (Johansson & Rumar, 1966).

Michault (1984) showed that there were three variables influencing the recognition of the road signs: the age, the cultural level and the amount of time since the initial issuing of the driver license. Whitaker (1985) studied the "airport sign", with a silhouette of an airplane and a directional arrow. The drivers did not interpret the orientation of the airplane as direction information when the arrow was absent. The reaction time was faster when the two symbols (i.e. airplane and arrow) were in agreement with the direction. Positive messages are easier understood than prohibitive ones and the slash; placed in the drawing obscures the perception of the symbol (Dewar, 1976).

2. Experiment I

The Brazilian Traffic Code includes warning and regulatory signs. This study was designed to investigate the knowledge of road signs by the professional drivers, in order to ascertain the presence of possible differences in this knowledge among professional drivers who work only in the urban area of Ribeirão Preto and other who drive longer distances (Alves dos Santos, 1988).

Sample:

Group 1- There were 500 drivers, residents in Ribeirão Preto, employees of company carriers, driving cargo trucks in the city and the near area.

Group 2- A 150 professional drivers of the same category, driving cargo trucks in the same area and at longer distances, city, neighbourhood and further.

Instruments: Plastic cards were used containing 10 road signs and an answer blank for the subjects.

Procedure: Each driver received a card and was asked to write out the official name of the road sign which has been learned previously in a driving school as well as he/she should behave in response to the sign. A total of 65 responses were obtained for each sign including the names and the behavioural meaning.

Results: Statistical Analysis revealed that only 4% of the official names were correctly recalled. In reverse, 43% of the answers concerning behavioural meanings were correct. In other words, the correct names of 96% of the road signs were not recalled and in 57% of the behavioural meaning were not known. The hit rate of some road signs did not reach 10%. Warning signs were recognized 1.67 times less than regulation signs (i.e. ratio of 3:5). Pictorial road signs were recognized more frequently than abstract and schematic signs. The A10 Brazilian road sign indicating - traffic emerges from right and A11- staggered junction

first junction first to the left were incorrectly identified 92% of the time. In contrast, correct identification of the airport roadsigns was 93% whereas the A30 sign(cyclists) was 66%. The continuous and interrupted demarcation lines of the highways were badly identified.

These results may justify the conclusion that one of the difficulties lies in the licensing process. A low level of instruction is required from the candidate: simple learning and technical names, without no accompanying symbol to behaviour learning.

3. Experiment II

Until now the Brazilian engineers were responsible for the road construction and the vehicle safety. But the best highway and the best vehicle do not make traffic safe without the user's collaboration. To improve this behavior an appropriate learning program is necessary, acquired through instruction, training and more demanding driver exams.

Regarding the results of Experiment I, it was proposed to work out a link between the technical engineering code and the comprehension of the road user. The traffic signs are not ergonomically adapted to the Brazilian drivers. Roadsign seem not to be an efficient conveyer of the coded message. Although it is extremely difficult to change roadsigns in Brazil, the authors have suggested a new teaching and learning program (Rozestraten, 1996; Alves dos Santos, 1988).

In ergonomics four main types of action may be distinguished:

- 1) the environmental ergonomics(temperature, illumination, oxygen)
- 2) the ergonomics of furniture and clothing (chairs, tables, shoes, trousers)
- 3) the ergonomics of machine and human work activities (wheel, gearshift, domestic and industrial machines with handles and pushbuttons)
- 4) the perceptual-cognitive ergonomics regarding the comprehensibility and facile learning of all types of symbols. For example: computer icons may be not ergonomical, and even useless, if there is no comprehension of keyboard manipulation.

All roadsigns are symbols which may not always be clear. As a simple example: the roadsign with an upward vertical arrow must be understood as a straight horizontal direction.

During instruction at the driving schools in Brazil candidates must associate names with roadsigns. Experiment I showed that pictorial signs as airport, school and workers were better recognized than signs indicating intersections and junctions. Besides the unclear design for the drivers with a low level of education, the technical names seem to be in a foreign language: because neither the designs nor the language are well understood.

In order to make the learning process easier and to provide an adequate behavioral repertory for the road users, the authors developed a manual "The Traffic signs and Safe Behavior" (Rozestraten, 1996). The most essential is the behavior involving "knowing what to do" rather than the name of the sign per se.

The manual follows the immediate rules:

- 1) Ranging signs in appropriate categories
- 2) Combining the technical name with a popular name
- 3) Indicating the most frequent location of the sign

4) Establishing the behaviours appropriate to the sign requirements or suggestions.

This program is referred to as: the Explicated Behavioural Method. If the signs are not very clear and do not provide ergonomically adequate behaviour, then signs must be better explained in order to associate them with the correct behaviours. There is some similarity between the icons on the computer screen/related keyboard manipulation, and the road signs/ the related behaviours of the road-users.

In order to test the efficiency of this Explicite Behavioural Method, Silva (1993) studied two groups of 15 men and 10 women: an experimental and a control group, using the matched group experimental designs (Mcguigan, 1968).

The experimental group was subjected to a pretest (A) of related behavioural knowledge of road signs. Afterwards the same group studied the signs using the Explicit Behavioural Method (Independent Variable). The following step involved the administration of the posttest (B) concerning behavioural knowledge of road signs; and finally, the official government traffic exam (C) concerning signnames was administrated.

The control group followed the traditional learning method, where the names and designs associations was required. The group was then subjected to both: test B, requiring behavioural related knowledge of the road sign and the official governments traffic exam.

An Analyses of Variance showed a statistically significant difference between test A and B of the experimental group in favour of the test B. The same test B and the official governments traffic exam were used with both groups. The results of test B showed a statistically significant difference between the two groups, showing better results in the experimental group. However not no significant difference was obtained for results of the official government exam. Thus it was clear that the simple association between name and design do not guarantee the aquisition of appropriate sign related behaviour. The same results obtained in the official government exam does does not show any difference between the groups regarding behavioural knowledge.

4. Conclusion

Results of the experiments, described above, suggest that ergonomical efficiency, specially involving perceptive-cognitive ergonomic activity, may be relative, and depends on the educational level of the population under study. In one cultural context road signs may be very clear and elicit appropriate behaviour, whereas in another cultural context the same signs may not be understood. In addition it was showed that explicit behavioural learning programs improve the ergonomical efficiency of transmitted traffic messages.

References

- Alves dos santos, R. (1988), Conhecimento da sinalização de trânsito em Ribeirão Preto, Dissertação de Mestrado, IP-USP, São Paulo.
- Dewar, R.E. (1976). The slash obscures the symbol on prohibitive traffic signs, *Human Factors*, 18(3), 253-258.
- Dewar, R.E.; Ells, J.G. and Mundi, G. (1976). Reaction time as an index of traffic sign perception, *Human Factors*, 18(4), 381-392.
- Forbes, T.W. (1969). Factors in highway sign visibility, *Traffic Engineering*, 39, 1-8.

- Iida, I. (1990). *Ergonomia, Projeto e Produção*, São Paulo: Ed. Edgard Blücher.
- Johansson, G. and Backlund, F. (1970), Drivers and road signs, *Ergonomics*, 13, 749-759.
- Johansson, G. and Rumar, K. (1966), Drivers and road sign: A preliminary investigation of the capacity of car drivers to get information from road signs, *Ergonomics*, 9, 57-62.
- Ladan, C.J. and Nelson, T.M. Effects of marker type, viewing angle and vehicle situation, *Human Factors*, 20(1), 65-74.
- Lucet, M.; Benguigui, R.; Rousseau, F.; Jayet, M.; Mure, M.J.; Matalon, B. and Averous, B. (1975), *Connaissance de la signalisation routière*, Paris, ONSER-Cahiers d'Études, Bulletin 35.
- McGuigan, F.J. (1976), *Psicologia experimental: Uma abordagem metodológica* tradução de Suzana Behmer Cardoso. São Paulo, EPU.
- Michault, G. (1984), *L'usager et la signalization routière*, Recherche Transports Sécurité, Arcueil-Cedex, 3, Juillet.
- Moraes, A. and Soares, M.M. (1989), *Ergonomia no Brasil e no mundo*, Rio de Janeiro, ABERGO/UERJ-ESDI/UNIVERTA.
- Mourant, R.R. (1969), Driver's eyes movements and visual work load. In Highway Research Board. *Drivers and driving*, Washington D.C. (Highway Research Record, 292).
- Loo, R. (1978), Individual difference and the perception of traffic signs, *Human Factors*, 20(1), 65-74.
- Rozestraten, R.J.A. (1996), *Os Sinais de Trânsito e o Comportamento Seguro*, Porto Alegre: Sagra-DC Luzzato.
- Shinar, D. and Drury, A. (1983), Sign registration in daytime and nighttime driving, *Human Factors*, 25(1), 117-122.
- Silva, V.N.A da (1993), *Estudo comparativo dos resultados do Método Tradicional utilizado pelas auto-escolas credenciadas em Campo-Grande-MS, para o ensino e aprendizagem dos sinais de trânsito e do Método Explicativo Comportamental proposto*, Monografia UFU, Uberlândia.
- Sperandio, J.C. (1980), *La Psychologie en Ergonomie*, Paris, Presses Universitaires de France.
- Summala, H. and Hietamäki, J. (1984), Drivers immediate responses to traffic signs, *Ergonomics*, 27(2), 205-216.
- Whitaker, L.A. (1985), Is the symbol sufficient to convey route information? *Human Factors*, 20(2), 229-233.

Low-Cost Safety Improvements at Freeway Discontinuities

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Abstract. Despite the already very high level of traffic safety on motorways, road operators are constantly trying to develop and test measures to improve safety on these roads. The high share of motorway traffic in the total car mobility in the Netherlands (nearly 40% of all carkm) is one of the motives to look for further safety improvements. Traffic movements at motorway discontinuities, such as on and off ramps, weaving sections, and lane drops, are potential sources of accidents. This paper reports on the effects of low-cost measures to improve traffic operations at "tapered" freeway exits. These are two lane exits with one initial exit lane and one tapered exit lane. Little is known about driver behaviour at such tapered exits although they are widely applied. Especially, the efficient and safe use of these facilities by drivers is of concern. Two tapered exits were used to test new pavement markings and traffic signs. Effects of these changes were determined by an observational before and after study. Traffic operations were evaluated and drivers were interviewed. Analysis showed a considerable decrease (more than 50%) of the manoeuvres considered most undesirable. Also, the safety measures did not influence flow characteristics negatively. The exits were generally perceived as safe to very safe by the drivers.

1. Introduction

In the Netherlands improving traffic safety is one of the priorities of the government. Ambitious goals have been set for traffic safety policy. It is intended to decrease the number of casualties by 50% and the number of wounded by 40% by the year 2010, compared to the 1986 level.

To achieve these goals, large scale schemes have been initiated, generally referred to as "sustainable safety" (1), which have important consequences for the road network as a whole. Apart from the cost of such large scale schemes, implementation of the scheme will take a very long period of time. Possibly, measures on a more detailed infrastructural level can achieve comparable results for much less cost. Also, small infrastructural changes may considerably improve the traffic operation quality as perceived by the individual driver.

This paper describes the effects of small adaptations to motorway facilities. The resulting differences in traffic operations have been evaluated and indicate consequences for traffic safety. The described case concerns the change of the pavement markings and traffic signs at freeway exits with a tapered lane. The changes were intended to counter those lane changing movements which endanger other traffic at the exits.

The next section describes different concepts of measures for improving safety. Then, section 3 describes the evaluated situation. Section 4 describes the evaluation results. Conclusions are given in section 5.

2. Overview of possible safety measure concepts

In general, two forms of safety can be distinguished. Safety which is dependent on the drivers' behaviour (active safety) and safety which is independent of the drivers' behaviour. Drivers can, for instance, "actively" influence their own safety by maintaining larger distance gaps. On the other hand, the driver's safety can be influenced "passively" by driving a car with air bags. In this paper only active safety is discussed. Measures which influence active safety in fact always try to influence behaviour. Such measures can be divided into three categories:

- "changing the driver": e.g. with information and education;
- changing vehicle characteristics: e.g. adding collision warning systems;
- changing infrastructure design.

In current practice, efforts are made with all three active safety measure categories. However, the level of safety often strongly varies by location. If the first two safety measure categories have an effect, this will only be on a long term and will probably not help much in relieving specific local safety problems. Therefore, the only option to improve local unsafe situations is by adjusting the infrastructure.

A large scale scheme, generally denoted as "sustainable safety", became the long-term government policy since the publication of the "Third Scheme on Traffic Safety". This scheme consists of a large scale rearrangement of the current traffic system. All roads are to be categorized according to their functions and the infrastructure is to be (re-) designed with design standards that are focussed on traffic safety (see [1]). The cost of this scheme and the time it will take to implement are both very considerable. To increase safety at known unsafe locations, measures on a smaller scale are faster to implement and may be just as effective. Also, the cost of small scale measures are limited.

Fitzpatrick et al. [2] describe an evaluation study of such small scale measures. They evaluate the effects of changes of pavement marking at lane drop exits at motorways. Lane drop exits are exits with one of the carriageway lanes used as exit lane. For instance, at a 3 lane carriageway the shoulder lane may serve as exit lane, which means that downstream of the exit only 2 lanes remain for the carriageway. At such exit configurations, drivers at the shoulder lane who want to stay on the carriageway need to change lanes. This lane drop was only indicated by traffic signs. Because the situation could be unclear to some drivers, lane changing could occur very late, and in an erratic fashion. To better communicate the lane drop to the road users, pavements markings were added at three test sites. These markings consisted of different lane striping starting 800 metres in advance of the theoretical gore point. Also, arrows indicating the exit lane were added to the pavement markings. The traffic operations before and after implementation of these measures were evaluated. In the new situation, two of the three sites showed that lane changing occurred significantly earlier and that the occurrence of erratic lane changing behaviour significantly decreased. It was

hypothesized that changes at the other site might have occurred outside the studied area. Another study showing the opportunities for similar measures to influence traffic operations is presented by Dijker & Vermijs [3]. They found, that traffic signs at lane drops at motorways influenced both the location of lane changing and the occurrence of different types of lane changing manoeuvres compared to the same site without these traffic signs.

In safety, objective and subjective safety can be discerned. Subjective safety is safety, as perceived by the road user. Objective safety is the observable safety. Subjective and objective safety do not need to be the same. Situations which are subjectively perceived as dangerous, may be objectively very safe. Next to the effects on traffic operation (objective safety), also the effects on subjective safety have to be taken into account.

This paper describes the effects of small adjustments made to the design of so called "tapered exits" at motorways. At these exits, manoeuvres occur which are considered unsafe. The design changes consist of different pavement markings and traffic signs. The effects of the measures on traffic operation are evaluated. The next section describes characteristics of traffic operations at tapered exits and the evaluated sites.

3. Characteristics of exits with tapered lanes

On Dutch motorways off ramps are designed in different ways. Depending on the traffic flow on the off ramp, the available space, and design speed, a specific design is chosen. One type of off ramp is the tapered exit. An exit lane to which, after a certain distance, another, called "tapered" in Dutch traffic engineering, lane is added characterizes this type of exit (Figure 1). Eventually there are two lanes to exit from the main road. This type of off ramp is used in situations in which the capacity of a single lane is not sufficient.

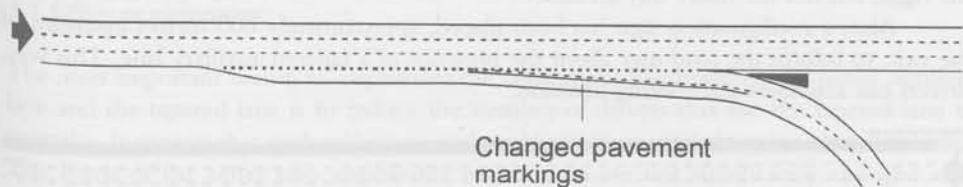


Figure 1. Layout of a tapered motorway exit

The composition of the tapered off ramp allows some vehicle movements which are undesirable in terms of traffic safety and traffic flow (Figure 2). The manoeuvre which is considered most problematic is the manoeuvre where a driver first uses the initial exit lane and then uses the taper to overtake another vehicle. This manoeuvre can lead to a conflict with a driver who wants to exit directly using the taper. Besides a decreased safety, this can lead to less than optimal utilization of the tapered exit, and to clustering of traffic on the right lane upstream of the exit. The second undesirable manoeuvre is a temporary return to the carriageway, and then exiting again by the tapered lane (manoeuvre 2). The last unwanted manoeuvre is a very late exit, from the median or middle lane (manoeuvre 3). A driver performs a late exit when he stays on the median or middle lane until less than 150 metres before the nose of the island and then exits via the tapered lane.

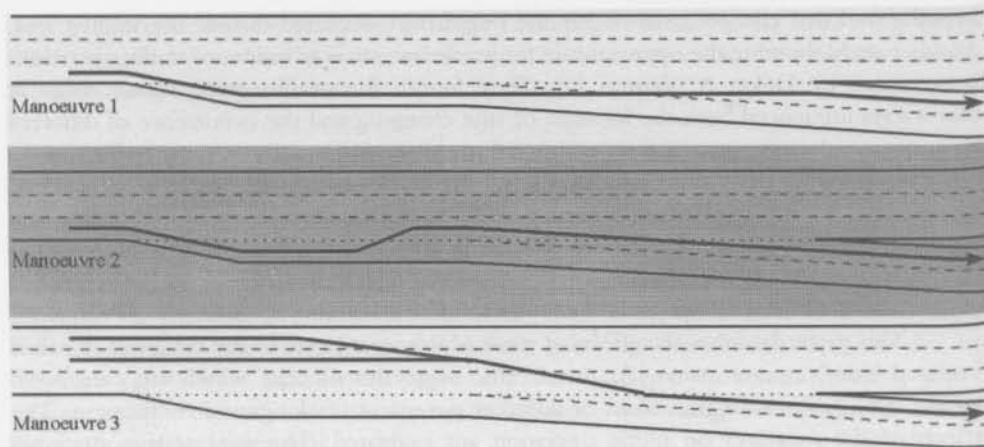


Figure 2. Undesirable exit manoeuvres.

To improve the quality and the safety of the traffic operation, two changes were proposed to the standard design, specifically to the pavement markings and traffic signs. The effects of these design changes were evaluated by comparing measurements before and after the implementation of the changes. To improve the use of the tapered lane two adaptations have been implemented in combination at each of two test sites. The pavement markings have been changed in such a way that it is no longer permitted to overtake via the taper from the initial exit lane. To accomplish this, a continuous line on the right side next to a dashed line is implemented (Figure 3). As a result, it is allowed to change lanes from left to the right, but not the other way around.

Also, a configuration sign has been placed, approximately 600 metres upstream of the exit, to inform the road user about the presence of a tapered auxiliary lane. This way, drivers can anticipate the coming situation.

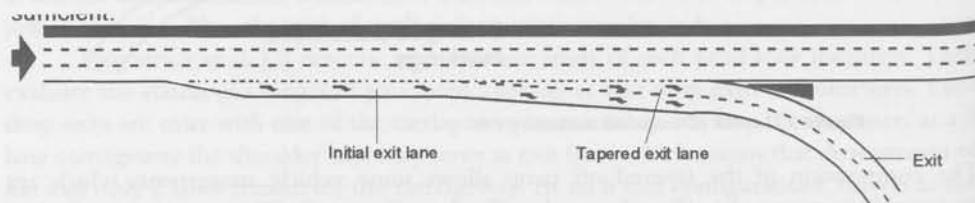


Figure 3. Pavement markings at a tapered motorway exit.

Unfortunately, it appeared impossible to carry out a desirable experiment using randomly chosen experimental and control locations to perform before and after measurements (Hauer [4]). In contrast, two test locations have been selected that seemed most appropriate to implement the design changes and to perform the required measurements. So, the study design was confined to a simple observational before and after study without control group. Therefore, the study results have to be considered as preliminary.

The first location of the experiment is the 6 lane A20 motorway southbound to the

A16 motorway, at the junction 'Terbregseplein' near Rotterdam. This off ramp is characterized by a relatively short exit lane, after which a tapered lane with a length of 270 metres is added to the off ramp, which is almost 100 metres longer than the ROA-standards (Dutch guidelines for the design of motorways) prescribe. The second location is the exit to Zoetermeer-West southbound to Utrecht on the 6 lane A12 motorway. In contrast to the other location, this off ramp is characterized by a very long initial single exit lane (435 metres), followed by a relatively short distance on which the tapered lane can be used (160 metres).

Driver behaviour was observed using video surveillance, at both sites for one working day before and after implementation of the changes. The morning peak and evening peak, and a less busy afternoon period were analysed. During the measurements, the external conditions did not influence the traffic operation negatively. For 5-minute intervals, flow rate by lane, and the location and manoeuvres of lane changing at the off ramp were determined. To determine the drivers' perceptions, a survey was conducted as well. For this survey car drivers were interviewed at two gas stations, because of high response with this kind of survey. A distinction was made between a gas station within city limits and a gas station on a motorway, because it was assumed that different categories of road users are customers at these gas stations. The most important parts of the survey are questions about the familiarity with the composition of tapered auxiliary lanes, the way the taper is used, and the perception of safety by the driver, i.e. the subjective safety. This resulted in 200 useable interviews.

4 Observed effects of the implemented measures

4.1 Effects on manoeuvres

The most important reason to implement the continuous line between the initial auxiliary lane and the tapered lane is to reduce the number of drivers that use the tapered lane to overtake. It appears that with respect to undesirable manoeuvre 1 there is a clear reduction. The levels of the other two undesirable manoeuvres are not significantly changed after implementation of the measure. Comparison of traffic operations on both locations before and after implementation of the changes shows a great similarity. Not only does the same percentage of exiting drivers perform undesirable manoeuvres, but also the observed changes in driver behaviour after implementing the measures at both locations appears about the same (Table 1, Figure 4).

From the results in Table 1 it can be derived that the implemented measure probably may lead to a significant decrease in the number of undesirable lane changes. This means that the proposed measure is very promising and its effects should be tested more carefully in additional experiments.

In contrast to the frequent occurrence of the undesirable manoeuvre 1, there are only few drivers who return to the carriageway from exit lanes. Less than 1 percent of the car drivers performs this manoeuvre (Table 2, Figure 4). Although there is a slight increase, the data do not allow any conclusion about an influence on this aspect of traffic operations.

For the late exiting manoeuvre, the results on both locations are very much similar. About 1 percent of the exiting traffic are drivers that exit at the last moment (Table 3, Figure 4).

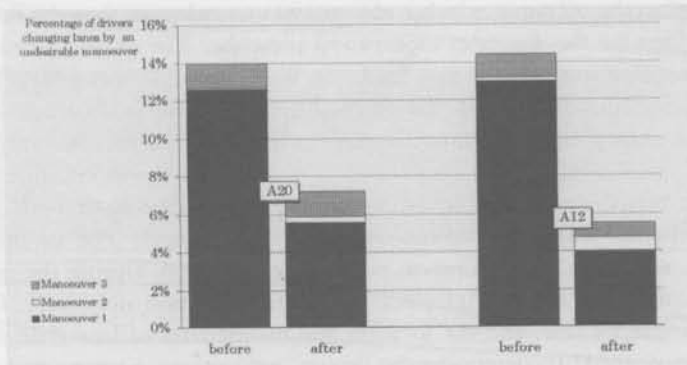


Figure 4. Percentage of undesirable manoeuvres before and after implementation of design changes.

Hardly any difference is observed for the occurrence of this manoeuvre 3 before and after implementation of the measures. From this can be concluded that the measure hardly has any influence on this aspect of driver behaviour. Apparently, the new overtaking regulations at the exit do not encourage drivers to exit at the last possible moment. The decrease of the number of drivers overtaking via the tapered exit lane can only be attributed to the new lining at the tapered lane which is directly aimed at this manoeuvre.

Table 1. Percentage of the exiting drivers who change from the initial exit lane to the tapered lane (Undesirable manoeuvre 1).

	Terbregseplein (A20)	Zoetermeer-Centrum (A12)
Before design changes	12,6%	13,0%
After design changes	5,6%	5,6%

Table 2. Percentage of exiting drivers who change from the exit lanes to the carriageway. (Undesirable manoeuvre 2).

	Terbregseplein (A20)	Zoetermeer-Centrum (A12)
Before design changes	0,1%	0,2%
After design changes	0,3%	0,7%

Table 3. Percentage of late exiting drivers (Unwanted manoeuvre 3).

	Terbregseplein (A20)	Zoetermeer-Centrum (A12)
Before design changes	1,3%	1,3%
After design changes	1,3%	0,8%

4.2 Consequences for capacity

The objective of the measures is to decrease the number of undesirable manoeuvres on a tapered exit lane, as well as to improve the traffic flow. In any case, it is not desirable that

the implementation of a continuous line disturbs the traffic flow. It is assumed that the flow is optimal when traffic is equally distributed over the two exit lanes. This distribution is determined by observing the amount of exiting traffic on both exit lanes. This ratio depends on the total flow rate of exiting traffic. If this flow rate is small, it is hypothesized that only few car drivers will postpone exiting until they reach the tapered lane.

From the Figures 5 and 6 it can be learned that the percentage of initial exit lane users indeed increases with decreasing exit flow rates.

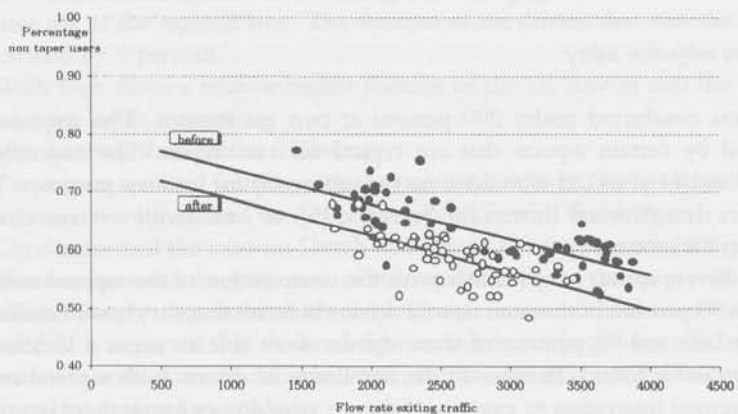


Figure 5. Share of exiting traffic using the initial exit lane (A20 motorway).

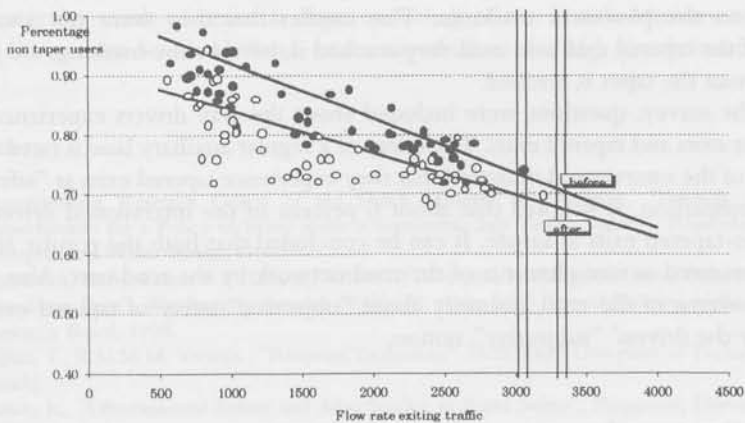


Figure 6. Share of exiting traffic using the initial exit lane (A12 motorway).

Before the design changes were implemented, extremely high flows (>3000 veh/h) were measured in the shoulder lane of the carriageway, just upstream of the exit. The measurements show a slight improvement in the flow distribution among the exit lanes after

implementation of the measures: 5 percent more drivers use the tapered exit lane (Figures 5 and 6).

The observations show that on the "Terbregseplein" a higher fraction of car drivers uses the tapered lane than on the exit Zoetermeercentre. This can be explained by the differences between the two sites. In contrast to the exit near Zoetermeer, the exit on the "Terbregseplein" has a short single initial exit lane, after which over a distance of 270 metres the tapered lane can be used to exit. Therefore the fraction of drivers who use the tapered auxiliary lane on the "Terbregseplein" is higher than near Zoetermeer.

4.3 Effects on subjective safety

A survey was conducted under 200 persons at two gas stations. The response group is characterized by certain aspects that are typical for car drivers. The majority are male between 25 and 44 years old who drive on the motorway for business purposes. This agrees with statistics data (Central Bureau for Statistics, [5]) of nationwide average characteristics of car drivers on motorways.

Car drivers appear very familiar with the composition of the tapered auxiliary lane. No less than 90 percent of the interviewed drivers indicate that they were familiar with this type of exit lane and 98 percent of these drivers were able to name a location where a tapered exit can be found. Because of the familiarity of drivers with tapered exit lanes in general, it seemed interesting to examine if drivers who do not know there is a tapered exit at the studied off ramps, perceive the presence of tapered exit lanes. Only 29 percent of the interviewed drivers indicated that they consciously look for the presence of a tapered exit lane. For verification, the survey included a question about how car drivers orientate, as in the old situation this was hardly possible. 32 percent of the car drivers indicated they orientated on the pavement markings. This implies that they were not aware of the presence of the tapered exit lane until they reached it, because the markings are just visible at the moment the taper is reached.

In the survey, questions were included about the way drivers experience safety of both regular exits and tapered exits. The safety of a regular auxiliary lane is rated very high. 80 percent of the interviewed indicated that they experience tapered exits as "safe" to "very safe". In comparison, it is noted that about 6 percent of the interviewed drivers rate the regular, non-tapered exits as unsafe. It can be concluded that both the regular and tapered exits are perceived as safe elements of the road network by the road user. Also, it appears that the concerns of the road authority about "objective" safety of tapered exits are not reflected by the drivers' "subjective" notion.

5. Concluding remarks

This paper described an example of simple, low cost adjustments of infrastructure design to improve traffic safety. In this case, the adjustments concerned changing the pavement markings and traffic signs at a tapered exit. It was intended to decrease a number of manoeuvres considered as undesirable (dangerous). The following results were found:

- The number of overtakings from the initial exit lane via the tapered exit lane decreased significantly after implementation of the continuous line. In the old situation about 13 percent of the exiting drivers used the tapered lane to overtake. After the adaptations this percentage came down to about 5 percent.
- The length of the initial auxiliary lane most probably determines the number of road users that uses the tapered lane to exit. The longer the initial exit lane, the less car drivers use the tapered lane to exit.
- The implementation of the continuous line between the exit lanes may lead to a better use of the tapered lane. The fraction of car drivers that uses the tapered lane increased by 5 percent.
- With high flows a relative higher fraction of the car drivers uses the tapered lane than with lower intensities.

Additionally, a survey showed the following:

- Car drivers are very familiar with the tapered exit lane. No less than 92 percent of the interviewed indicated that they were familiar with the design.
- Car drivers find the exits on Dutch motorways safe or very safe (80%). There is no difference between the judgment of the regular exit and the "tapered" exits.

These findings strongly suggest that with simple design measures the drivers' behaviour may be influenced. It is expected that similar design measures can improve traffic operations for other situations as well. A more elaborate experimental design is needed to corroborate the findings from this preliminary study.

Acknowledgement

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References

- [1] Transportation Research Centre of the Dutch Ministry of Transport, "Towards Safer Roads - Opportunities for a Policy to Bring about a Sustainable Safe Traffic System", Rotterdam: Ministry of Transport and Public Works, 1996.
- [2] Fitzpatrick, K, M. Lance & T. Lienau, "Effects of Pavement Markings on Driver Behaviour at Freeway Lane Drop Exits", Washington: Preprint (#950448) of the 1995 Annual Meeting of the Transportation Research Board, 1995.
- [3] Dijker, T., R.G.M.M. Vermijs., "Ritsproef Evaluation", Delft: Delft University of Technology, 1997 (in Dutch).
- [4] Hauer, E., "Observational Before and After Studies in Road Safety", Pergamon, Elsevier Science Ltd, 1997.
- [5] Central Bureau of Statistics, "Traffic and Transport Statistics Pocketbook", The Hague: SDU Publishers, 1994 (in Dutch).

Safety Considerations for Road Tunnels

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Abstract. The construction of tunnels is increasingly being done with the aid of tunnel boring machines (TBM). The costs of safety measures, including emergency escape routes, for such tunnels are relatively high, so that it makes sense to optimise safety measures in relation to risk levels. However, this entails the risk that attention may shift away from "safety" towards "risk levels", overlooking scenarios with unacceptable consequences however low the probability of their occurrence might be.

This paper deals with the safety considerations applied by Lloyd's Register Management Services (Rotterdam, The Netherlands) based on a combined "probabilistic" and "deterministic" approach and taking into account, in addition to individual risk level, public perception versus group risk and events which ought to be non-credible. Specific attention is given to the ALARA (As-Low-As-Reasonably-Achievable) principle, which the authors believe should be governed primarily by safety elements rather than the cost consequences.

1. Minimum safety level and risk calculations

The design of a road tunnel should meet a certain minimum safety level. No matter what the construction method is (a traditional tunneling method like cut-and-cover, immersed tunneling, etc. or the method with the tunnel boring machine; for Holland a rather new phenomenon) this minimum safety level should be the same. When a minimum safety level is stated and accepted the other side of the safety problem is how to calculate the risks or how to prove that all the taken measures lead to at least the minimum safety level. So there seem to be two problems: how to calculate the risk and how safe is safe enough?

To calculate the risk the first step to be taken is clear and without doubt. The future functions of a tunnel should be known, because the functionality stipulates partly the safety problems that will have to be solved. If cargo is allowed in the tunnel, the safety problems will be different. With all kind of well known risk assessment techniques the failure modes can be found. The next steps are still under discussion in Holland.

One method, which is especially suitable for the calculation of the influence of measures, is the *deterministic scenario analysis*. In this technique a limited number of scenarios is subject of a thorough analysis. The scenarios are meant to describe special parts of imaginable and predictable accidents. The influence of measures on the development of the accident can be predicted in a qualitative and sometimes quantitative way. Scenario-analysis is a very explanatory technique. The problem with the technique however is that it is hard to find out how broadly based a measure is and how much measures are needed to fulfill the minimum safety level requirements. Going back to the two problems: how safe is safe enough and how to calculate the risk, the scenario analysis is a useful technique to solve (at

least partly) the second question, but not directly the first.

Another possibility is to make a *quantitative risk assessment* (QRA or probabilistic approach). These assessments are especially useful to give an impression of the expected risk which can be compared with minimum safety levels used for other activities. In Holland for industrial installations such quantitative levels are stated in regulations, but are not applicable for the safety in tunnels. The minimum safety level is on the one hand a level for the individual (individual risk) and a set of levels for a group of people dying because of the same accident (societal risk). The disadvantage of these calculations is that often not enough statistical information is available to make a reliable calculation. A second and related difficulty is to predict the influence of certain measures. Especially the influence of measures to minimise the probability of occurrence of an accident can only be guessed. For example there is no quantitative relation known between an increase of light in a tunnel, or the decrease of the maximum speed with ten kilometers an hour and the probability of an accident happening.

The scenario analysis is used in the QRA, or probabilistic calculations. These calculations are based on accidents that are described as a chain of events. Each event can be followed with a certain probability by even worse events. The result of each accident description is twofold: a probability of occurrence, calculated with the individual probabilities of the events, and the consequences, mostly expressed in the number of deaths. Summing these probabilities and consequences in the right way and the quantitative risk analysis gives the chance to die using the tunnel and a relation between the number of deaths and the frequency of occurrence. So the input of the deterministic scenario analysis is essential for a probabilistic calculation.

Although this relation exists, the scenario analysis is more than input for a probabilistic calculation. Looking at the perception of risk by society the scenario analysis is an essential tool. Quantitative risk assessment is mostly based on the calculation of the number of death. Society, and especially victims of an accident, is interested also in the wounded people. The less severe the wounds, the better it is. These features are not a subject of the probabilistic calculations. The scenario analysis is the best way to show the responsible persons the effect of some measures on the number of wounded people and the severity of the wounds. Of course a quantitative risk assessment including the wounded and the severity of the wounds could be made, but a lot of investigation will be necessary to do so.

In the design phase of a construction we already want to be prepared for the possible accidents and be able to anticipate on them. When it is known that certain events or accidents can lead to severe problems, who wants to take responsibility for not taking measures because the probabilistic calculations have proved that the chance of occurrence is small enough? The scenario analysis is the perfect tool to show which measures can be taken, which effect they have on safety and what the cost consequences will be. With information about the scenario analysis the responsible people are able to take their decisions well informed. In case of an accident, investigations to evaluate the designphase will lead to the conclusion that the responsible persons were well informed and all possible measures were taken.

If an event can lead to a real disaster we will have to do everything to prevent this

from happening. Only taking measures to minimize the probability of occurrence is not enough. Measures to minimize the consequences should be taken, even if the probability of occurrence is very small and the measures are not expected to be used ever in the lifetime of the tunnel. For example if transport of flammable goods like fuel is allowed in the tunnel, we know that a disaster can happen. If only the probability of an accident with this truck is decreased by measures, the disaster still can happen. The tunnel can be declared safe enough only if the real disaster (consequences) cannot happen anymore. For example measures should be taken that people can quickly flight from the tunnel in case of fire, that the tunnel is strong enough to bear the heat, that no cars can enter the tunnel from the moment the accident has taken place, etc. If these measures are too expensive the transport of flammable goods cannot be allowed in the tunnel.

So during the analysis, scenario's could be found that lead to accidents that cannot be tolerated. If these accidents cannot be excluded by waterproof legislation and the accompanying regulation and enforcement (for example the exclusion of transportation of dangerous goods in a tunnel) and it is not possible to take enough measures to make the consequences acceptable, the decision should be taken not to build this construction. The probabilistic approach doesn't help to analyse and find information for these kind of decisions.

Probabilistic calculations are not very useful to the design of innovative measures to improve safety in an economic way. The detailed view on certain circumstances that is needed to find the causes and design the right solutions, cannot be obtained from a calculation using hundreds and hundreds of smartly composed scenario's and resulting in a few numerical values. A detailed scenario description that is explanatory and imaginative is on the other hand very useful to designers.

Even more useful to and the designers and for verification goals is a set of scenario's which is normative for all the failure modes in the tunnel. The probabilistic calculations can help to put the scenario's in order and to determine the relative influence on the outcome of the calculations of the different scenario's. So the probabilistic calculations give a lot of insight into the importance of certain failure modes and scenario's and can help to find an important part of the normative set of scenario's.

2. The combination of deterministic and probabilistic approaches

Apparently both approaches have their pro's. The simple solution to combine the approaches is of course often used. Only in case of determining the minimum safety level both approaches seem to conflict in practise. All measures taken, a probabilistic calculation can lead to the conclusion that the minimum safety level requirement is met. So no more measures are necessary according to that approach. But for some of the (normative) scenario's improvement can still be found and some of the scenario's still have unacceptable consequences. Measures need to be taken, but who will pay the bill? To define an objective minimum safety level that can be used in a scenario-analysis maybe is impossible. But somehow the weigh between money and safety has to be made.

3. Decide on safety

It is clear that a sharp line between safe enough and unsafe does not exist. This kind of safety levels need attention of the responsible people. It is not like a technical normative, where calculations are enough prove that the minimum level is met.

Of course, once set, a minimum safety level based on the probabilistic approach should always be met, but all measures that can reasonably be taken to improve safety, should be taken.

The risk assessments should produce enough information for an objective weigh between safety, costs and maybe other issues by the responsible people. These assessments should therefore be made by very experienced people. Only a continuous weigh between measures to improve on safety and the cost consequences can lead to an optimal design with respect to safety.

Only persons with long term responsibility should weigh between safety and costs and decide on safety issues. The possible measures to improve safety and their costs should therefore be reported clearly to the responsible people. To report in a clear and explanatory way both methods, the probabilistic approach and the scenario-analysis, are useful. The responsible persons will mostly be no safety experts, the expert responsible for the report should take this into account.

4. Conclusion

The two techniques, probabilistic risk calculations and scenario-analysis are both very useful for risk assessments. Both are needed to decide on safety measures to be taken. The probabilistic approach has better possibilities to define a minimum safety level, but is not very explanatory and does not take into account certain perceptions of society, like the non-credible accidents and the possibilities to flight whatever happens. The scenario-analysis is on the other hand very explanatory, but minimum safety levels cannot be defined. The minimum safety level based on the probabilistic approach should always be met, but above this minimum level the use of the ALARA (also called ALARP) principle should lead to an acceptable safety level. To achieve this safety level, risk analysis should be made by very experienced people in a continuous optimisation between safety and cost consequences. This should lead to a clear and explanatory report on safety measures, that should be used by the people that carry a long term responsibility for the safety measures. These people should decide on the safety measures to be taken, because they will held responsible for future consequences, if an accident will happen.

Safety of Underground Public Transport

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I would like to share with you the National Transportation Safety Board's experience of a fatal collision on the Metrorail system in the Maryland suburbs. This accident shows how a company's attitude or the corporate culture provided a negative influence on safety. The accident involved a collision in January 1996 between two trains on Metro's Red Line. A moving train struck an unoccupied standing train that was not in service, killing the operator of the moving train. The Safety Board's investigation of this accident found examples of an organizational culture that considerably detracted from safe rail transit operation.

At first, it appeared that a train operator simply did not comply with his training. Then different pictures emerged suggesting that a superintendent at the train dispatching facility ignored warnings and did not stop the train. Later still, it appeared that an executive manager had acted capriciously when he changed a long-standing operating policy without consideration of the consequences. This accident resulted not from singular actions but from an organization-wide set of beliefs held about the infallibility of the automatic train control equipment. The Metro accident occurred shortly after a major snowstorm had begun and trains had started to overrun station platforms at several of the above-ground stations. The accumulating snow and ice reduced the effectiveness of the train's braking system. All trains were operating in the fully automatic mode; that is, they were being controlled by the system computer, not by the operator on board the train or by controllers in the system's central control facility. Shortly after 10:00 pm, train 111, northbound out of Washington, D.C. enroute to the Shady Grove station in suburban Maryland, emerged from below ground to above ground track. When it reached Twinbrook Station, 12 minutes before the accident, the automatic train control directed the train to stop at the platform. The train did stop, but completely overran the platform. At the next station in Rockville, the train partially overran the station. Because the operator had to secure the controls to assist passengers at that station, the train had lost its automated command to operate at the reduced speed of 44 mph. So, after departure from Rockville, the train began accelerating automatically above that speed, heading for 75 mph, still within the design limitations of the rails and signals, at least when weather conditions were favorable. The train 111 operator called the controller to report the over-speed situation and was told that this was due to his overrunning the previous station and that he was to continue in automatic operation. As the train approached the Shady Grove station, the controller, who could see the location of train 111 on his monitor, called the operator and asked if the speed had dropped. Because it had, the controller later told Safety Board investigators that he had a feeling the system was doing what it was supposed to do and didn't believe that he had to put his job on the line by telling the train operator to go into manual mode.

Previously, when the rails were slippery, operators were given the authority to run the trains manually so they could properly adjust the approach speeds to fit the weather. However, a new policy had been put into effect just two months before the accident that prohibited any manual operation...I'll talk about this a little more in a moment. At the Shady Grove station, where the accident occurred, a gap train was parked 470 feet beyond the platform on the same track that the accident train was using. A gap train stands by to fill in for unexpected needs, such as when a scheduled train breaks down. It was parked there despite an unwritten Metrorail order that these trains were to be kept on the adjacent inactive track. You can guess what happened next. When train 111 arrived at the Shady Grove station, it slid past the platform at about 30 mph and struck the standing gap train. The operator of train 111 was found crushed in wreckage near the cab door. There were no other injuries. The operator of train 111 had no advance warning of the gap train's position because the trackside signal showed a clear indication. Metrorail had learned a procedure for circumventing the signal system to keep trains from slowing or stopping before they reached the station platform when the gap train was on the same track.

The Safety Board's investigation team was launched the night of the accident. Once the follow-up investigation work began, a fairly clear picture emerged of what had happened and why. Here are several of the findings from our investigation that address the organizational and management issues that I think are important to consider for safe underground transportation.

- Metrorail had recognized that leaving the gap train on the incoming active track presented an unnecessary hazard. But we learned that the gap trains were frequently stored on the active track, apparently because of confidence in the automatic train control system.
- There was no formal training program for controllers at the control center, other than an annual operating rules examination. Consider that the controller knew of the accident train's overruns at two previous stations, he knew about the deteriorating weather, he knew about the unusually high speed of the train, and he knew the gap train was parked beyond the Shady Grove station. And yet he did not see a need to stop train 111.
- Equally disturbing was our finding that no one, including the superintendent of the central control center, had the authority to intervene and stop the accident train unless a collision was certain. The controller felt that he would be putting his job on the line if he were to allow the operator to take manual control of the train.
- Because manually operated braking was being blamed for a perceived flat-wheel problem, which would indicate poor braking technique, a decision was apparently made by the Deputy General Manager to eliminate all manual operation, even in inclement weather. No train operator knew of or was consulted about the change, and most of management including the General Manager did not learn of the decision until after the accident.

The Safety Board found that the management style, processes and organizational structure at Metrorail were rigid and militaristic from the Deputy General Manager on down, with no tolerance for opposition that could have provided better informed decisions. This created an organizational environment that enabled experienced managers at Metrorail to

produce an ill-advised and unsafe operating policies, and allowed these improper methods to be tolerated.

It would be tempting to blame the conditions and circumstances of this accident on one person, the Deputy General Manager. But this would not have recognized the entire corporate culture at Metrorail as a safety problem. Certainly the Deputy General Manager was part of the problem, but what about the apparent indifference and disregard by some employees' for safety precautions, and the absence of informed opposition when flawed solutions to problems are being considered? The logic for identifying the corporate culture of Metrorail as the cause of this accident only holds together when we consider the extent to which management and operating personnel believed the automated train control system would protect them, and that the system would provide adequate margins of safety regardless of the quality of the decisions and policies.

The Safety Board made 20 recommendations to the Metrorail Authority as a result of the Shady Grove accident and as a result major changes took place in Metrorail management and in their operating practices. Several top level executive managers left the transit agency, including the Deputy General Manager. A new Director of Safety was hired and will be reporting directly to the General Manager. This is an organizational structure that the Safety Board has been recommending for years in all modes of transportation and is particularly evident among the major airlines. The root cause of this accident goes beyond a mere lack of planning or poor personnel decisions. It involves:

- Futility in the belief in an infallible technology,
- The lack of appreciation for the role of the human in a highly technical system,
- The lack of an avenue for divergent opinions, and
- The establishment of an organizational culture that discouraged communication, divergent opinion, and an appreciation for the importance of safety.

In the last 15 years, much has been written, learned, and communicated about the role of corporate culture on transportation safety. As a result transportation companies and governments around the world have come to recognize and understand better how operator errors, irrespective of their immediate causes, are often influenced by management conduct and attitudes. In conclusion, you can see that any one of 5 people could have prevented this accident;

1. The Operator could have stopped his train but was apparently too afraid.
2. The Operations Control Center operators could have stopped the train but feared for their jobs.
3. The Operations Control Center supervisor could have intervened but he was also afraid for his job.
4. The Deputy General Manager could have involved all parties in the decision to eliminate manual operation during inclement weather.
5. The Shady Grove Station manager could have placed the Gap Train on the other track per Metro policy.

What we learned from this accident is how important it is to recognize that management has responsibility for creating and fostering a climate that encourages safe operations.

Measuring External Safety at Schiphol

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Abstract. Aviation is among the safest ways of transporting goods and people and Schiphol is among the safest airports in the world. These facts notwithstanding, understandable public concern over aviation accidents - internationally but especially in the Netherlands - has led to intense efforts to improve aviation safety, both by the airport and the government. In the Netherlands the government has set a level of maximum risk that an aviation accident cause the death of persons not engaged with air transportation; the risk is assessed by a risk contour model. As air traffic volumes increase at Schiphol, the risk model is limited in its measure of risk, not taking into account demonstrated safety improvements. A more comprehensive assessment of the actual risk that takes into account present and projected safety improvements at Schiphol would show that the demand for external safety can be met, even as air traffic volume increases.

1. Aviation is safe but...

It is widely recognized that air transportation is one of the safest modes of getting from one place to another; on a per-passenger-kilometer basis, it is safer than rail or water and much safer than road. Similarly, air transportation of cargo is safe compared to alternative modes. Despite this recognition, there is a dread of aviation accidents. Researchers have extensively studied this dread-beyond-the-numbers and several explanations, which go beyond the awe of flying, have emerged:

- Multiple deaths. Accidents involving airplanes tend to cause multiple and violent deaths and the perceived harm of multiple deaths is significantly greater than the sum of individual deaths. For example in 1996 there were two major aviation accidents in the Netherlands: the Hercules accident at Eindhoven airport and the Dakota accident off Den Helder, at the cost of more than 30 lives each. But in the week of each aviation disaster, there were at least as many people killed in car accidents in the Netherlands. Yet the aviation accidents received far more public attention and have been much more intensively investigated.
- Fluctuation with events. The public perception of risk fluctuates with recent events: clusters of accidents spaced in short periods of time raise the public perception of risk, even though there is no evidence that one accident makes the occurrence of another one more likely. After a period with no major accidents, this concern is reduced. For example, after the 1996 ValueJet accident near Miami and the TWA accident off the coast of New York City, the public outcry practically

forced the U.S. government to convene a commission to recommend improvements to American aviation safety.

- **External risk.** An important aspect of public concern for aviation safety is the so-called external risk: the risk to people on the ground of an aircraft crashing on them. The acceptability of external risk is low compared to other risks. This has been explained by a well-known finding of psychological research that the acceptability of risk is greater in the case of voluntary exposure by the individual to the risky activity. Characteristics of external risk include the lack of control and non-voluntary exposure to the risk of the individual. So, for example, people go skiing but don't like second hand smoking. Boeing estimated that in the period 1970-1992, 879 people worldwide were killed on the ground as a result of aviation accidents. The Bijlmermeer disaster of 1992 is one of the worst cases in history of external harm resulting from aviation.

That the public concern for aviation safety is greater than rationally could be expected is no excuse for not improving aviation safety. Indeed, the aviation industry has a remarkable record of safety improvement and the public generally seems willing to accept the current level of risk. However, the current increase in global air traffic volumes threatens a proportional increase in accidents. This means that for a given rate of safety, the number of accidents might be expected to increase accordingly. It is very likely that the same public that accepts the current number of accidents, would not accept a greater number of accidents resulting from the same accident rate with higher transport volumes.

2. Schiphol is safe, but....

Schiphol is safe. As the 1993 RAND safety audit stated, Schiphol is a modern and safe airport, a safety leader even in the "most safe" category of modern first-world international hubs [1]. But in spite of this acknowledged safety reputation, safety is a much more prominent issue at Schiphol than it is at comparable airports.

Part of the increased Dutch public attention for aviation safety is due to the 1992 Bijlmermeer disaster in which an El Al cargo 747 crashed into an apartment building in the Amsterdam Bijlmermeer. Almost 50 people who happened to live near the airport were killed. To illustrate the power of public perception when it comes to aviation accidents, most Dutch people, when asked, believe that many more lives were lost in the crash. This phenomenon can be explained by the fact that originally it was feared that about 250 people would have been killed in the crash. This number of casualties has stuck psychologically in the public mind.

Another reason for the heightened concern for airport safety lies in the fact that for the past several years a series of highly publicized policy debates have been going on in the Netherlands about the future of aviation. Topics of debate included questions like whether or not the Netherlands should accommodate a proportion of the international increase in air transport, whether to do this at Schiphol airport (by constructing a fifth runway) or to build a second national airport. In each of these debates external safety has emerged as an issue.

Associated with these public debates have been an increased awareness and outcry regarding negative aspects of the growth of traffic at the airport. External safety is linked to other public issues concerning the growth of the airport. The number of noise complaints is about 20 times higher at Schiphol than it is at other European airports with comparable levels of decibels and exposed population. Because noise is associated with safety - if one can hear an airplane closeby, one can imagine it crashing in the direct vicinity - public concern for external safety is accordingly heightened.

In response to these concerns, a number of steps have been taken to improve external safety. The airport itself has made pioneering efforts at safety improvement. As an example of the type of improvements, the ISMS (Integrated Safety Management System) can be mentioned. Within the framework of the ISMS, the most important actors at the airport, including ATC, AAS, KLM and other Dutch and foreign carriers and airline handling companies, have set up a safety information exchange system, which includes reporting of sensitive information on near-accidents. Also, the government has imposed external risk limits on the airport.

3. Government regulation of external safety

The government has declared that Schiphol must maintain a level of external safety, which is measured in terms of the likelihood of an accident. This level is comparable to external safety levels that hold for fixed-site installations such as nuclear reactors or chemical processing plants.

Just like for these fixed-site installations, external risk for Schiphol is determined by a risk contour model, which is calculated by using probabilistic risk assessment. This model is largely based on historical accident data for Schiphol and other "comparable" airports. Without going into details about the model, the basic input for the model consists of:

- flight path patterns;
- the number and type of aircraft;
- the safety record of the type of aircraft.

So, the external risk posed by a single flight is mostly determined by the recent safety record of the type of aircraft passing overhead and by how many people live underneath.

The levels of external safety Schiphol needs to maintain are measured in terms of individual risk; the likelihood of the loss of 1 human life in one year must be less than 1 in a million. And in terms of group risk: the likelihood of the loss of 10 or more human lives in one year must be less than 1 in 10 million. The accumulated risk of air traffic is the sum of the risks of each individual flight.

4. What happens when air transport volume increases

Based upon the risk contours, Schiphol is nearing its external safety limit. That is, the increasing volume of air traffic at the airport will exceed the regulatory limit in the near future. A risk assessment based on volume will see risk increasing as the volume expands,

all other things staying constant. If we assume that the risk contour model is an accurate estimation of the level of external risk, Schiphol is left with four options:

1. Try to change the external safety limit.

Given the current heated debate on the noise restrictions on the airport, this option can be considered impossible.

2. Reduce growth to stay within the limits.

Given the stated position of KLM and other Dutch carriers, this option is economically highly damaging.

3. Move people from underneath the flight paths

Again, given the heated debate on the costs and benefits of Schiphol, this is impossible.

4. Revise the way one thinks about safety.

This last option is viable only if the external risk is actually less than the model states. If so, changing the way we think about measuring external safety can achieve two goals:

- maintain the regulated limit for external risk
- maintain economic prosperity resulting from Schiphol

5. A risk model based on volume alone is not enough

The use of the risk contour model to capture external safety is not enough, for a number of reasons:

1. The assumption of linearity of risk in the volume of operations is too limited.

A cornerstone of the model is its calculation of the likelihood of an accident for an individual flight. Individual flight risks are then summed up over all flights to calculate the total risk. The model thus simply assumes that the greater the air traffic volume, the greater the risk. But accident rates do not necessarily remain constant as volume increases. If the airport can increase its traffic volume and its safety capabilities at the same time, the accident rate could actually decrease. Examination of historical data and analogies with other disciplines of expert performance shows that the biggest are the best. A study of aviation accident records by Arnold Barnett of MIT demonstrated that the largest carriers and the airports handling the largest traffic volumes are actually the safest. In other disciplines there is also precedent for this phenomenon. Health services research has shown that hospitals and surgeons who perform the largest numbers of risky surgical procedures generally have the lowest complication and mortality rates. These data suggest that high volumes of expert operations generate a critical mass of added experience and expertise that increases the safety performance.

2. The model has no causal structure.

The risk contour model only looks at accidents and not on precursors to accidents, or the

factors contributing to the occurrence an accident. For instance, the model doesn't take into account well-known differences in carrier performance, crew training and experience. Because there is no incorporated causal model, improvements in safety are not reflected in the risk contour. So, safety improvements like the increased surveillance of risky carriers are invisible in the model.

However, to claim that these safety improvements are unmeasurable, is the same as stating that their effect is zero.

6. Towards a more comprehensive way of measuring safety

In conclusion, what is needed is a more comprehensive way of measuring external safety at Schiphol airport. A risk model based on volume solely has its limitations. Also, accidents – fortunately – occur too infrequently to be a comprehensive source of information. Our point is that because the risk contour model only looks at accidents, it does not make use of all the safety information, which is available. More data are needed to estimate the safety level of airport operations. To get at this information, one needs to look at data from incident and hazard reports, data from training and simulation, data from inspection and maintenance reports as well. If these data are unavailable, use could be made of expert opinion in a systematic way. Experts could be asked to supplement the safety data with their knowledge of the situation. This should be done by making use of methods like focus groups. Getting these data might pose problems in terms of the confidentiality of the sensitive information and of conflict of interest between the actors involved. Nobody likes to report to the competition that one of his or her employees nearly caused a serious accident. However, the workings of the ISMS at Schiphol airport demonstrate that these problems can be solved. Actors with conflicting interests will have to work together when it comes to improving safety.

References

- [1] Hillestad, R. et al, Airport Growth and Safety: A Study of the External Risk of Schiphol Airport and Possible Safety-Enhancing Measures. Santa Monica, California: RAND Report MR-228-EAC/VW, 1993.

Downsizing Power and Speed, the Safe Road to Fuel Economy, Road Safety and Sustainability

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Abstract. The power and speed of cars, trucks and motorcycles are unnecessarily high. Enforcing motorway speed limits and setting lower speed limits are effective instruments for reducing fuel consumption and emissions and improving road safety. The trend towards more powerful engines and higher performance must be halted if the desired reduction in CO₂ emissions and the desired improvement in fuel efficiency and traffic safety are to be achieved. Specific power ratings need to be halved at least and performance levels need to be reduced substantially if future vehicles and traffic are to be "sustainable". The "Car of the Future" can embody every reasonable consumer feature such as interior space, comfort, safety and image profile, but - to be sustainable - its engine power, performance and weight need to be reduced. Putting "less of the same" into a new generation of vehicles - instead of putting more (technology toys and performance) into them - is a promising, safe and cost-effective route towards real fuel economy, safety and sustainability.

1. Introduction

Traffic is one of the main causes of the most serious environmental problems world wide, such as acidification, photochemical air pollution, climate change, local air quality and noise levels. When assessed against the criterion of "sustainable development" introduced by the Brundtland Commission and in the light of the concepts of sustainability and safety [1], and given road traffic's total dependence on oil, the current transport system is clearly environmentally unsustainable. Above all, growth is the problem. Assuming that the number of vehicles will rise to over one billion worldwide within two decades, and taking into account its contribution to CO₂ emissions and the referring to the Kyoto agreement, the consumption of oil by the Transport sector will have to fall sharply. In addition to curbing car use - an illusion at current fuel prices - the only effective measure is a forced decline in the average fuel consumption per vehicle per km of at least 50% between now and 2010. This seems a feasible target if technical vehicle improvements are geared more towards fuel efficiency instead of upgrading power, performance and weight and if, at the same time, driver behaviour could be guided towards fuel efficiency and away from speeding and strong acceleration. Recent research projects in the Netherlands show that a

combined approach of downsizing power and speed, enforcing speed limits and in-car guidance of drivers' behaviour can achieve a 50% reduction target. How can this be integrated into future road safety and environment policy?

2. Speed, emissions, fuel consumption and other vehicle characteristics

Speed kills. But what is the effect of speed to the environment? It is widely known that fast driving speeds up fuel consumption. Nevertheless, little is known about the overall environmental and fuel efficiency effects of reducing vehicle speeds in various degrees through enforcing and lowering speed limits in various ways. This question has been targeted in a recent research project in the Netherlands into the costs and benefits of speed limit enforcement and of reducing speed limits [2]. Reducing speeds through strict enforcement or through introducing intelligent, in-car speed-retarding systems and downsizing the performance levels of cars will yield large benefits to society at large. Up to 1% of GNP could be saved, according to this study, if speed limits are fully enforced and optimised to their maximum effectiveness, giving overall CO₂ emission and fuel consumption reductions of up to 30% and risk reductions of up to 40%. Thus current Dutch climate change policy target for passenger cars (CO₂:-10% by 2010) could be achieved by enforcing and lowering speed limits alone. Table 1 shows the potential effects of these approaches.

Table 1. Direct and indirect effects of lower speed limits and optimised enforcement.

Parameters Base index	Base = current limits (1995)	Improved enforcement	Optimum in-car enforcement plus lower speed limits	
			Average	High
VMT	100	94	91	86
Energy	100	89	79	68
CO ₂	100	89	79	68
NO _x	100	85	64	48
Casualties	100	85	83	73
Fatalities	100	79	75	60
Travel time	100	99	99	98

The connection between vehicle design and speed on the one hand and emissions and fuel consumption on the other has been examined in detail [3], showing the following correlations (though exceptions occur in practice). In so far as these lead to avoidable effects (extra emissions or fuel consumption), they should be given priority in abatement policies designed to achieve optimum cost/benefit ratios.

1. Vehicle weight - fuel consumption/CO₂ emissions

Large, heavy cars consume more fuel than small, lighter ones. Heavier vehicles require a higher power output for the same performance, especially when accelerating and under urban driving conditions.

2. Cylinder capacity/power/performance - fuel consumption/CO₂ emissions

Cylinder capacity, maximum power, acceleration capacity, top speed, and, above all, the specific power rating (kW/kg) are significant indicators for fuel consumption and CO₂ emissions. The largest engines and highest power and performance ratings tend to be found in the heaviest vehicles. High-powered (petrol) cars consume more fuel - other things being equal - than those with smaller engines.

3. Speed - fuel consumption/CO₂ emissions/NO_x emissions

Above about 60-70 km/hour, fuel consumption, CO₂ emissions and NO_x emissions increase. Above about 80 km/hour in the case of goods vehicles and about 100 km/hour in the case of private cars, the increase begins to rise faster on account of the increase in air resistance. On average, a modern 1,100 kg car requires a power output of less than 30 kW to travel at 120 km/hour.

4. Driving habits - fuel consumption/CO₂ emissions/other emissions

Consumer surveys and car tests show that the difference in fuel consumption between a "racy" and an economical driving style can be over 40%. A "racy" or "aggressive" driving style with frequent accelerations and braking also causes a sharp and even extreme increase in CO, C_xH_y and NO_x emissions.

5. Speed - accidents and fatalities

Accident frequencies and fatality rates increase more than proportionally when speed levels increase, especially above a given speed limit. Passive safety features such as crush zones are most effective at lower speeds that triggered their design. The so-called safe German Autobahns without a general speed limit, are twice as unsafe as the Dutch highways with a mixed speed limit system of 100/120 km/hour.

The above shows that there is a significant causal relationship between fuel consumption, CO₂ emissions and emissions of NO_x, CO and C_xH_y on the one hand and vehicle design features such as weight, specific power, performance, and behaviour patterns (speed and acceleration) on the other. TNO Motor Vehicles Test Lab concludes that optimum speed, with the lowest emissions and fuel consumption, is between 60 and 80 km/hour for goods vehicles and between 70 and 90 km/hour for private cars. Thus, reducing the power and speed of vehicles is highly effective in attaining environmental as well as road safety goals.

3. Road safety: the hidden power < > risk paradox

In the U.S.A. a fierce battle has been going on concerning the (assumed) lack of safety of small and fuel efficient cars in connection with the possibility of achieving further energy savings by means of body downsizing [4]. As regards passive safety, there is indeed a general statistical connection between vehicle weight and risk. But accident statistics do not prove that large, heavy cars are intrinsically safe. Collision tests and statistics from, inter alia, the US Highway Loss Data Institute (HLDI) and the Swedish Folksam [5] prove that in practice

it is not weight or size that determines risk, but the quality of the safety structures and, above all, the vehicle's "character" in terms of (too much) power, performance, roadholding and "macho" image. Vehicles in the same weight class perform very differently in both collision tests and accident statistics. In German statistics the highest risks occur not only in the structurally unsafe category of very small cars (minis) designed in the 50s and 60s, but also in the category of the latest fast sports cars, with twice the weight, such as the Audi Quattro and BMW M3. What is the reason for this?

The *active safety* of private cars has increased significantly in recent decades thanks to improvements in vehicle design. In this connection, a paradoxical phenomenon, which can be explained in terms of *compensatory behaviour*, occurs: the so-called "ABS effect". German experiments revealed that, contrary to expectations, a disproportionate number of cars with an anti-blocking system were involved in accidents. Apparently, the perception of extra safety removes inhibitions characteristic of a safe, defensive driving style. Available insurance statistics [5] show that cars with perfect road-holding and a high power rating are involved in accidents to a disproportionate degree, especially sports cars and Mercedes, BMW and SAAB models, which achieve high scores for both active and passive safety. In the U.S.A., the two-door (first generation) SAAB 900 - usually a Turbo - has been found to be three times as unsafe for its drivers as the four-door model, whereas the passive safety of both is the same. In conjunction with specific driver characteristics such as age (young) and sex (male), this aspect resulted in recorded risk variations in the U.S.A. of up to 800% within the same weight category (see Table 2).

Table 2. Accident risk within size classes.

Type	risk of death	accident frequency
Average	1.0	100
Mercedes S	0.9	160
Cadillac Fleetwood	1.0	87
BMW 520	1.0	157
VOLVO 240	0.5 - 0.8	91
VOLVO 740	0.7	88
SAAB 9000	0.5	135
SAAB 900 4D	0.6	143
SAAB 900 2D	1.9	178
Porche 944	2.2	very high
Nissan 300 ZX	4.0	very high
Corvette	4.7	very high
VW Jetta	1.1	93
VW Golf	1.5	130
Golf GTI	1.5	164
Mazda 323	1.9	100

Source: HLDI statistics 1985 - 1989 (USA).

The obvious conclusion is that, in the case of fast cars, design features (such as character, performance, perfect active safety features, airbags and sophisticated crash testing) in

conjunction with psychological factors, such as overestimation of one's own abilities and risk compensation, lead to a high level of *active unsafety*. Since the new car fleet average top speed is now up to 190 km/hour, this phenomenon is true for all cars except real minis.

Indeed, some cars must be regarded as "killers", especially large and heavy cars (such as 4WD and pick-ups) and "muscle cars". Taking into account the not monitored fate of "collision partners", any car's risk profile should include accident frequency and active unsafety as well as risk and crash test figures. Furthermore it must be noticed that specific car model risk statistics vary considerably over time and place. For example, the Volvo 240 or Mercedes 200 series perform less well in Australian risk ratings than in the US ratings.

It is therefore disappointing that HLDI and the US Insurance Institute for Highway Safety completely ignore these hidden risk factors and wrongly proclaim vehicle size to be the best safety guarantee ("buy big").

4. Trends in vehicle performance, market segments and car culture

On the basis of the correlations described above, a review of recent developments can help to indicate the necessary remedies. After a century of development, the car has been perfected technologically, with enormous improvements in user friendliness, comfort, handling, safety, performance, costs and emissions. In every respect, the car is big business and in many industrialised countries it accounts for over 10% of GNP. The dominant impact of this industrial product on our streets, the economy, activity patterns, our culture and emotions cannot be explained in terms of economic and demographic factors alone. A study of the factors determining car ownership, car use and driving habits [6] shows that "intrinsic" (affective) motives, connected with life style, satisfaction of emotional needs and cultural trends, have a major influence on motorists' behaviour and, consequently, on vehicle design and road safety.

Viewing the subject from a psychological angle, Sachs and Diekstra [7] show how the car fits in perfectly with the *factors determining behaviour*: the need for security and a territory; auto-regulation; anthropomorphisation; the need for physical power, heroism and social superiority (chivalrous competition); the desire to be different and project an identity; and the need to experience risks (neuronic stimulation). Car design and the irrational aspects of the car system cannot be properly understood without taking these unconscious motives into account. The usual concepts of status, freedom and privacy do not provide an adequate explanation. Being aware of these motives, one can notice how they work out in our culture and in political decisions that relate to cars, fuel prices or the car industry. Indeed, no other industrial product offers so much satisfaction for so many desires.

In recent decades, almost unnoticed [8], it has become customary for each new car model to be faster, more powerful, larger and heavier than the last model in its own range. As a rule, cars are distinguished by their exact place in a hierarchy that is strictly dictated by dimensions, engine capacity, power, performance and image profile. The technological, psychological and economic developments of the car market are expressed in various forms of upgrading, which are part of the car culture and our spending patterns, and which counteract fuel efficiency:

1. All cars are getting larger and heavier.

Every model change since WW II proves that there is a law of continuous upgrading, due to the competition between car manufacturers, designing towards offering more than the current models or competitors in class. The interior space and the weight of the average European and Japanese car in each model range is now at the same level as that of the range above in the 1970s. The VW Golf Diesel body weight increased from 830 kg (model 1) to 1130 kg (model 4). The new Mazda 626, BMW 5 series and Mercedes S are the first exemptions, offering more interior space and performance with less size or weight than their predecessors.

2. All cars are getting faster.

Current small cars have the same performance as medium-range models 25 years ago, while medium-range models have the same performance as sports cars 25 years ago, and sports cars have the same performance as racing cars 25 years ago. The proportion of affordable cars with a top speed of over 200 km/hour is soaring, thanks to turbos, four-valve cylinders, more swept volume and power output and low air resistance. It is not so much the upgrading in the top range that is striking, but that in the bottom and medium ranges. The average European family car now has a higher performance rating than the renown Mini Cooper S or the SAAB 850 GT, with which Eric Carlsson won the toughest rallies in the 1960s.

3. The number of models and variants is steadily increasing, as is the use of accessories that increase fuel consumption, such as air conditioning, tuning sets, and wide tyres. Uneconomical models such as Jeep-type vehicles, Pick-ups and MPVs are increasing their share of the market. Turbo-DI diesels offer petrol-level performance, and low powered variants (2CV, R4) have disappeared anyway. The number of engine variants (in cm^3 and kW) and performances levels for each model range have dramatically increased. The result is a dynamic and more enticing range of models, with (upward only) variations in power, comfort and accessories to suit every taste. Publicity is generated by means of a massive multimedia campaign, with the trend being set by car magazine journalists, who, in their professional capacity, come into contact almost exclusively with the fastest cars.

4. Motorists are buying ever larger, faster and more expensive cars.

The sale of large cars and model variants with a high power rating and fuel consumption is of great commercial value: more is earned from these cars than from smaller or simpler versions of the same model. For instance, the basic VW Golf or Mercedes E or S is about half the price of the 1996 top versions. For many motorists, each car they buy is larger and faster than the last.

5. Effects of upgradings

A comparison between European car models today and those of 10, 20 or 30 years ago in terms of power ratings, fuel consumption and performance shows that nearly all the progress

in engine technology and efficiency has led almost exclusively to an increase in top speed and acceleration. From the standpoint of global warming, energy conservation and road safety, these trends are all in the wrong direction. The upgrading of the vehicle fleet has ensured that in most OECD countries the average fuel consumption of new (petrol-engined) cars has ceased to decline, after falling continuously since the first oil crisis. As a result of engine and materials technology and of lower air resistance, the performance of new car models will steadily increase, and at the same time they will become slightly more economical at constant speeds (by an estimated 1% per year) but not in practice.

The Kyoto CO₂ reduction targets and the energy conservation targets of most OECD countries will nevertheless not be achieved, if these trends are to sustain. Forecasts of transport CO₂-emissions in OECD and ECMT countries tend to show large increases rather than reductions or a standstill [9]. In a word, sustainable development remains unachievable within current "laissez-faire" approaches that do not address upgrading and performance.

As far as road safety and driving habits are concerned, the future looks even less rosy. Add-on (passive and active) safety features increase weight and offset part of the efficiency gains. Road network speed levels and driving dynamics have risen sharply in just a few decades. Speed limits in the Netherlands are exceeded during a third of the total mileage driven and the problem of overall and effective enforcement seems insoluble on the basis of current priorities.

Attempts to improve driving habits by the "soft" means of information, education and public campaigns will remain virtually ineffective as long as performance continues to provide the wrong behavioral "stimulus configuration". Assuming that the intrinsic and affective motives [7], or the quality of the infrastructure, cannot be influenced in the short term, a reduction in the potential speed of vehicles is an absolute prerequisite for achieving speed reductions. Thus, since driver self-control is becoming increasingly difficult to achieve voluntarily, one must think of "vehicle self-control" [10].

6. Limitation of speed, power and performance

Significant reductions in fuel consumption and CO₂ emissions per vehicle require not only best available technology but also the limitation of the top speed and - even more - the limitation of acceleration capacity by means of reducing power output and power-to-weight ratios. These ratios need to be reduced by at least 60% in every vehicle class to enable CO₂ emissions to be halved in the medium term despite a moderate growth in car use. In addition, weight reduction will remain necessary to compensate for the effects of the growth in car use. This would require a structural shift in the market so that the share of compact cars increases at the expense of cars weighing over 1,000 kg. The use of large capacity engines of over 2,000 cc or 100 kW would not be appropriate any more. Specific power ratings would have to fall gradually to under 3 kW/100 kg.

Reducing absolute speed in all traffic conditions and collisions and reducing the frequency of overtaking behaviour will reduce both accident frequencies and fatalities dramatically!

Technologically, engine and performance downsizing is not a problem. The motor industry is quite capable of designing vehicles which meet modern safety and comfort requirements while being extremely economical in terms of fuel consumption (3 litres/100 km). On the basis of the performance level of popular diesel-powered cars from around 1980, such as the VW Golf and Mercedes 200D, the average fuel consumption can be halved if - using the best technology available - driving habits improve and the average vehicle weight declines.

The semi-sustainable European medium-range (Golf class) petrol-fuelled car in the year 2000 geared to a low fuel consumption, could have following characteristics: length: 4 metres; 4/5 seats; weight: <800 kg; engine capacity <700 cc; variable valve timing and/or compressor for high torque at low rpm; fully electronic engine management and intelligent transmission; top speed: <140 km/hour; 0-100 km/hour >20 seconds; 3 l/100 km fuel consumption. A fuel consumption computer ("economy-meter" or "black box") will optimise driving habits and save an extra 5% fuel.

7. Policy consequences

How can current trends be reversed, given that fierce competition, low oil prices and the dominant car culture force manufacturers to participate in the race to constantly upgrade car models? What role can governments play in rolling back current upgrading and in downsizing power and speed? How can car manufacturers and retailers be brought to develop and sell fuel-efficient/low-powered cars that they do not believe to be profitable under current market conditions? And how can consumers be brought to purchase cars which they feel do not meet their basic needs as far as power, performance and image are concerned? One thing is for sure: those cars will not sell on the basis of current market preferences.

The first political statement in this direction was made by the European Conference of Ministers of Transport (ECMT). In their resolution of 21 November 1991, they came out unanimously in favour of limiting power and performance ratings for all categories of vehicles in the interest of road safety, environmental protection and energy conservation. The ECMT's call is also directed at the OECD, ECE and EU. More recently, in its communication on "A Community strategy to reduce CO₂ emissions from passenger cars and improve fuel economy", the European Commission finally acknowledged the role of upgrading and the need for reducing power and weight. The Commission underlines the need to encourage fuel efficiency through fiscal incentives, but unfortunately it fails to identify engine downsizing and in-car feedback instruments as a "no regret" approach.

The question therefore needs to be addressed: what single or combined measures should be taken to achieve the "downgrading" of market trends and the downsizing of power and performance? Four different but related approaches can be distinguished:

1. social-psychological instruments, such as communication and education;
2. fiscal and economic incentives;
3. covenants or voluntary agreements with manufacturers;
4. (international) regulations, directives and standards.

A brief survey of these different instruments suggests that instrument 1) cannot be considered effective, given current market preferences and "auto-cultural" values. The

measures under 2) and 3) are favoured as an alternative to 4) and can be highly effective once industry supports a target or a deal. But this will not happen in the foreseeable future, given current market preferences and the low oil prices and the promise of abundant future supplies, at least in the medium term. Thus the regulatory approach seems inevitable if politicians have the courage to promote stricter fuel efficiency and road safety at the expense of the current emphasis on performance. However, even if this were to happen, we should not harbour any illusions about the resistance which limiting the power-to-weight ratios or performance of cars will provoke. The "car-industrial-cultural complex" is likely to prevent any such approach from being embodied in directives until serious oil crises arrive. It must be concluded that it is the car industry that holds the key to any effective implementation of downgrading, be it voluntary or regulatory. In view of Kyoto and the long way to go, the first steps should now be taken by the OECD and EU member countries towards a comprehensive set of measures, starting with "no regret" measures and shifting to more unpopular and painful ones, as set out below:

1. Tax measures should be introduced to encourage purchase and ownership of compact and economical cars and discourage purchase and ownership of powerful, heavy and uneconomical cars. Such measures are currently being prepared in the Netherlands.
2. CO₂ emission standards and fuel consumption standards should be formulated for relevant vehicle size classes, and regularly tightened up. CO₂ standards need to prevent market reactance to upgrading, so fleet-average efficiency standards need to be incorporated as well. Standards can be set voluntarily or by EU directives.
3. Econometers, board computers and cruise control devices should be fitted as a standard in-car instrument that supports drivers in safe and fuel-efficient driving.
4. Speed limits should be enforced continuously and effectively so as to reduce real vehicle speeds and to improve driver's awareness of speed and fuel consumption. Current speed limits should be lowered to the levels where total costs/benefits to society are optimal: 90 or 100 km/hour on highways (LDV only; HDV: 80 km/h).
5. Speed limiters should be fitted not only to goods vehicles and buses but also to motorcycles, private cars and delivery vans, as a transitional measure towards the limitation of power ratings in all vehicles.
6. Power-to-weight ratios and the performance of passenger cars, motorcycles and, to a lesser extent, goods vehicles and buses should be limited within a tiered stepping-up time table for 2000, 2005, etc.

References

- [1] Towards road safety and sustainability; National traffic safety survey for the years 1990/2010 (SWOV, Leidschendam, NL; 1992).
- [2] "Just a bit less speedy"; cost-benefit analysis of reducing speeds on the road network in the Netherlands. Working Group 2Thousand/Free University of Amsterdam/Delft Technical University (1996).
- [3] Special emission measurements; VITO, Mol (Belgium), and IW-TNO 1992 report no. 731000006. Project in use compliance an pollution by cars in use, annual report 1992/ 1993 (IW-TNO). The emissions of cars under real-world driving conditions (IW-TNO report 735060117, May 1991). Calculation of the optimum driving speed of private cars and goods vehicles (minimum emissions and fuel consumption) on roads with different speed limits (TNO-IMW, report R91/315, 8 November 1991).

- [4] The safe road to fuel economy (MCR-Technology Inc.), Centre for auto safety, Washington, April 1991).
- [5] Risk statistics from the Highway Loss Data Institute (USA), Folksam (S) and FOCUS no. 29, 19 July 1993: "So sicher ist ihr Auto" [Your car's safety].
- [6] Slotegraaf, drs. G., dr. E.M.Steg and prof.dr. C.A.J. Vlek: Diepere drijfveren van het autogebruik (subconscious determinants of car use); Un. of Groningen, Aug. 1997.
- [7] Sachs, Wolfgang, Die Liebe zum Automobil (Rowohlt 1984). Diekstra, Prof. R F W, Saying goodbye to the car; the car jungle; in Transport and Environment Postgraduate Course at Delft Tech. Un. Also: The car as the last territory; and: Cars and behaviour; psychological barriers to fuel efficiency and sustainable transport (OECD 1996) by Prof. René F W Diekstra and Martin C Kroon.
- [8] Braess, Hans-Hermann [BMW], Nichts steigt so schnell wie Ansprüche [Nothing rises faster than claims]; ATZ Automobiltechnische Zeitschrift 95 (1993). Delsey, Jean, Trends in the power ratings of cars and heavy goods vehicles, INRETS/ ECMT, Sept. 1993. Bingham, J F, Downsizing of automotive spark ignition engines, in "Low consumption/low emission automobile", OECD/IEA, Paris 1991.
- [9] CO2 Emissions from Transport. ECMT/CEMT, Paris 1997.
- [10] Kroon, M C (1996), Engine downsizing - the key to fuel efficiency and road safety. Paper for the OECD/IEA conference "Towards Clean Transport: Fuel efficient and clean motor vehicles" (OECD 1995).

Safety and Commercial Realities in an Avionics Application

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Abstract. To fly aircraft under all (adverse) conditions, pilots must rely fully on the data presented to them, and on the reliable and timely forwarding of their commands to the relevant aircraft subsystems. The avionics application, Flight Control Display Module (FCDM), connects these subsystems with the aircraft flight deck by means of modern digital data buses. It combines, controls, processes and forwards the data between the subsystems and the flight deck. High reliability of these functions is required to ensure the safety of the aircraft. The experiences with the software development methods to meet these requirements are presented.

For air transport the safety requirements are stated in DO-178B: software considerations in airborne systems and equipment certification. The main part of the FCDM software is subject to the most severe classification of DO-178B. Compliance to DO-178B is assessed by an independent, government authorised, third party. This third party issues a certificate releasing the product for operational use. The influence of these safety requirements and the independent DO-178B compliance assessment on the software development and verification methods are described. The black box has a successful application in air transport. The extension of the black box approach in FCDM is discussed.

The development of aircraft is a commercial venture. In order to meet the market demands, permanent changes occur during the software development process. Many different versions of and/or extensions to the product for the various customers are required. The reliability, maintainability, safety and certifiability of the product may not be compromised. The impact of all these customisations on the development and verification methods is assessed.

General standards for safety critical software are emerging. Some differences and similarities with DO-178B are highlighted. These standards provide opportunities for general purpose products. Their possible impact on airworthy equipment is assessed using the FCDM case.

1. Introduction

To fly aircraft under all (adverse) conditions, pilots must rely fully on the data presented to them, and on the reliable and timely forwarding of their commands to the relevant aircraft subsystems. An avionics application which is currently being developed by NLR, the Flight Control Display Module (FCDM), connects these subsystems with the aircraft flight deck by means of modern digital data buses. It combines, controls, processes and forwards the data between the subsystems and the flight deck. High reliability of these functions is required to ensure the safety of the aircraft. In this paper the experience with the software development methods to meet these requirements in a commercial environment are

presented. The final section highlights some differences and similarities between the emerging general standards for safety critical software.

2. Air transport software safety requirements

For air transport, apart from the normal customer-supplier relation relating to the functional requirements, the safety requirements are stated in DO-178B: software considerations in airborne systems and equipment certification [1]. The aim of this document is to provide guidance to both the software developers and the certification authorities. Usually acceptance of software is based on an agreement between the developer and the customer. In civil avionics an independent third party, the certification authority, performs the ultimate system (aircraft) acceptance by certifying the aircraft. It is only then that the software is airworthy and can be considered ready for use in the aircraft concerned. DO-178B provides a world wide "level playing field" for the competing industries as well as a world wide protection of the air traveler, which are important due to the international character of the industry. The certification authority is a national governmental institution which in our case delegated some of its technical activities to a specialised company.

Based on the impact of the system failure the software failure can contribute to, the software is classified into 5 levels. The following is a verbatim copy of the DO-178B text. The failure probability in flight hours (i.e. actual operating hours) according to the Federal Aviation Requirements/Joint Aviation Requirements FAR/JAR-25 [2] has been added.

Level A: Catastrophic failure

Failure conditions which would prevent continued safe flight and landing

FAR/JAR-25 extremely improbable, $< 1 \times 10^{-9}$

Level B: Hazardous/Severe-Major

Failure conditions which would reduce the capability of the aircraft or the ability of the crew to cope with adverse operating conditions to the extent that there would be:

- a large reduction in safety margins or functional capabilities
- physical distress or higher workload such that the flight crew could not be relied on to perform their tasks accurately or completely
- adverse effect on occupants including serious or potentially fatal injuries to a small number of those occupants
- FAR/JAR-25 extremely remote, $1 \times 10^{-9} < \text{hazardous failure} < 1 \times 10^{-7}$

Level C: Major

Failure conditions which would reduce the capability of the aircraft or the ability of the crew to cope with adverse operating conditions to the extent that there would be, for example,

- a significant reduction in safety margins or functional capabilities

- a significant increase in crew workload or in conditions impairing crew efficiency or
 - discomfort to occupants, possibly including injuries
- FAR/JAR-25 remote, $1 \times 10^{-7} < \text{major failure} < 1 \times 10^{-5}$

Level D: Minor

Failure conditions which would not significantly reduce aircraft safety and which would involve crew actions that are well within their capabilities. Minor failure conditions may include for example,

- a slight reduction in safety margins or functional capabilities
- a slight increase in crew workload, such as, routine flight plan changes, or
- some inconvenience to occupants.

FAR/JAR-25 probable, minor failure $> 1 \times 10^{-5}$

Level E: No Effect

Failure conditions which do not affect the operational capability of the aircraft or increase crew workload.

The following text will only consider the part of the application which is classified as level A.

DO-178B on purpose refrains from making a statement about an appropriate software life cycle. The life cycle is described rather abstract as a number of processes that are categorised as follows:

- software planning process,

The software planning process entails the production of the following documents

- Plan for Software Aspects of Certification. The main purpose of this document is to define the compliance of the software development process to DO-178B for the certification authorities. This document contains many references to the project documentation generated as part of the life cycle model used.
- Software development plan, which defines the chosen software life cycle and the software development environment, including all tools used
- software verification plan, which defines the means by which the verification objectives will be met
- Software configuration management plan and software quality assurance plan

- software development processes consisting of

- software requirement process
- software design process
- software coding process
- integration process

Each software development process has to be traceable, verifiable and consistent. Transition criteria need to be defined by the developer to determine whether the next process may be started. In case the inputs of a process are incomplete, e.g. the

previous process has not been completed, transition can be allowed when the transition criteria are satisfied. Special attention needs to be paid to the verification of process inputs which become available after the subsequent process is started.

- integral processes

The integral processes are divided into

- software verification process
- software configuration management process
- software quality assurance process
- certification liaison process

The integral processes are a result of the criticality of the software. Consequently the integral processes are performed concurrently with the software development processes throughout the entire software life cycle.

Verification is defined as "the evaluation of the results of a process to ensure correctness and consistency with respect to the inputs and standards to that process". Verification can be accomplished by review, analysis, test or any combination of these 3 activities. Review provides a qualitative assessment of correctness. Analysis is a detailed examination of a software component. It is a repeatable process that can be supported by tools. DO-178B recognises two types of tool:

- software development tools, which can introduce errors
- software verification tools, which can fail to detect errors

The FCDM project has only developed software verification tools. Every tool needs to be verified against the Tool Operational Requirements (TOR), the contents of which is prescribed in DO-178B. Software development tools need to be tested using normal and abnormal conditions. Software verification tools need only be tested using normal conditions. For software tools the same documentation and configuration control procedures apply as for the airborne software. Every software tool needs approval of the certification authority. Testing is "the process of exercising a system or system components to verify that it satisfies specified requirements and to detect errors". By definition the actual testing of deliverable software forms only part of the verification of the coding and integration processes.

3. Experience gained with safety critical software development

Usually the software development process is agreed between the customer and the supplier. For certifiable software a third party is involved, adding a stage in the approval process. The organisational independence improves the position of the assessors. In our case the customer had ample experience with DO-178B certification and decided, after approving the process documentation, to postpone the review with the certification authorities until the completion of the coding process. Only minor modifications were needed in the process documents, implying that DO-178B can be adhered to without prior knowledge of certification.

The project team was set up consisting of 2 separate groups, a development group and a verification group. The verification group was headed by a team member with sufficient authority to report, at his own discretion, to the company management outside of the project hierarchy.

To ensure a strict traceability from requirements to design, to code and to integration a review was planned after completion of each process. Experience with previous mission critical software development suggested variability of detailed system requirements, so analysis is used wherever possible. Part of the analysis can be strictly defined and subsequently implemented in a customised tool. Tool support reduces the costs for repeated analysis. The software verification tools performed according to expectations to reduce the impact (both in time and costs) of the many late requirements changes.

The customer required use of the C programming language was considered a potential risk for the successful application development. The C language contains numerous constructs that are unspecified, undefined or left to be defined by the compiler supplier [3]. This risk was reduced by choosing an ANSI-C compliant compiler complemented by a project coding standard defining, amongst others, a safe subset of C. Compliance to this project coding standard can be checked automatically by customising a commercial tool. During verification of this tool the version management by the tool supplier turned out to be inadequate. The tool was already sold at least 5 years to hundreds of customers. This illustrates the rigour of the applied verification processes.

4. Overview of the avionics application

The flight display subsystem is designed to operate in both Visual Meteorological Conditions (VMC) and Instrument Meteorological Conditions (IMC). Under visual meteorological conditions the displays aid the pilot during flight, under instrument meteorological conditions the instruments are necessary for the pilot to be able to fly, consequently the correct functioning of the instruments is safety critical. The latter conditions imply that a number of equipment items needs to be duplicated to achieve the required failure probability.

When configured for instrument meteorological conditions the display subsystem consists of the following equipment:

- 2 Flight Control Display Modules,
- 4 Smart Multifunction Displays,
- 2 Instrument Control Panels,
- 1 Reconfiguration Control Unit.

The FCDM is the interface between the on-board sensors and the displays. The sensors and some aircraft subsystems send flight parameters via digital buses to the FCDM, which validates the parameters and sends them to the displays. A number of parameters is also computed within FCDM itself.

In case of failure of an equipment item or a discrepancy between two sensors, the Reconfiguration Control Unit permits the crew to choose between different configurations. When a sensor is reconfigured, it is logically switched-off. This illustrates

how software and a multiplied hardware device reduce the failure rate to to the required level. Consequently the software becomes safety critical.

During normal operation FCDM processes about 100 different flight parameters, coming from 10 different sensors. Each parameter is classified as:

- critical: loss or undetected error could lead to a catastrophic failure condition. Examples of critical parameters are the attitude parameters: pitch, roll, and heading. The software that handles these parameters is classified as level A.
- essential: loss or undetected error could lead to a major failure condition. An example of an essential parameter is the VOR (VHF Omnidirectional Range for position determination). The software that handles these parameters is classified as level B.
- non-essential: loss or undetected error could lead to a minor failure condition. Examples of these parameters are the long term navigation parameters, like the flight plan. The software that handles these parameters is classified as level D.

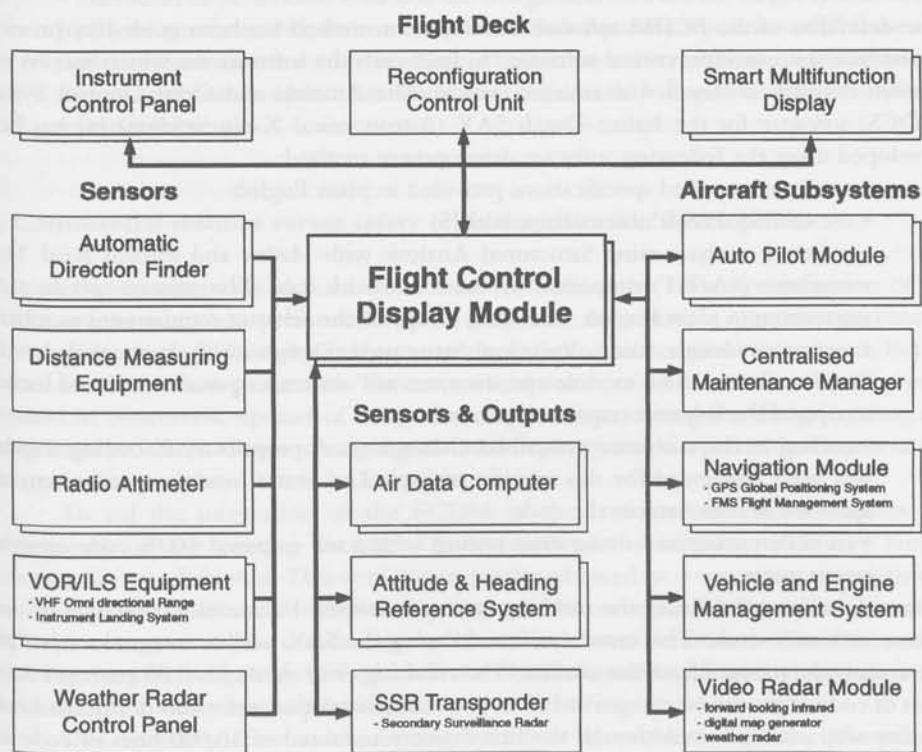


Figure 1. Overview flight control display module environment.

Depending on the criticality of the data, validation is performed in four different ways:

- coherency test: a check on correct length and parity of the data,
- reception test: a check on the timely arrival of the data,
- sensor discrepancy test: a comparison between two parameters produced by the

two independent redundant sensors,

- module discrepancy test: a comparison between two parameter values produced by the same sensor; one value directly read by FCDM from the sensor, and one obtained from the redundant FCDM via a cross-talk bus.

FCDM itself does not have a black box capability. However, since FCDM is a spider in the web of the avionics subsystems, it is made responsible for monitoring the health of these subsystems. Any discrepancy between multiplied equipment and abnormal behaviour is logged into non-volatile FCDM memory and also send to the on-board maintenance device. The logged errors can be downloaded from FCDM during on-ground maintenance. This log allows an early warning system to prevent possible future malfunctions leading to accidents.

5. Experience gained with safety critical software development methods

The definition of the FCDM software development method has been guided by previous experience with mission critical software. In spacecraft the software on which success of a mission depends is classified as mission critical. The Attitude and Orbit Control System (AOCS) software for the Italian-Dutch SAX (Astronomical X-ray Satellite) [4] has been developed using the following software development method:

- customer supplied specifications provided in plain English
- use of ESA PSS-05 life cycle model [5]
- software analysis using Structured Analysis with Hatley and Pirbhai Real Time extensions (SA/RT) supported by the Teamwork tool. The process-specifications are written in plain English, including a copy of the relevant requirement number(s)
- software design using Yourdon Structured Design (SD) supported by the Teamwork tool. The module-specifications are written in pseudo code and include a copy of the relevant requirement number(s)
- coding in the customer prescribed C-language. A proprietary C-coding standard was used, enhanced for this specific project. The entire module-specification was included as comment in the code
- module testing and integration testing with a self imposed 100% code coverage requirement.

After validation and delivery the resulting system contained 1 error in 20,000 lines of non-comment source-code. This error was found during the SAX satellite integration tests plus the entire operational life of the satellite. The resulting error density is 0.05 error per 1,000 lines of code. This can be categorised as an extremely low value, refer also to [6]. This error density was achieved even though the first delivery consisted of 16,000 lines of code and subsequently about 8,000 lines of code were added/modified resulting in a total size of 20,000 lines of code.

For FCDM the customer prescribed the use of the DOD-STD-2167A [7] life cycle model and the use of the C-language. Based on the successful SAX AOCS development the following elements of the SAX AOCS software development method are retained:

- customer supplied specifications provided in plain English

- software analysis using Structured Analysis/Real Time supported by the Teamwork tool
- software design using structured design supported by the Teamwork tool
- use of NLR proprietary C-coding standard, with project specific enhancements

Based on the SAX-AOCS experience of a very substantial amount of changes during and after the implementation phase, even more emphasis is placed on tools to support the development activities. Added to the software development method are:

- automated test tool to aid the construction and cost effective repetition of module tests and as many of the integration tests as practical
- a mandatory 100% code coverage for level A software. This code coverage consists of statement coverage (every statement executed) plus decision coverage (every decision executed for pass and fail) plus the modified condition/decision coverage (mc/dc). Mc/dc requires that for every operator in an expression, its independent effect on the outcome of the expression is demonstrated
- execution of all module tests and the integration tests on the target system with a hardware emulator with instrumented code. Subsequently repetition of all these tests with non-instrumented code to check whether the same results are obtained as with the instrumented code. An emulator considerably expedites the analysis of unexpected results.

6. Commercial realities versus safety critical application development

Due to the commercially defined short time to market, the customer definition of the system requirements was performed concurrently with the software requirements process. The resulting analysis was subjected to a number of informal technical assessments, but no formal verification was performed. The commercial nature of the aircraft development even resulted in concurrent updates of the system requirements during the design, coding and integration processes. Consequently the planned deployment of separate development and integration teams turned out to be infeasible.

To aid the integration of the FCDM in the customer developed displays and subsequently in the existing aircraft, a first version of the software with very limited functionality was delivered. This version was produced based on a successive completion of the documented software development processes. However none of the formal reviews with the customer or the certification authority had been performed. The first version served its purpose well. A lot of feed-back was obtained, resulting in many changes to and clarifications of the system requirements.

Due to the success in eliminating system level problems by the informal co-development of the first version of the FCDM and the displays, the customer requested to continue the informal co-development and allocate all project resources to it. The personnel resources of both teams were combined, however the 2 separate team managers with their complementary responsibilities remained. All activities were executed for only one of the teams. The respective team leader ensured that the relevant procedures are strictly enforced.

From a functional point of view this concentrated development effort resulting in 4 pre-releases of the software, has been very successful. Up to date the software contains nearly all functions while at the same time around 150 changes to the system requirements have been accommodated. Valuable feed back from the user (pilot) has been obtained. Also the development of the displays and especially its integration with FCDM and the aircraft have been expedited considerably.

This informal co-development has only been possible because the documented software requirement process and software design process had been completed before the coding of the first software version started. The available Teamwork models also aided in assessing the consequences of proposed changes. The drawback of the informal co-development is that a very considerable amount of documentation work remains, as based on the software size it was impossible to enlarge the team. Also all verification and the exhaustive mc/dc testing still needs to be performed. It is inevitable that the verification will result in a new version of the software, which will be submitted to the certification authorities. The reverse side of the early and successful delivery of the co-development versions is the risk of the invalidating some already completed flight trials of the aircraft.

An important lesson learned from the informal co-development is to try to keep the verification process up with the actual implementation to comply with the commercial time to market. The many system requirement changes require a cheap and easily repeatable verification process. This can only be achieved by using strictly defined development methods which allow strictly defined analysis. The well defined analysis should be executed by automated tools. These tools should be sufficiently user-friendly and efficient to allow the analysis, design and testing to be updated concurrently with the code modifications resulting in a spiral development model. As a complete integrated suite of development tools is not commercially available, the best option is to use as much available tools as possible. For some simple unsupported (verification) tasks proprietary tools can be produced cost-effectively. Only the tool for checking compliance to the coding standard was sufficiently user-friendly to be used during the co-development. The Teamwork tool is too labour intensive to keep the analysis and design up to date.

Independent personnel is required for the verification of the coding and integration processes. This requirement combined with the outdated status of the analysis and design, means that the verification can not keep up with the co-development. After the last pre-release delivery costly re-work needs to be done, which also delays the certification schedule. It is unclear how much of the schedule time gained during the co-development is lost due to the resulting delay of the certification. At least co-development saves re-certification effort as well as the generation of much documentation describing pre-releases.

7. Comparison of standards for safety critical systems

This section will highlight some differences between several standards for safety critical systems, based on the avionics application experience.

DO-178B has been specifically constructed for airborne systems and pre-dates the other standards. Currently other standards for safety critical systems are available, ISO/DIS

15026 [8] and IEC 1508 [9]. Like DO-178B also ISO/DIS 15026 recognises an "integrity assurance authority" besides the customer and supplier. This authority issues a certificate of compliance. The number of software integrity levels and their criteria are to be negotiated with the integrity assurance authority. As an example the IEC 300-3-9 [10] is included in the standard. JAR/FAR-25 requires a catastrophic failure to occur less than once during 10^{-9} flight hours. IEC 300-3-9 classifies a system exhibiting a failure with catastrophic consequence and an incredible frequency (defined at $< 10^{-6}$ per year, which at a commercial utilisation rate of 1000 flight hours per year for the aircraft involved, equals 10^{-9} per flight hour) only as intermediate. Like DO-178B ISO/DIS 15026 does not recommend a life cycle. An example life cycle with methods to achieve confidence are included. This example life cycle defines 8 phases based on the waterfall model and consequently does not accommodate the commercial necessities of co-development and short time to market.

IEC 1508 classifies the failure frequency in 4 levels, the most severe allowing between 10^{-6} and 10^{-4} dangerous failures per year. This is more frequent than DO-178B combined with JAR/FAR-25. IEC 1508 declares itself unapplicable for lower failure rates. IEC 1508 defines a safety life cycle with 16 phases which include modifications after delivery, retrofit and decommissioning. The inputs and outputs per phase are specified. Highly recommended techniques are prescribed. Not using these requires a mandatory justification. As a minimum ISO 9000 quality assurance is required. Although the need for iteration is mentioned, the software life cycles and the recommended techniques do not seem to accommodate this commercial necessity. DO-178B is based on independent execution of the verification by the supplier combined with the organisationally independent certification authority. IEC 1508 prescribes the independence of the assessors per safety level for a number of activities. The options are independent person, independent department and independent organisation. For systems with the highest integrity level IEC 1508 states a structured method supported by a tool as "highly recommended". C is classified as "positively not recommended" and IEC 1508 is impartial for C with subset and coding standard. The emergence of these standards means market opportunities for tools which support the development of safety critical systems. This may benefit the development of safety safety critical systems in various ways:

- tools may be qualified once by the vendor, reducing considerable project qualification effort,
- tool checks may become more comprehensive reducing (re-)verification effort,
- tool operations may improve allowing to support the commercially necessary co-development,
- commercial tools should significantly lower the effort needed to produce safety critical systems and hence their price, making those systems affordable for many more applications.

8. Conclusion

For software development in air transport the safety requirements are stated in DO-178B. This document is sufficiently clear to allow a first-time developer to define, without

external support, a compliant development process. This document is used by both software producers and by the independent certification authority which ensures compliance. Developing software according to the traditional waterfall model allows compliance to be achieved.

Producing aircraft is a commercial venture which means that the various aircraft subsystems need to be co-developed in order to achieve the commercially determined time to market. The spiral model is more appropriate than the waterfall model. An integrated tool set is needed which supports the co-development i.e. which allows when a change occurs to concurrently update analysis, design, code, integration and verification (including traceability information). Currently available tools do not provide this capability. To minimise the effort of the recurring verification, analysis is the preferred method, supported by tools wherever available. For simple verification tasks customised tools can be developed cost-effectively. Emerging general purpose safety standards suggest that safety critical systems will also have to be built for other application areas. This could make the required tools commercially attractive for tool vendors, which in turn, could reduce the costs associated with safety critical system development.

The need to deploy all human resources to development has significantly reduced the development time as well as allowed co-development of the avionics application with several other aircraft subsystems. It can not be assessed whether this time reduction is offset by the resulting delay in updating the documentation and certification. By performing these iterations before certification at least the re-certification costs of the intermediate versions have been avoided.

References

- [1] DO-178B, Software Considerations in Airborne Systems and Equipment Certification, (December 1992).
- [2] Federal Aviation Requirements/Joint Aviation Requirements FAR/JAR-25.
- [3] Safer C, L. Hatton (1995). Mc Graw-Hill.
- [4] Development procedures of the on-board attitude control software for the SAX satellite, G.J. Dekker, NLR technical publication TP 96573 L (1996).
- [5] ESA Software Engineering Standards, ESA-PSS-05 (1991).
- [6] Software faults: the avoidable and the unavoidable: Lessons from real systems, L. Hatton, Proceedings of the ESA 1996 product assurance symposium and software product assurance workshop (ESA SP-377), Noordwijk, March 1996, page 271-275.
- [7] DOD-STD-2176A Department of Defense (DoD) Defense System Software Development (February 1988).
- [8] ISO/DIS 15026 Information technology - System and software integrity levels (1996).
- [9] IEC 1508 Functional safety:safety related systems, 7 parts, (June 1995).
- [10] IEC 300-3-9 Dependability management - Part 3: Application guide - Section 9: Risk analysis of technological systems (1995-12).

Rescue Vessels: The Influence of Design for Safety on the Design Process

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1. Introduction

This paper investigates the rescue vessel design process and analyses changes in it resulting from the creation and integration of a computer based formal safety assessment tool. The research is being undertaken by the Department of Marine Technology at Newcastle University, in collaboration with the Royal National Lifeboat Institution (RNLI), both in the U.K.

As safety becomes more central to the planning of transportation systems, so the emphasis is shifted from conforming to prescriptive regulations to a more goal setting approach, as in the safety case technique. Rescue vessels are subject to extremely hazardous conditions, requiring unique safety and reliability standards to be achieved far in excess of normal regulatory requirements. Safety is therefore a central performance consideration throughout the design process. At present safety decisions are based largely on the experience of the designers, expressed in a semi-formal way. However in their search for improved performance in all aspects of design, including safety, the RNLI have funded this research to investigate the rescue vessel design process and to consider in detail how decisions concerning safety should be made. The overall aim is to provide a software tool based on formal safety analysis methods, which can assist the designer.

A formal safety analysis system has been developed, based on failure mode and effect analysis (FMEA) and the modified Boolean representation method (MBRM), which generically models safety information such that the consequences of design actions can be identified. A supporting software framework has been written incorporating the FMEA and MBRM formal safety assessment theory. In order to produce a safety assessment tool specific to the domain of rescue vessels, the generic software framework must be populated with data relevant to the safety of rescue vessels. The "Trent" class rescue vessel, one of the most recent additions to the RNLI fleet, was used to create a standard rescue vessel safety model, which was then embedded into the software framework. The resultant software gives the rescue vessel designer the power to conveniently manipulate or input new data concerning the various systems on the vessel.

The influence of changes in design, operational factors or environmental inputs on various aspects of safety within the system can be assessed in both qualitative and quantitative terms. With this new facility, the design process is changed from a top-down assessment approach to a bottom-up investigation of the influence of design decisions.

Formal safety analysis is thus integrated at an early stage, and remains a concurrent activity throughout the design process.

2. Design for safety

Safety analysis refers to the studies of process and equipment failures and their influence on operability. Safety analysis of an item involves studying both the probability that it will perform a required function under stated conditions for a stated period of time, and also the consequences of the failure in terms of possible damage to property or environment and injury or death of people [1]. An item could be a piece of equipment, a component, a procedure, a subsystem, or a complete system. A risk is defined as the probability of a hazard occurring, combined with its associated effects or consequences. Formal safety analysis is devoted to the process of estimating the safety of a product and identifying appropriate measures to reduce risks to an acceptable level.

Traditionally, safety analysis has been primarily used in many industries for verification purposes [2]. However, this approach fails when large and complex engineering products with significant elements of novelty are designed. For such cases safety aspects should be integrated into the design process from the initial stages, with the aim of systematically reducing or eliminating serious risks at the design stage. As such, the emphasis on safety must shift from conforming to prescriptive regulations to a more open approach with safety becoming central to the planning of transportation systems.

3. Current rescue vessel design

The Royal National Lifeboat Institution's commitment to the combined maritime rescue services of the United Kingdom and the Republic of Ireland is to provide all-weather rescue vessel cover for up to 50 miles offshore within 2 hours of launching [3]. The RNLI's 1983 Strategic Plan demanded that all offshore rescue vessels be of the self-righting type by 1993. This in conjunction with the policy to retain afloat rescue vessels for 20 years resulted in a need to replace the early Waveney and Arun class rescue vessels. In response to these requirements two new types of rescue vessel were developed with a speed of 25 knots, propeller protection, and the ability to take the ground. The "Trent" and "Severn" class rescue vessels have evolved out of these developments [3].

In order to investigate the implementation of formal safety assessment in the context of RNLI rescue vessel design it is necessary to look first at current rescue vessel design procedures. In the design of any product the designer must consider many different, and possibly conflicting, performance objectives in order to formulate the design requirements, from which possible solutions will be synthesised [4]. The design and development of rescue vessels recognises the extreme and particular operating conditions that the rescue vessel service can on occasion have to cater for. Safety is an important aspect of performance in rescue vessel design, and during the design process it is necessary to make specific decisions concerning safety. At present safety decisions are based largely on the experience of the

designers, expressed in a semi-formal way. Whilst successful in the past, the complexity of vessels is increasing: a modern rescue vessel is a combination of many systems, subsystems and components, linked together in complex and sometimes unexpected ways. Some of these links may not be apparent to even the most experienced designers. This makes it difficult to form safety judgements during the design process which take account of the myriad interactions on all systems, sub-systems, and aspects of safety throughout the vessel. In addition it is difficult to experiment systematically with alternative design solutions. As a result of this situation there are increasing possibilities of overlooking combinations which could cause malfunction or worse, as well as incurring costs caused by having excess redundancy. A diagrammatic representation of how safety is incorporated into the current rescue vessel design process can be seen in Figure 1.

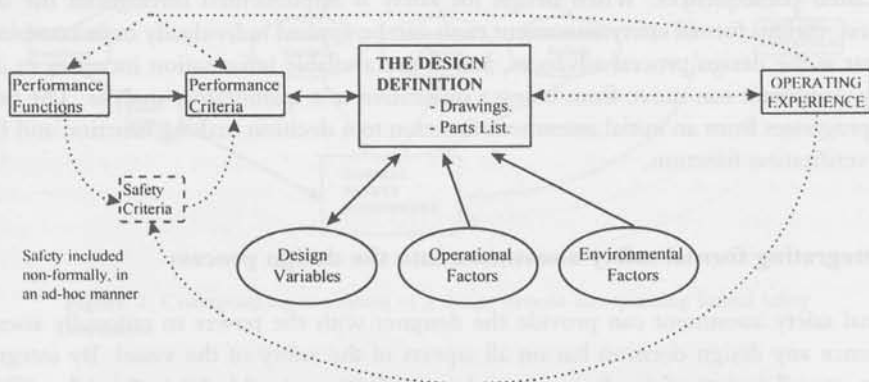


Figure 1. Conceptual representation of the existing rescue vessel design process scope.

4. Formal safety assessment

In order to explicitly reduce or eliminate serious risks by design, safety must become a fundamental and continuous activity within the design process: "design for safety" must provide a systematic approach to the identification and control of high risk areas [5,6]. This is achieved by the application of various safety analysis methods within the design process.

System risk can be assessed using top-down or bottom-up approaches by investigating respectively the causes or the consequences of a failure event, on either a qualitative or quantitative basis. A "top down" safety study begins with examination of previous accidents and incident reports of similar systems, in order to define the top or ultimate events, the causes of which can then be identified deductively to the required level of resolution. This method is acceptable only if relevant failure data is available, and even then it can be difficult to be certain that all system failure events, their respective causes, and the complex links between events have been identified. For example, some plausible fault conditions may be so rare that no recorded occurrences exist. However, these conditions

may be sufficiently serious to not be ignored. Fault Tree Analysis is an example of a top down method. In contrast, a "bottom up" safety assessment procedure breaks down an overall system into sub-systems and then into components, allowing hazard identification to occur initially at this level, and then to progress to the system level. Failure events and their combinations can then be studied comprehensively at all levels. The resulting computational burden can be high but is manageable with modern computers. Event Tree Analysis is a typical bottom up method.

In pursuing the above, a qualitative approach, which only looks at the chains of events, can be used to locate possible hazards and to identify appropriate precautions that will reduce the frequencies or consequences of such hazards. On the other hand, a quantitative safety analysis incorporates event probabilities and can provide the designer with the quantified probability of occurrence of each critical failure condition as well as the associated consequences. When design for safety is implemented throughout the design process, various formal safety assessment tools can be applied individually or in combination so that as the design process advances, and as the available information increases in detail, safety assessment can move from being a qualitative to a quantitative analysis. The process also progresses from an initial assessment function to a decision making function and finally to a verification function.

5. Integrating formal safety assessment into the design process

Formal safety assessment can provide the designer with the power to rationally assess the influence any design decision has on all aspects of the safety of the vessel. By integrating safety into all aspects of the design procedure it becomes possible to monitor the effects of design changes rapidly. The designer can then both identify the consequences of design decisions and explore possible options for improvement, especially when risks are judged to be unacceptable with respect to corresponding criteria. Figure 2 demonstrates conceptually how this can be achieved. Formal safety assessment activity parallels the conventional design procedure, providing a model to simulate the impact on safety of changes in the design variables, and operational or environmental factors.

6. Creation of a formal safety assessment tool

Having conceptually identified how formal safety assessment will affect the design process, the practicality of creating a tool to fulfil these requirements has been investigated. In the development of a design for safety system applicable to rescue vessels, three objectives were identified, with the first two being addressed in parallel, the third then combining their results:

- A formal safety analysis system with supporting software, based on formal safety assessment methods, which generically models safety information such that the consequences of design actions can be identified.
- A clear description of how individual systems interact within the overall design of

a specific rescue vessel.

- A design aid for rescue vessels, produced by populating the generic formal safety assessment software tool with data from the rescue vessel design study.

Based on the examination of both the requirements of design for safety in rescue vessels and the available formal safety assessment methods the resultant formal safety analysis system developed contains two safety assessment procedures: failure mode and effect analysis and modified Boolean representation method.

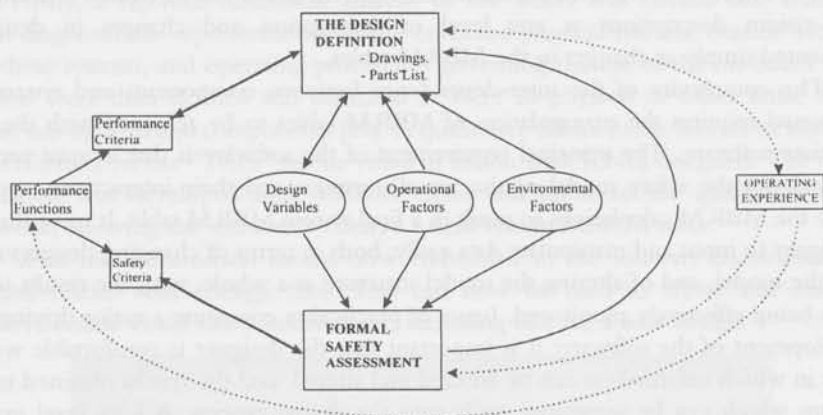


Figure 2. Conceptual representation of a design process incorporating formal safety assessment.

6.1 Failure Mode and Effect Analysis (FMEA)

FMEA rigorously examines systems, sub-systems and components to discover all the modes of failure, their causes and effects. This specific failure analysis of the components, sub-systems and systems rationally explores the designer's knowledge, and is useful in that it can provide an initial exploration of areas that may need more detailed work. The analysis includes the influence of human and environmental factors in addition to purely on-board physical systems and can be performed on a qualitative (event chain) or quantitative (probability) basis. FMEA follows a well documented format, and is advocated by the recent International Code of Safety for High Speed Craft [7].

6.2 Modified Boolean Representation Method (MBRM)

MBRM is an inductive bottom up method for identifying system top events and associated causes, and as such is a good method where there is a high degree of innovation. Information is held in a tabular format which is easier to deal with in a large analysis of a complex system such as a rescue vessel. Held integrally within the tables are the logic relationships between component/ sub-system/ system failure events. The MBRM approach looks at the problem in terms of component modes, using them to identify hazards, and ensuring reliable hazard tracing. Work done in a failure mode and effect

analysis feeds directly into the creation of MBRM tables. In MBRM, component or sub-system decision tables are combined into a single composite decision table [8]. This is effectively a pooling of associated information corresponding to any system state. The final system MBRM table contains all the possible system top events and the associated cut sets (paths of basic failure events resulting in that state). Data held within the final MBRM table represents the qualitative system model, and is the basis for both qualitative and quantitative system safety analysis, providing the designer with a hierarchy of possible actions that can be taken to improve safety. This is because the MBRM tables can be treated as component or sub-system descriptions at any level of aggregation and changes in design are implemented simply as changes in the MBRM tables.

The complexity of the inter-dependence between components and systems in a rescue vessel requires the manipulation of MBRM tables to be achieved with the aid of appropriate software. The principal requirement of the software is that it must provide a framework for the safety model of the vessel's systems and their interactions, and must facilitate the MBRM calculations to result in a final system MBRM table. It must also allow the designer to input and manipulate data easily, both in terms of changing design variables within the model, and of altering the model structure as a whole, with the results of these changes being effectively monitored. Issues of practicality constitute a major driving factor in development of the software: it is important that the designer is comfortable with the manner in which information can be entered and altered, and the results obtained must be of a form which can be integrated easily into the design process. A high level graphical programming package, "LabVIEW" [9], was chosen as the primary software development tool.

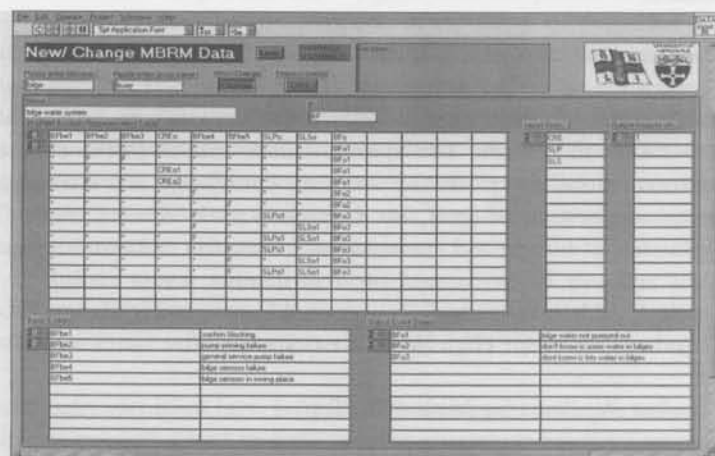


Figure 3. User interface for input/alteration of an item's safety information.

Using LabVIEW, software has been written to accept qualitative safety data in the form of MBRM tables and process them to produce a final system MBRM table. Many additional on-line tools have been created to make the process of inputting and altering MBRM data easier and error-free, with all user interfaces also being created using LabVIEW. An example of the user interface for inputting/altering an item MBRM table can be seen in Figure 3.

6.3 The rescue vessel safety information model

The MBRM data manipulation software created is essentially generic and could be applied to any safety analysis situation. In order to create a dedicated rescue vessel design tool the developed software framework must be populated with standard rescue vessel safety information: the RNLI "Trent" class rescue vessel, shown in Figure 4, was used to provide this data.

Firstly, a rigorous functional analysis of the vessel was carried out, resulting in explicit diagrammatic representations of the on-board physical systems, outside events that affect these systems, and operating procedures governing the use of the on-board systems. All items were then defined and tabulated as were all physical or other links, between systems, sub-systems and components [10]. A qualitative failure mode and effect analysis was then performed on the "Trent" rescue vessel in liaison with RNLI designers. The resultant information was developed into MBRM tables and input to the qualitative software framework, allowing the software to derive a final system MBRM table.

With this information model now embedded in the software framework it is a dedicated rescue vessel design tool. This can now be used to create and manipulate alternative rescue vessel safety information, including that for a new design.



Figure 4. The RNLI "Trent" Class Rescue Vessel.

7. Qualitative and quantitative analysis

Having created a model of rescue vessel safety in terms of a final simplified modified Boolean representation several conclusions can be drawn. Qualitative analysis software has been written in LabVIEW. This identifies those paths to an undesired top event which have the fewest component failure modes. It also highlights the events which lead most frequently to undesired top events. However it must be borne in mind that qualitative analyses can only indicate areas of concern, and the addition of probability values to the

tables will significantly increase the usefulness of this assessment, as risk is the combined effect of likelihood and consequence. This can be achieved by assigning probability estimates to the basic event states which make up the final master table, and processing these probabilities in conjunction with the logical relationships between events held within the table, in order to derive estimates for the probabilities of system output event states. With this additional probability data the designer can identify the critical paths requiring attention on the basis of these probabilistic estimates. The development of probabilistic data to accompany the existing qualitative "Trent" model, along with the quantitative analysis software, is currently under development.

8. The practical impact of safety assessment on rescue vessel design

The successfully implemented software will enable the designer to study the influence of changes in design variables, operational factors or environmental inputs, on different aspects of safety within the system. It is anticipated that the software will be used in several modes. At the beginning of the design process, when data is scarce and only rough estimates are required, the software can provide a summary of which areas might be affected by a particular design change. At other times, for instance when the design is increasing in complexity, or is complete and only verification is necessary, the software would be required to perform a full range of analyses. The designer can choose the level at which he wishes to work, with an option to increase complexity at any time.

As with the creation of a finite element model, the creation of a formal safety model is expensive and time consuming, but both greatly increase the level of confidence in the final design. It should be recognised however that incorporating formal safety procedures into the design process requires a major commitment of resources. The safety information model described here, and embedded in the MBRM software is a model of the proposed design, formulated exclusively in safety terms. This model is an additional design output not required in the conventional design process. It is however analogous to a finite element model used by designers, when appropriate, to analyse the structures of their product, and to improve the design if possible. An interesting by-product of formal safety assessment is that it maintains a convenient and inherently updatable (and hence up to date) model of the artefact to which it is applied.

Once fully functioning, this software will become an integral part of the iterative design process: on the basis of qualitative and quantitative analysis of the master MBRM table the designer can consider making alterations to the system or components and sub-systems within it. These may require a major change in the arrangement of the system or simply minor changes such as in the specification of a component. MBRM can easily accommodate both of these types of alteration. Alteration of systems, along with qualitative and quantitative comparisons allow the designer to use the formal safety analysis system to compare various design options on the basis of formal safety criteria. In doing so the designer is able to approach safety as a fundamental part of the iterative design process.

9. Conclusions

When developing a methodology for tackling safety in rescue vessel design, it is important to look at the role of safety analysis in the design process as it is at present, allowing alternative design procedures to be proposed. At present safety is considered in a semi-formal manner, relying on the experience and knowledge of the design team to ensure that safety issues are adequately considered at all stages.

In contrast, other important considerations in the design process adopt much more rigorous procedures. With the increasing complexity and sophistication of rescue vessels, the design team may be unaware that a critical combination of individual system failures could present an unacceptable level of risk. The outline methodology developed and reported on here describes how design variables, operational factors and environmental factors may be combined with safety criteria by using formal safety assessment procedures in such a way that the development of a specific design can be guided by safety considerations.

Failure mode and effect analysis (FMEA) and modified Boolean representation method (MBRM) have been used to model and analyse the complex dependencies found within the sophisticated system of a rescue vessel. Using the graphical programming language "LabVIEW", a framework embodying MBRM has been created to store and qualitatively analyse safety data provided by FMEA. A case study of the "Trent" class rescue vessel has been performed, detailing the vessel's functionality, performing a qualitative FMEA, and converting the data to MBRM format.

This "standard lifeboat" model has been embedded in the software framework, creating a computer based tool which manipulates the safety information to identify prime areas of concern. The functionality of the framework is constantly being enhanced thus becoming a system dedicated to rescue vessel design. The formal safety assessment system is currently being developed to incorporate probability data, and to enable quantitative evaluation of alternative design solutions.

With this tool, formal safety analysis can be integrated into the design of rescue vessels, so ensuring that the high safety standards of the RNLI are maintained as complex technological designs planned for the future are executed.

References

- [1] Henley, E.J. and Kumamoto, H., (1992), Probabilistic Risk Assessment, IEEE Press, New York.
- [2] WANG, J. (1994), Formal Safety Assessment Methods, PhD Thesis, Dept of Marine Technology, Newcastle University.
- [3] Hudson, F.D., Hicks, I.A. & Cripps, R.M., (1993), The Design and Development of Modern Lifeboats, IMechE Proceedings, Part A: Journal of Power and Energy, Vol.207, pp.3-22.
- [4] Birmingham, R., Cleland, G., Driver, R., Maffin, D., (1997), Understanding Engineering Design Context, Theory and Practice, Prentice Hall, London.
- [5] Bazovsky, L., (1961), Reliability Theory and Practice, Prentice Hall Inc., Eaglewood Cliffs, New Jersey.
- [6] Wang, J. and Ruxton, T., (1993), Design for Safety of Made to Order Products, ASME Publication, 93-DE-1, National Engineering Design Conference, March 1993, pp.1-12.
- [7] IMO, (1995), International Code of Safety for High Speed Craft, London.
- [8] Sen, P., Birmingham, R., Cripps, R., Cain, C., (1997), A Methodology for the Integration of Formal

- Safety Assessment into the Design of Lifeboats, IMDC: 6th International Marine Design Conference, Newcastle University.
- [9] LabVIEW, User Manual for Windows, (1994), National Instruments Corporation.
- [10] Birmingham, R., Sen, P., Cripps, R., Cain, C., (1997), The Application of Formal Safety Evaluation into the Design of Lifeboats, SURV IV: Surveillance, Pilot and Rescue Craft Conference, Gothenburg, May 1997.

Technical Design and Implementation of a New Transport Concept: Combi-Road

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Abstract. Combi-Road is a new transport concept for containers that has been developed in The Netherlands. For the transport of containers, an unmanned automated guided vehicle is used that runs on a dedicated track. This paper discusses the development process of the vehicle guidance- and communication system. The various systems have been developed in parallel to get an early overview of the cost of realisation and utilisation of the vehicle and communication system. Generally, the same development steps have been made for both the vehicle design and the communication system before all systems were integrated in a prototype. This prototype has been tested on a full functionality track where all interactions between the systems have been investigated under a wide range of conditions. This has provided important information for the design of the systems in a short time.

1. Introduction

Combi-Road is an automated transport system for containers, using unmanned Automatically Guided Vehicles (AGV) that run on a separate track to allow safer and more reliable transport of goods than on congested roads. The concept of Combi-Road has been initiated at the end of 1994, the development under discussion has been carried out in the period until the end of 1996.

The motivation for starting any development is the economic balance between cost and benefit of utilising the system. To make a good estimate of the cost of the vehicle and its utilisation, the technical concept must be known in some detail. With a clear identification of the technical concept, the consequences for the infrastructure are also known.

It is chosen to develop a full-functionality prototype of the vehicle and (part of the -) infrastructure as there were quite a number of new technologies involved in the defined concept.

This publication discusses the development process of the vehicle guidance- and communication system. The prototype vehicle is equipped with electrical traction, which has been developed at HOLEC Ridderkerk. The hardware of the communication system has been developed by the TNO Institute for Applied Physics. The vehicle and steering system have been developed by Terberg Benschop in co-operation with the TNO Road-Vehicles Research Institute.

Following a general description of the development process, the developments for

the various systems are discussed. Finally, a review is made on integration and testing of the various systems in the prototype vehicle.

2. General development approach

The various developments in the vehicle systems have been carried out in accordance with the scheme presented in Figure 1.

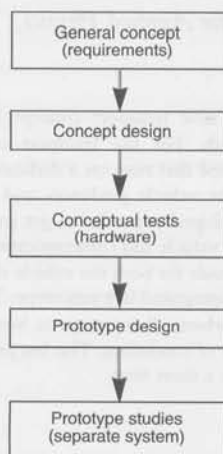


Figure 1. Development steps.

In the initial phase of the development, the functional demands are defined for the various systems. At this phase, the conceptual idea of automated trucks is further specified in terms of transport capacity, resulting in operational speed and payload requirements. These requirements lead to functional specifications for the communication, traction system and vehicle.

A concept design is made and various alternatives are evaluated and the result of this evaluation leads to an overview of how existing technology can be utilised and what new developments are needed to meet the functional specifications.

Conceptual systems are built and experiments are carried out to test new developments. For the vehicle guidance system, a model was made and simulations of various (adverse) circumstances were carried out. The results of these tests and simulations are used to combine existing technology with the new development for the design of the prototype. Further analysis is carried out on the prototype design as preparation for the tests with the full-functionality prototype.

After these development steps, the tests with the full-functionality prototype are carried out under a wide variety of conditions, testing all interactions of the various systems on the vehicle.

3. Vehicle development

3.1 General concept

The concept of using automated vehicles for transport of semi-trailers is the starting point of the development. The most straightforward solution is to apply automated driving and steering to a standard tractor for pulling semi-trailers. A guidance system which mechanically steers the vehicle is chosen as the concept to be investigated.

3.2 Concept design

The starting point for the CombiRoad truck design study was a series of MultiBody simulations to compare the performance of various design options. The design options that were studied are the axle configuration of the towing vehicle and the general concept for the guidance system. A general tractor semi-trailer model was extended with various steering systems for this purpose.

A steering system lay out with non steering wheels where guidance is achieved by force was compared to a lay out where the wheels are steered by the guidance system. Although the stability of guidance by force is better, the system with steering wheels since the guidance forces are considerably less. The stability of this set-up can be made sufficient and furthermore it offers more possibilities for active steering. The basic lay out of the vehicle and steering system is depicted in Figure 2.

Another key aspect that was investigated is the required width of the track to ensure that there would be sufficient clearance for the truck and trailer to negotiate the track successfully, even under extreme weather conditions. For this purpose, detailed consideration was given to the effect of cross winds, the slope and gradient of the track, and the dynamic effects associated with high speeds of travel and cornering.

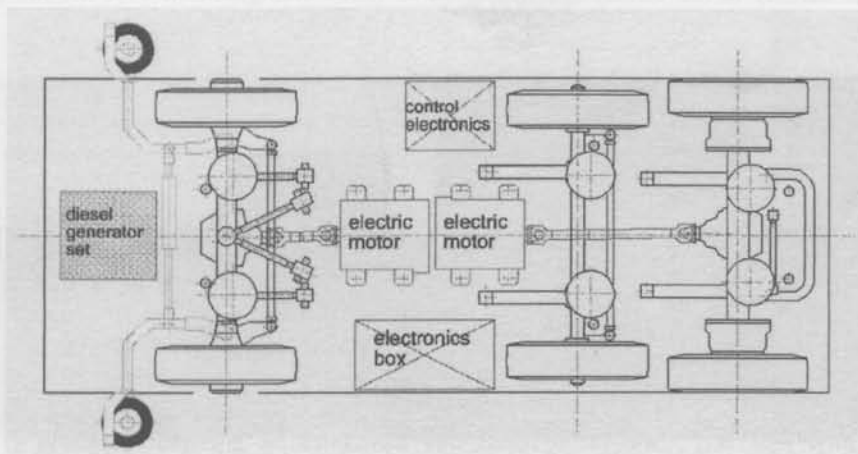


Figure 2. General lay out of Combi-Road Vehicle.

3.3 Conceptual tests

To test the general concept of steering by guidance wheels, a stretch of track was realised using road barriers at a test site (see Figure 3). A standard truck was modified to facilitate steering by guidance and the vehicle was tested in various loading configurations.



Figure 3. Modified truck on the first test track.

Tests were mainly conducted to check the system's sensitivity to uneven track surfaces and underinflated tyres, as well as to define the basic relationship between speed, load and stability. It was found that the steering concept is quite insensitive to vertical disturbances and that variations in steering angle are mainly induced by lateral track disturbances. The general stability of the vehicle is sufficient in all tested configurations over the full speed range.



Figure 4. Current collector system.

From these tests, it was concluded that the concept for steering the vehicle is suitable. The test results have been further used to set up more detailed specifications for the power collector system that is mounted at the ends of the guidance system. Figure 4 shows the current collector system that is on the prototype vehicle and in the purpose built test track that are discussed further on.

3.4 Prototype design

The vehicle is designed by Terberg Benschop BV and verified by Multi-Body simulations to evaluate the design in combination with the guidance system. For this purpose, a detailed simulation model has been built for vehicle and active steering system. Active steering is achieved by an hydraulic actuator that gives the vehicle a preferred direction at junctions.

This involved modelling the individual components of the suspension system such as the track rods, roll bars, pneumatic springs, leaf springs and shock absorbers in some detail, as well as the proposed steering geometry (see Figure 5). For extra precision, non-linear tyre characteristics were included using DELFT-TYRE software.

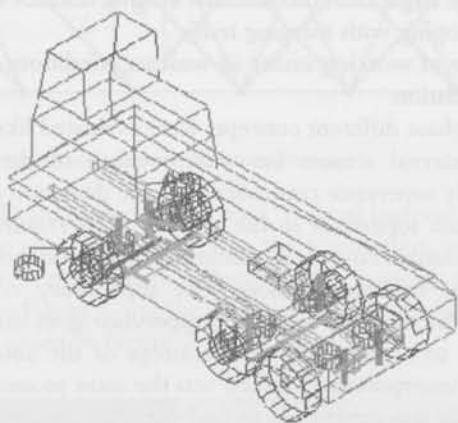


Figure 5. Detailed simulation model.

3.5 Prototype studies

The above described simulation model is used to study the behaviour of the vehicle and the forces on the guidance system in the design configuration. The stability of the vehicle is assessed for a variety of design variations in the suspension (i.e. damper settings, wheel orientation), to investigate tuning possibilities.

Furthermore, the lay out of the guidance system is varied to study the stability of the vehicle as well as the forces that occur due to irregularities in the track. The concept of active steering is studied and the specifications for the steering system are set up to ensure that a preferred direction is maintained also when disturbances (i.e. side wind, road gradient) occur.

4. Communication development

4.1 General concept

The development of the Combi-Road control system involved the development of a system for obstacle detection as well as the development of a speed control system. The speed control system is based on the information from the obstacle detection system, the status of the vehicle, the status of the road surface and its destination. It calculates and controls the speed of the vehicle. A system that combines obstacle detection with communication to and from the vehicle is chosen as the general concept.

4.2 Concept design

The primary requirements for the obstacle detection were:

- fail safe behaviour
- fault tolerant
- detection range larger than the minimal braking distance of each individual vehicle
- capability of coping with merging traffic
- robust, capable of working under all weather conditions
- graceful degradation

In the concept design phase different concepts were evaluated like sensors mounted on the individual vehicles, external sensors but interpretation of the sensor readings in the individual vehicles, fully supervisor controlled obstacle detection and only communication of obstacle position from supervisor to the vehicles. The requirement that the detection range under all circumstances covers the minimal braking distance of the vehicle excluded the concept of vehicle mounted sensors. The supervisory controlled concept is not favourable because of the fact that when the supervisor goes down all vehicles under its supervision will come to a stand still. The concept of the autonomous vehicle on the intelligent track (track incorporating sensors) was the most promising.

A feasibility study was carried out to find out what sensor concept could be used for the obstacle detection. Infra red and micro wave techniques were studied. The outcome of the study was that the effects with micro wave techniques like reflections and multi-path interference could give serious problems on a track incorporating sensors and an infra red technique was chosen.

4.3 Conceptual tests

Lab tests were mainly carried out to set up the basic design for the transmitter and the receiver. Infra red light is transmitted by ordinary LED's and a photo diode is used for reception. In front of the photo diode Fresnel optics is used to focus the light coming from the LED's.

Tests showed that a ranging distance of 40 meters was no problem with different contamination levels of the receiver and other disturbances. Outdoor tests were done to assess the level of contamination that may occur on the receivers and it was concluded that

the infrared system would function properly under the required range of environmental conditions.

4.4 Prototype design

The infra red system is used for both communication and obstacle detection, the absence of communication is used as detection of obstacles. For this purpose, a distributed sensor is realised in a beacon system where the detection and communication functionality are combined. The concept of obstacle detection is depicted in Figure 6.

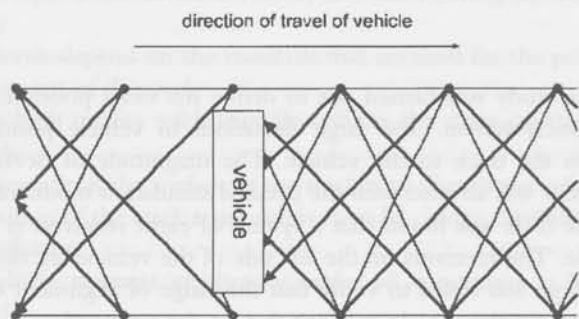


Figure 6. Beacon system with obstacle detection concept.

Infra red transmitting LED are placed in the track at fixed intervals. Along the track, also receivers are placed at the same fixed interval as the transmitters, which normally receive the signals from two different transmitters. When a vehicle is on the track, the signal pattern is disturbed as indicated in Figure 6 and the position of the vehicle is determined. One of the prototype receivers is given in Figure 7.

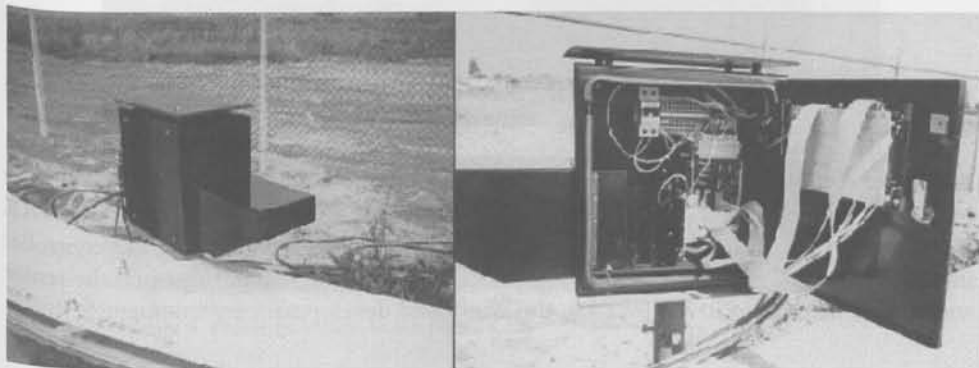


Figure 7. Prototype receiver along the track.

The receivers along the track also get the status from the vehicle, which is equipped with the same kind of LED transmitters as in the track.

The Combi-Road vehicle receives free space information from the LED transmitters in the track just in front of the vehicle. The absence of communication between two transmitters indicates that an obstacle is present on the track in front of the vehicle.

The speed of the vehicle is set by command from the transmitters in the track, but may be interfered by the obstacle detection system. The design of the speed controller was done within a Matlab/Simulink simulation environment, using a vehicle model as well as a model for the obstacle detection system. The controller was extensively tested in the Matlab before it was ported to the target hardware of the truck controller.

4.5 Prototype studies

An optical simulation study was carried out to define the exact position, orientation and geometry of the optical system. Too large deviations in vehicle position may disrupt communication from the track to the vehicle. The magnitude of deviations in vehicle position that may occur was assessed with the detailed simulation model of the vehicle that is displayed in Figure 5. It was found that a system of eight receivers is required for the Combi-Road vehicle. The receivers on the left side of the vehicle are displayed in Figure 8. A working prototype was tested to verify that the range of alignment errors the system can handle is sufficient for the vehicle motions that can be expected.

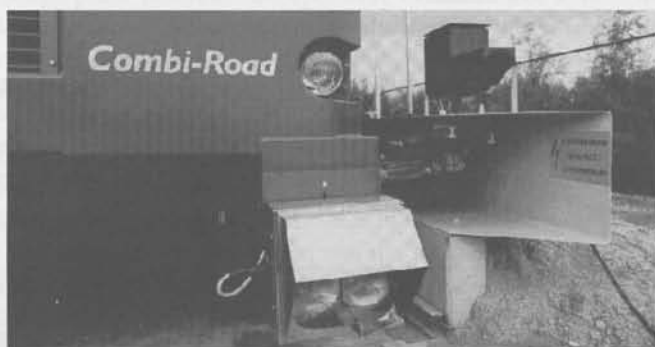


Figure 8. Receivers on the vehicle.

Porting of the software for speed control was done by automatic generating of C-Code by Matlab and compile and link these sources in the real time environment based on the VAX works operating system and DEC-alpha based hardware. After the porting the controller implementation on the target platform, it was coupled to the computer that runs the sensor and vehicle model and it was tested in this controlled development environment.

5. Prototype testing

The prototype vehicle has been built and all systems have been installed on the vehicle to be able to test the full concept. For this purpose a 200-metre-long section of track,

including power supply and communication system has been built at HOLEC's premises in Ridderkerk. A picture of the vehicle and test site is given in Figure 9.

The vehicle has been tested under a wide range of conditions over a period of 6 months. Prior to the overall testing, some system failures were induced and tested to ensure safe operation under all test conditions.

After general verification of the vehicle stability over the test speed range, the tests that were done previously as concept tests for the guidance system were repeated to assess the influences on communication and power supply. More specific tests for the vehicle concerned the active steering system, and vehicle operation under extreme conditions.

The main aspects that have been newly identified during the tests with the prototype are given below:

- Noise levels depend on the materials that are used for the power collector system and the lay out of the track
- Using a high quality track strongly reduces the strain on the steering system and the vehicle
- Reflections from the surface of the track may disturb the infra red sensors
- The position of the track transmitters must be chosen carefully to prevent blocking due to pollution
- The vehicle operates satisfactory under all conditions as long as wheel slip is prevented



Figure 9. Prototype vehicle in test track.

These tests have resulted in a thorough knowledge of the systems and their interactions under realistic and more extreme conditions.

Making the prototype, the technological limitations become clear, new developments are carried out and detailed specifications for the systems are identified. This

knowledge facilitates a far better evaluation of the transport concept and opens a view on new applications.

6. Conclusions

Two different hardware developments of the Combi-Road transport system are presented. The systems have been developed in parallel, to reduce lead time. A communication- and obstacle detection system has been developed by TNO's Institute of Applied Physics and the vehicle is a joint development of Terberg Benschop and the TNO Road-Vehicles Research Institute.

Similar steps can be identified for the developments: A concept is defined and various general analyses are carried out to assess the potential of alternatives. With the selected set-up, test settings are defined to verify the behaviour of the system. These test results are used to develop the final systems that are integrated in the prototype vehicle.

Making the prototype, the technological limitations have become clear, new developments were carried out and detailed specifications for the systems are specified. This knowledge facilitates far better evaluation of the transport concept and opens a view on new developments. It was found that Combi-Road is a technical feasible concept for safe unmanned transport of containers on a separate track.

Safety as an Industrial Issue

Ab van Poortvliet

Delft University of Technology, The Netherlands

1. Welcome

Ladies and gentlemen, I am very pleased to have the opportunity to present and discuss my research findings on this conference. During the last four years I have worked on a Ph.D. project at the school of Systems Engineering, Policy Analysis, and Management, which is a department of Delft University of Technology. Like the project, the presentation is on governmental and industrial risk decision making, and the consequences for safety.

2. Overview of the presentation

The presentation starts with a short introduction to a particular kind of safety problem in passenger transport. Next, the framework for analysis is discussed, which is used for the analysis of three cases: roll-on/roll-off passenger shipping, passenger transport by rail, and large commercial aviation. The presentation finishes with conclusions and recommendation. As always with short presentations, I cannot escape from some simplism. In particular when examining the cases I will be blunt. Fortunately, we have time for a discussion afterwards, I will be glad to try to answer your questions.

3. Examining high-risk issues

The presentation is about high-risk issues and the occurrence of disasters in passenger transport. Analysis can be done at several levels:

- Individual level. The focus is on the actions of the individual who is involved in the operations. An important issue at this level is the man-machine interaction.
- Group level. The focus is on small groups such as crew. Coordination and team work are the important issues here.
- Organizational level. The focus is on procedures, organizational culture and managerial decision making within a single company (and its subcontractors). Fleet management is an important issue.
- Sectoral level. The focus is on interactions between different organizations. Regulation, the transfer of goods, and the dissemination of knowledge are important issues.
- Societal level. The focus is on the function of the transport system in the society. Issues such as risk acceptance by the public, mediation, and decision making by the

democratic institutions such as Parliament are important here.

In some respect, the levels range from narrow to wide. Traditionally, the focus was on the individual level, which widened to the group level. Nowadays, the organizational level is also employed in the practical investigations. As a consequence, there is much knowledge of the processes on these levels.

High-risk issues, however, are often industry-wide. And they are dealt with within a sector when, for example, formulating and enforcing standards. Therefore, it is desirable to examine such safety issues (also) at the sectoral level. Because very little analysis has been done at the level, the excursion we are going to make is a little explorative.

The main interest here is in structural characteristics of the sectoral systems, and in the mechanisms which drive the risk management process. The goal of such an analysis can hardly be a precise explanation of a single event, but should yield an understanding of the main long-term developments. Regarding the report of the "Gore Commission" on aviation safety, this is an interesting issue.

4. Framework for analysis

Literature survey suggests that the organizational structure and the strategies for risk control are important at the sectoral level. More precise:

- actors, i.e. organizations, groups and individuals whose actions are important at the level
- the social and formal status of the actors
- the relationships between the actors, their contacts and the mutual dependencies
- diverse influences from the environment
- measures that eliminate or reduce a hazard
- measures that reduce the spread of the possible outcomes
- measures to aim at the largest risks
- measures to learn from events

These factors influence the occurrence of events, and events influence these factors. The perspective which has been applied in the research is that the risk decision making process is a result from these factors. Here, it should be noticed that the actions are not simply based on the best insights, but that these are the result of procedures and exerted influence because of personal and/or group interest. To inquire into the factors and the risk management process, I used document analysis and interviewing technique.

Now, we will examine three cases in passenger transport. I will start each case analysis by providing fatality data. Of course, this is a simple and limited indicator for safety, but on most points it suffices for the present discussion. Next, a small number of mechanisms are per case suggested for understanding the developments in that sector.

5. Roll-on/roll-off passenger shipping

In the case of roll-on/roll-off passenger transport we see serious problems. After a considerable period in which disasters were absent in North-Western Europe, three large

scale disasters occurred within a period of ten years.

- the Herald of Free Enterprise capsized in 1987
- the Scandinavian Star fire disaster in 1990
- the Estonia capsized in 1994

In particular the issue of transverse stability has been discussed regarding the Herald and Estonia disasters (and other accidents and incidents as well). How could this have happened? Three mechanisms are distinguishable in the industry, which make it vulnerable to major adverse safety developments.



Figure 1. Fatalities in roll-on/roll-off passenger shipping (North-Western Europe).

1. Managing safety only by prescriptive, international regulation

Safety regulations are highly means prescriptive in shipping, which is a highly competitive industry. De facto, safety regulations limit the commercial exploitation. Therefore, each organization goes for the maximum which is allowed under the regulations (or even further). Here, the main point is that safety awareness is not stimulated in such an environment. In fact there are hardly groups which focus on safety and act like advocates for the issue. And the groups that exist are not in the position to say: "this will not pass!"

Due to the minimum compliance culture, the safety level really is strongly dependent on the adequateness of the regulations. Each inadequate norm or each uncovered issue in the regulation can be literally fatal. In reality, the regulations are not formulated nationally but internationally agreed upon within IMO. These are a compromise between what is politically correct and publicly appealing and what is commercially and practically realistic over the globe.

One of the consequences is that the standards are not always up to the Western desires (technical norms, required instruments such as quality assurance, management codes).

2. Reactive risk management

The maritime sector did not lack the insight to risks incidents and accidents. However the

insights were not coupled to sectoral actions or concrete policy proposals on how to deal with the issue.

The stability issue, for example, is not a popular issue to put on the agenda, because of the high costs to the industry, and the small to zero chance of political success. Thus risk decision making was primarily non-decision making, until disasters occurred.

Then, by the lack of well-thought proposals prepared in advance, disaster driven regulation resulted. This is not optimal, regarding the Estonia disaster. Ironically, the tragedy within ro-ro passenger shipping can be partly understood by the fact that no large-scale disasters happened within Western societies for decades. During this period, an expensive fleet of ever bigger vessels developed, which only widened the gap between the insights into what should be done, and what policy actions were actually taken.

3. Limits in learning

Learning is limited in several ways. First, incidents and accidents are almost by procedure attributed to individuals. This is comfortable for the establishment, but dangerous in the case of a structural problem, which is not solved this way.

Second, the results of accidents are hardly disseminated to (and processed by) the different manufacturing and operating companies. Learning, if present, is often group or organizational learning rather than sectoral learning.

Third, decision making on safety policy occurs only within IMO. No rivalry between different fora stimulated the risk decision making process, and no match of problem to forum could be made.

6. Passenger transport by rail

Accident statistics in Dutch rail show a single large disaster which occurred in 1962, and numerous fatal accidents. I will put forward that the freedom of large-scale disasters over the last three decades is not purely a coincidence, but that the risk reduction is structural. The effective risk reduction can be understood by 3 mechanisms:

1. Enabling factors

The one-dimensional characteristics of the railway track, as well as the large reservoir of public financial resources, enabled the introduction of highly reliable railway technology. The strong engineering culture within the sector stimulated the approach of solving the problem of human fallibility by means of technology.

2. Priority setting

The main risk which was identified was fixated upon until it was reduced significantly (which took decades). It should be noticed that the priority setting was possible by the strong centralized decision making. It was functional as no equally large risks - both objectively and subjectively - existed at that time.

3. Learning under controlled conflict

Though learning was until the nineties limited to technical issues, it was of good quality. In a situation of rivalry and structural conflict, the NS internal accident investigation and the analysis of the rail accident board were adequate for the problems that were covered.

Recommendations had to be rejected or adopted. In particular for the Minister of Transport, there was always pressure to adopt the recommendations. It is difficult to reject the recommendations on the sensitive issue of public safety after fatal accidents. Thus the recommendations could not be put aside easily.

Due to formal procedures, the information on safety issues was adequately distributed over the sector, learning from accidents was sectoral learning.

In conclusion: because of incremental adjustments after accidents, the gap between what measures were considered to be necessary, and what actually was done never grew very large.

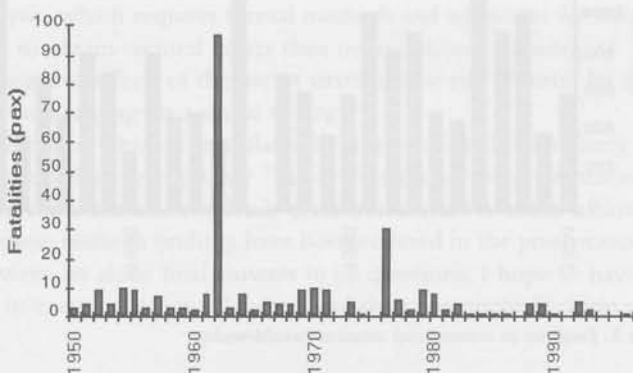


Figure 2. Fatalities in passenger transport by rail (in the Netherlands).

7. Commercial aviation

Air disasters have occurred and will continue to occur, is my opinion when I look at the accident statistics. The number of fatalities has been fairly constant despite the growth of air traffic. However, it should be noted that the social and political reactions have grown much stronger and that "new" issues such as third party risk. Altogether, the safety problem has grown over the decades. Again, three mechanisms are introduced to understand the developments:

1. Risk management by standardization

The number of standards is impressive in aviation. The use of standards implies an organizational structure with main roles for standard-setting fora, inspectorates, and inspected companies, whereas the democratic institutions such as Parliament were more or

less excluded from risk decision making.

Though there is a compliance culture in the aviation sector, the goal oriented character induces interpretation which induces discussion between equally influential groups, which induces actions. In this way, standards not only standardize the products and the production processes, but also the interactions between different groups. Altogether, standards yield an efficient process of corrections until the norms are met. This is positive for technical risk control (as long as the standards are adequate), but negative for the social dimension of risk management. What is not covered by the standards, is obviously not important in risk management. Risk communication was consequently paid little attention to, which may well have contributed to the great number of crises after air disasters.

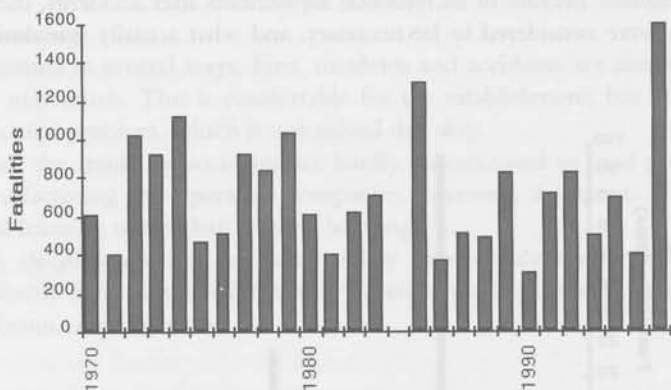


Figure 3. Fatalities in commercial aviation (world-wide).

2. Multi-fora risk decision making

Due to the presence of international, regional, national, and organizational fora many processes flow in parallel in risk management. This is not efficient due to a lack of coordination, but the system has a high problem solving capacity, which allows many problems to be addressed simultaneously. In addition, due to mutual competition the efficiency of each form is relatively high, whereas the safety problems are in practice matched to be best fitting forum.

3. Learning from all kinds of events

Learning occurs at several levels, and from all kind of events: from irregularity to large scale disaster. The instrumental learning is efficient, but limited by the fact that safety norms are seldom challenged. In addition, cultural constraints make that each country had to solve its national problems (which started top change recently), and that the cooperation between manufacturers and airlines on important issues such as human factors is not as close as it should be.

8. Conclusions and recommendations

Integrated examination of the technical and social dimension of risk management in the three sectors, and comparison of the factors and the developments, yields the following "determinants of safety":

1. Take preventive action by fail-safe design, which is stimulated by advocates for safety and the experiences from the past. Note: fail-safe design was in the cases the most effective technical measure for risk control.
2. Guarantee quality by means of standards, which only works when the organizations involved have equal influence. Note: not all aspects are covered by standards, remain sensitive for societal issues.
3. Set priorities by means of programs, which requires coordination (often by means of centralization). Note: the strategy should only be applied when a small number of risks is both objectively and subjectively dominant.
4. Learn by analysis, which requires formal methods and advocates for safety. Pay attention to dissemination to obtain sectoral rather than organizational learning.
5. Reduce the negative effects of the use of strategies for risk control, by applying a mix of strategies rather than relying on a single strategy.
6. Learn by interaction, which is stimulated by organizational redundancy and (controlled) professional conflicts. Define explicitly "public functions" for governmental organizations in order to avoid too isolated, completely technocratic risk decision making.

Most of these research findings have been covered in the presentation. Though these do not give answers, let alone final answers to all questions, I hope to have made clear that it is well worth to examine structural factors and the consequent decision making processes within a sector.

Safety Certificate for Rail Transport Companies

Developing an audit method

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1. Introduction

As is the case throughout Europe, major changes are currently underway in the Dutch rail transport system. Propelled by European policy (EU directives 91/440, 95/18 and 95/19), the aim is to achieve free access to state-managed infrastructure. The Dutch government has enthusiastically welcomed the liberalisation of the rail transport system and has taken the necessary steps with regard to domestic traffic.

The first moves in this field came in 1994 with the reorganisation of the national railway company NS into a government-commissioned and a market sector. The three government-commissioned organisations (1. NS Railinfrabeheer BV, 2. NS Verkeersleiding BV, 3. Railned BV) manage the infrastructure, allocate timetable paths, provide access to routes and direct day-to-day operations. The transport companies NS Passengers and NS Cargo have been placed in the market sector and offer transport products to the market in competition with newcomers.

The government-commissioned organisation Railned has two missions: capacity management, which we will not discuss here, and assuming the government's responsibility for railway safety. The Ministry of Transport has granted Railned the necessary powers to perform these tasks on the now open rail network. The new arrangement still requires national legislation but has been provisionally implemented via a series of legal contracts.

Railned's Railway Safety Department (RnV) has been charged with a series of tasks, including ascertaining whether users of the public rail network meet the prevailing requirements in terms of expertise, organisation and railway safety and are able to comply with the safety and other regulations to which rail traffic is subject, and to issue a certificate to this effect. This task can only be fulfilled if Railned has a consistent overview of the requirements transport companies have to meet and an appropriate method of ascertaining (by means of a certification audit) whether they are indeed meeting them. This paper describes the broad outlines of the method developed to this end by RnV. The project got off to a flying start.

The first new transport companies had already come forward and had been taken into account by RnV before development commenced. The method described here is far from a finished product. The outlines of the audit method have been established but

development will continue for the time being. Only practice will show whether it is effective and further adjustment and refinement is inevitable in the coming years.

2. Traditional safety management

Prior to 1994, the rail transport system in the Netherlands consisted of a single company: NV Nederlandse Spoorwegen (NS). NS was a monopoly in economic terms and an integrated railway company in technical terms (i.e. it was responsible for the entire system: infrastructure, rolling stock, operations). The government gave NS full responsibility for safety in 1920. Government regulations were scanty and not kept up to date. The Railways Act (Spoorwegwet) dates back to 1875.

The Service Regulations for Main and Local Railways (RDHL) are more recent but are no longer geared to the current situation. Both remain in force but have significantly diminished in importance. Government oversight by the Railway Inspectorate was patchy, ad hoc and reactive.

The level of safety achieved under this regime was certainly acceptable and in some respects actually very good, but the way in which it was achieved displayed a number of characteristics that made it inappropriate for the newly created situation.

- Safety management was not made explicit but was interwoven to a significant degree with other aspects of operation. Consequently, it was not clear to what extent many rules, working methods, requirements and customs were intended for reasons of safety or for other purposes (e.g. commercial).
- To a large extent, safety was a technical issue and was spread across the three pillars: infrastructure, rolling stock, and operations.
- Safety was more a question of culture than of systematic management.
- Safety was based to a large extent on experience, with expertise passed down from one generation to another.
- Safety was primarily reactive - drawing on a long history of accidents and damage and the collective memory of what had gone wrong in the past.
- Safety regulations consisted to a significant degree of detailed, situation and operation-specific rules of conduct.

Working methods of this kind cannot cope with major changes, they are too operationally specific, are not transferable and cannot be certified. Even before NS was transformed, it was recognised that things could not continue as they were. A process of change was initiated but was far from complete at the moment the NS monopoly was broken up and the network opened to potential new users.

3. Principles for a new policy

Work began at the outset in 1994 to develop and promote a more modern form of safety management, which could be summed up in the following terms:

- An integrated approach to infrastructure, rolling stock and operations;

- Proactive and systematic;
- Based on risk assessment;
- Explicit management task;
- Measurable objectives;
- Pursuit of constant improvement in the overall rail transport system.

One implication of this is that companies taking part in the rail transport system must be able to make their contribution to the whole. For the supervisor, RnV, determining whether this is the case is the most important criterion for the awarding or withholding of a safety certificate. RnV also has to have sufficient instruments at its disposal to be able to mount effective control in accordance with the principles mentioned above. As far as transport companies are concerned, important characteristics of the requirements to be developed and the audit method to be applied include the transport company having sufficient freedom to be able to structure its business as it sees fit, whereby the requirements and procedure are non-discriminatory for new and existing transport companies and the procedure offers the transport company sufficient legal guarantees.

It was deemed necessary on this basis that (1) transport companies should be explicitly informed of what is required to operate a safe railway company, (2) a policy ought to be formulated on this basis regarding how RnV should determine whether or not the requirements are being met and (3) a procedure and criteria should be developed for the safety certificate audit.

4. New transport companies

The purpose of the entire operation is, as stated, to enable new transport companies to enter the previously closed rail transport sector. Providing access to new businesses generates certain tensions that have to be taken into account. The most important are set out below.

4.1 Political aspirations versus safety requirements

There is a strong political desire to achieve real competition on the railway network as rapidly as possible and hence to allow access to new transport companies. However, as a result of the fact that for many decades rail transport has been the exclusive preserve of NS, a number of substantial obstacles first have to be overcome by the newcomers. The availability of safe and infrastructure-compatible rolling stock, properly trained personnel and expert management has to be ensured. These elements are, however, virtually non-existent outside the NS group. What's more, new companies are often start-ups that lack the capital to buy them in. It has been frequently noted that new entrepreneurs severely underestimate the prevailing demands. Another aspect of the problem is that their lack of expertise in the railway field means RnV runs the risk of being pushed into a consultant's role, which is clearly incompatible with its function as an assessor and supervisor.

4.2 Pioneering firms

Safety in the rail transport system is – and will always be – based on thorough planning and preparation, effective co-ordination between parties, fixed procedures and predictable behaviour on the part of all concerned. New firms in the pioneering stage of their life-cycle will generally find it difficult to operate in such an environment.

4.3 Independence of the certifying body

For the time being, until legal regulations have been drawn up, the certifying body RnV remains part of the NS group and is hence linked to the main commercial transport companies NS Passengers and NS Cargo. In some people's eyes, therefore, NS decides whether competitors should be allowed onto the system or at least has a major influence on this via the safety certificate. This situation is, of course, undesirable from the point of view of free access.

5. The development route

The following activities were carried out, one after the other: (1) definition of a policy regarding the way RnV is to fulfil its supervisory role, (2) definition of a standard for safety management systems for rail transport companies and (3) definition of an audit method and criteria for testing whether a safety management system exists, whether it is operating, whether it is producing the desired results and whether it is being properly maintained. Information from a number of sources was used during the formulation of these definitions, including:

- Learning by doing. As noted, the first would-be rail transport companies had already come forward. As a result, and perhaps despite themselves, these companies served as guinea pigs;
- Study of existing practices elsewhere. Grateful use was made of Railtrack's experience with the "Railway Safety Case" used in the United Kingdom and that of the Netherlands Aviation Inspectorate in connection with the issue of Air Operator Certificates;
- Consultation of existing rail transport companies and the Ministry of Transport (Railway Inspectorate);
- Experts at TU Delft (Safety Science Group);
- Experts in the field of ISO 900X certification;
- Safety management literature.

5.1 Supervisory policy

To play the controlling role of regulator and supervisor properly, a consistent model is required in which regulatory methods and the manner of supervision can be linked. The supervisory policy is approached below from three different angles.

5.1.1 Business model

The first thing that has to be done is to establish the points of application with respect to the object that needs to be controlled, namely the rail transport companies. The widely used business model is applied to this end. The model contains the following three distinct levels:

1. Executive level, at which:

- Tasks are performed in the primary process;
- In accordance with procedures and/or criteria fixed in advance.

The procedures and criteria may come from outside, may be developed within the company (see level 2 and 3 below) in connection with its own business objectives or may be based on higher, goal-oriented regulations from outside.

2. The planning and implementation level which:

- Shapes the primary process and ensures that the preconditions are met to this end (people, resources and methods);
- Establishes implementation rules and criteria on the basis of the goals or resources fixed by level 3 or by external bodies;
- Oversees implementation.

3. The strategy and structure level which:

- Determines the business's policy/direction;
- Establishes objectives within the externally imposed frameworks and rules;
- Determines the overall structure of the organisation and hence its general coherence;
- Organises the planning and implementation level;
- Provides resources for the underlying levels;
- Supervises the underlying levels and ensures that the established objectives are met.

It should be made clear that this business model incorporates a distinction between tasks that are implemented and cannot necessarily be translated one by one according to the hierarchy in a diagram of the organisation. Generally speaking, level one tasks will be implemented by the lower echelons of the business and level three tasks by senior management. Significant variations can occur, however, depending on the company. The model is open to further refinement.

5.1.2 Types of regulation

A second element of supervisory policy relates to the manner in which the supervisor establishes rules, frameworks and standards. This is broken down into three strands:

1. Detailed rules, which provide direct and concrete specifications or rules of conduct.

E.g. the driver must stop at red signals; it should be checked once a month that tyre width is at least 30 mm.

2. Methodological rules, which indicate how a result ought to be achieved.

E.g. local safety rules should be fixed by the Regional Manager of NS Traffic Control; the transport company must register and analyse all incidents to allow improvements to be formulated.

3. Goal-oriented rules, where only the result to be achieved is defined.

E.g. the transport company must ensure that its drivers act at all times in accordance with the prevailing characteristics of the infrastructure.

The currently available rules were largely inherited from the former NS group, when it was still an integrated railway company and primarily take the form of detailed implementation rules.

5.1.3 Types of supervision

A third element in this regard relates to the characterisation of the actual supervision being implemented. Once again, there is a three-way breakdown:

1. Inspection

Inspection is the oldest form of supervision and entails the direct investigation, armed with a checklist, of whether all the implementation rules prevailing in the primary process are being properly observed.

2. Audit

The audit idea is more recent. It can be summed up as a more extensive form of inspection, which also examines the organisational context: how are things organised and do they function in the intended manner? Issues like communication, the breakdown of responsibility, training, procedures, etc. are all typical audit questions.

3. Meta-supervision

This type of supervision is another step further away from the grassroots. The emphasis here is on verifying the management systems within the business. Meta-supervision means that companies are asked to demonstrate that they have organised their business on the highest level and that their management systems work in every respect. The role of the supervisor thus shifts even further away from simply investigating what is wrong at practical level towards evaluating what the company brings forward.

In rough terms, we can state the following:

- Inspection is supervision at business level 1, using detailed rules as its reference.
- Auditing is supervision at business level 2, using methodological rules as its reference.
- Meta-supervision is supervision at business level 3, using goal-oriented rules as reference.

Table 1.

Business model	Regulations	Supervisory form
Execution	Detailed rules	Inspection
Planning/implementation	Methodological rules	Audit
Strategy and structure	Goal-oriented rules	Meta-supervision

Table 1 reveals a vertical relationship, in that there is a consistent progression in each area of attention from rough to more detailed, and a horizontal relationship indicating that e.g. strategy and structure, goal-oriented rules and meta-supervision are linked, and that for each row. That still doesn't tell us anything about what mix of supervision forms will be required

in practice. It merely indicates, for instance, that meta-supervision can only take place at the strategy and structure level and that the presence of goal-oriented rules is a precondition.

5.1.4 RnV's policy

It has been determined, in line with the principles set out in section 3, that:

- Regulations should take the form of goal-oriented rules rather than the traditional type in the rail transport system;
- Supervision ought to be carried out to a significant extent in the form of meta-supervision;
- There should be a greater focus in this respect on the uppermost control level within the organisation of the transport companies;
- Safety management at the transport companies ought thus to meet demanding standards.

This has been formulated in terms of a shift towards goal-oriented rules and meta-supervision, without saying anything about how far this shift ought to go. For a number of reasons, it is still necessary at times to maintain detailed rules (with respect, for instance, to personnel and rolling stock requirements). There are also reasons why random checks, based on audits and inspections down to shop-floor level, ought to be used in addition to meta-supervision in order to ascertain whether successive levels of translation from objectives to implementation have been adequately implemented. What this means in terms of the certification audit for the safety certificate is that one more step has to be taken than is the case with quality certification. Not only does the system have to be audited, its practical impact on working has to be evaluated in the approved manner.

5.2 Requirements affecting safety management systems

Having established that testing systematic safety management within the companies themselves is an important means of control for RnV, the need arose to determine what requirements have to be imposed on systematic safety management of this kind. A standard was developed to this end in consultation with the existing transport companies. Having taken stock of the available methods and standards, it was decided that the framework of ISO 14001 ought to be adopted and that a specific standard should be developed on this basis. This gave rise to RnV standards paper V-001 Requirements for safety control systems for rail transport companies, which now applies to all rail transport companies operating on the Dutch network. Although the arguments in favour of ISO 14001 were somewhat meagre at the time (late 1996), there is no reason thus far to suppose that the decision was a bad one. It proved relatively easy to achieve consensus and gain support in consultation with the transport companies. There are two chief reasons for this: the quality of the system and increasing familiarity with ISO 14001. The provisional conclusion, therefore, is that the RnV standards paper has laid firm foundations for the safety certificate.

6. Development of the audit method

Before examining the certification audit, which is described in (draft) RnV standards paper V-002 Safety certificate for rail transport companies; Requirements, criteria and procedure, we first have to determine certain characteristics of the certificate itself. The certificate is issued for a specific range of operations (passenger or goods transport, hazardous or non-hazardous materials, local or national, etc.). The certificate does not apply beyond this range. It is issued for a fixed period, during which RnV will continuously monitor safety performance and mount interim audits and inspections.

6.1 What is assessed?

The following elements are assessed as part of the certification audit:

1. The safety management system;
2. Management's expertise in the field of railways and railway safety;
3. The implementation of safety management in practice;
4. Production factors:
 - Personnel:
 - Medical and psychological suitability, and
 - Training and qualifications.
 - Rolling stock:
 - Initial admission;
 - Safe state of maintenance.

6.2 How is assessment carried out?

One consequence of the supervisory policy mentioned above is that the burden of proof regarding compliance with the prevailing requirements lies with the transport company. The latter must first persuade itself that its working methods are safe and appropriate within the established framework. These working methods then have to be put forward for assessment.

6.3 The Railway Safety Report

The transport company presents its working methods using the Railway Safety Report (Spoorwegveiligheidsrapport - SVR).

The SVR fulfils two functions:

1. It is used by the transport company to demonstrate that:
 - It is aware of the risks associated with its railway operations, it has assessed these risks and will control them in accordance with the prevailing requirements;
 - It has taken all the necessary precautions and has set these out in a safety control system in accordance with standards paper V-001.
2. The SVR is the document with reference to which RnV will carry out its interim audits.

This means that the SVR has to be updated throughout the duration of its validity, to ensure that it reflects the actual state of affairs within the company.

6.4 Elements of the audit

The way in which the SVR submitted by the transport company is assessed is very similar to the customary procedure for audits relating to quality system certification.

The following sequence occurs:

- Assessment of documentation;
- Management presentation;
- Practical assessment.

Not only does assessment take place at system level, random checks are also held to determine whether the system has been implemented according to the rules applying down to operational level and whether, in the view of the auditor, implementation of the described system will ultimately produce effective safety results. This requires the auditor not only to be aware of the demands that will be made of the system, but also to have a sufficient technical knowledge of railway affairs. The depth of the investigation will depend in part on the safety performance of the relevant transport company in the past.

Greater emphasis is placed on the management presentation in this procedure than is the case with quality system certification. The lack of expertise in the railway field, to which we alluded earlier, makes it absolutely necessary that RnV be persuaded that such expertise is actually present at the company. The explicit intention here, therefore, is that management should demonstrate through its presentation of the SVR and by answering the questions of the audit team that the SVR is truly part of its own thinking and not just a slick presentation prepared by a hired-in consultant.

Practical assessment is done by inspections and audits. This is, of course, only possible when there is some practice to assess. In the case of new transport companies that are not actually operating at the time they apply for a safety certificate, certain aspects can be assessed in practice (e.g. training of personnel), but others cannot.

There are several ways to address this problem, at the discretion of the chief auditor: (1) permission can be granted for trial operation (without passengers) supervised by RnV, (2) temporary permission can be granted to begin commercial operation, also under RnV's supervision, and (3) temporary permission can be granted, under the terms of which the company itself prepares an evaluation programme for the first few weeks and reports on it regularly. The degree of confidence built up during the first two stages of assessment will be a significant factor in determining which of the alternatives are to be chosen.

6.5 Prequalification

As noted, new transport companies can sometimes underestimate the complexity of starting up a rail transport business. It has been deemed necessary, therefore, to apply a form of prequalification prior to the certification audit. This is necessary to prevent either the transport company or RnV investing too much energy in an enterprise that has no chance of success.

6.6 Criteria

The test criteria are set out in the aforementioned draft RnV standards paper (V-002) and relate to the elements described in 6.1. They are formulated in fairly general terms and refer to the prevailing regulations which, as noted, are currently in a process of transformation from detailed rules to goal-oriented frameworks. Meeting these criteria and assessing whether they have been met thus requires both the transport company and the auditor to have the expertise to interpret them properly. The criticism might be raised that this undermines the legal security of the transport company, as such security can only be maximised when it is possible to determine by means of concrete yes/no questions whether the rules are being met. This is especially the case when, as indicated in 4.3, the certifying body is already somewhat suspect. Nevertheless, it has been decided for good reason and with the agreement of the transport companies that goal-oriented rules should be pursued to as great an extent as possible and that the transport companies ought to be given maximum freedom with which to determine their own working methods. Another reason - and one primarily of importance to the supervisor - for avoiding the trap of devising a test based on concrete yes/no questions, is that questionnaires of this kind tend to encourage a compliance-mentality, whereby people do what is asked of them but have no idea of why it is necessary nor how the different questions relate to one another.

There is, therefore, a dilemma here - greater freedom leads to reduced legal security. The repercussions of this may be reduced, though not avoided altogether, by formulating the criteria as concretely as possible, depending on the situation. Different interpretations will, however, remain possible for each definition. This problem may be alleviated to some degree by means of procedural measures (see 7.3).

7. Current situation

The working method presented here has been discussed with the transport companies and is currently being applied in practice. As said earlier the method is far from a finished product. Feasibility still has to be demonstrated in practice, and undoubtedly adjustments will follow in the next years.

A number of things still have to be done to enable the overall system to function properly. The most important are:

7.1 Final settlement and incorporation in legislation

EU directive 95/18 contains instructions regarding the award of licences and safety certificates to railway companies. According to these directives, licensing ought to incorporate a test of professional competence, following which compliance with national regulations alone is tested in the case of the safety certificate. Current practice in the Netherlands is for licences (only for internal traffic at present) to be issued without any testing of professional competence. It is for this reason that RnV has deemed it necessary to incorporate strict professional competence requirements in the audit for the safety

certificate. When the EU directives come to be incorporated in Dutch legislation, therefore, it will again be necessary to determine what is to be done at the respective stages of the entry procedure.

7.2 *Communicative control*

A form of control by RnV as a government agency, known as "communicative control", is linked to the supervisory policy described here. This may be distinguished from the traditional manner in which governments control ("command control"), in that the government is no longer the body in charge that can order implementation in line with policy. The government is now only one of the interested parties and must seek to close the gap between policy and implementation using persuasion, debating skills and other, softer measures. Given the limited number of participants in the rail transport system for the time being and the ease of monitoring, this form of control ought to be feasible. To this end, the consultative structures regarding railway safety that existed within the old NS group ought to be expanded to include the new operators.

7.3 *Independence of the certifying body/legal security for the transport company*

Solutions have to be found for the problem of "soft" criteria and the independence of RnV. The following solutions are possible and have already been implemented to some degree:

1. Improving the transparency and controllability of the certification process by:
 - Certifying the auditors;
 - Properly documenting the assessment process;
 - Accreditation of RnV by the Accreditation Council (in due course).
2. Involving trustworthy outsiders in the certification audit:
 - At a distance, as members of a Supervisory/Appeals Board;
 - External members in the audit team;
 - Revolving collaboration with accredited certification bodies.
3. Creating support for the methods and criteria used:
 - Through communicative control (see above);
 - By advising and supporting transport companies in their preparations (see 7.4)

7.4 *Lack of expertise*

It has been ascertained that new companies require expertise in the fields of railway operation and safety from the very outset. It is also clear, however, that such expertise is scarce and almost non-existent in the Netherlands outside the NS group. There is no way to solve this problem completely. A partial solution, however, is for detailed information to be provided on the requirements, the reasons for them and how they might be met, and for RnV to provide capacity for coaching new transport companies. Efforts should be made, however, to avoid mixing up the assessment and coaching functions. To this end, the respective tasks ought to be implemented separately within RnV and the coaching role should remain detached. What has to be avoided is a situation in which the coach gradually

assumes a degree of responsibility for the final result. Other partial solutions would be to have a railway safety course developed and to involve new transport companies in the existing consultative structures from as early a stage as possible. What we find in practice, however, is that new transport companies are concentrating on headhunting from the Netherlands or abroad, poaching expertise that has been built up elsewhere in the rail transport system.

Genuine solutions to this problem, which is one of the main obstacles to be overcome by new entrants, ought not to come from the agency charged with assessment of safety, but from other (government) institutions in whose interest it is to ensure free access to the network. Means of achieving this might include encouraging the foundation of a professional organisation with the necessary expertise in-house and subsidising new entrants to help them hire in expertise.

Safety of Transportation: Regulation and Safety

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To be right, Civil Aviation and Air Transport took off after the first war 1914-1918. In FRANCE and probably in all the main European countries, at this time, States began to become concerned by the safety of people and places overflight, this due to the increasing number of air crashes.

For instance in 1922, the French Government sent the first appeal for tenders regarding the setting up and the implementation of new disposals for manufacturing and maintenance of the French registered aircraft in a safe airworthy condition for operation.

Thanks to its background and experience in marine, only Bureau Veritas answered this tender. So, it got its monopoly by fact rather by law...

Aeronautics & Space Division was born and began to set up and implement:

- design and manufacturing rules,
- aircraft recording by registration, allowing to identify each aircraft by the essential characteristics in order to easier the preparation and carrying out of periodical visits on behalf of the States and to improve the follow up of the maintenance of the aircraft, in time.

Both constituted the Aeronautical Register consisting of:

- the International Aeronautical regulations (it has been put into practice, for a long time, by several Governments, even overseas) and
- the Register by recording.

Initiated by FRANCE, the first International Aeronautical Convention was organized in 1939. The objective was:

- to make the International Aeronautical Community concerned by the reality of the worldwide aeronautical development and by its internationalization and
- to point out the direct involvement of the States in the process in terms of liability and safety for people and goods carried and overflight.

Undoubtedly, it was the starting point of the States' awareness and the prelude to the creation/signature of the Chicago Convention and the organization of the International Civil Aviation by which Governments committed themselves directly regarding the safety of people and goods carried and overflight.

But, at that time, Bureau Veritas lost delegation of the French Government for design and control of compliance of the standard model with the basic specifications, General Direction of Civil Aviation (Ministry of Transports) being in charge of.

The announced objective of the ICAO always has been:

- to guarantee a common minimum safety level, freely accepted by the member States,
- to easier the exchanges and relationships between the members and, then, the international development of air transport.

This common level of safety, minimum and freely agreed/accepted by the members is fitting technical stipulations (design, manufacturing, exploiting) written up by most of them in terms of objectives or requirements to comply (so, the terminology "ICAO conditions or ICAO recommendations"); then, specific national process make them compulsory under standards or other forms, requirements....).

However, simultaneously, ICAO is allowing each member to set up, implement and enforce/impose (for import or overflight of its territory) its own level, in compliance with its environmental conditions:

- technological development,
- level of abilities,
- improvement in the field of safety,
- mentality, general behaviour.

So, several "national regulations" were confirmed. Their levels were different and higher than the ICAO one. For instance:

USA	—————>	CAR then FAR
FRANCE	—————>	AIR 2051,52 (now: JAR)
U.K.	—————>	British Civil Aircraft Requirements (BCAR)
U.R.S.S.	—————>	AP (now: FAS)
ITALY, HOLLAND, SWEDEN, NORWAY...		

Most of them resulted from the CAR/United States (American predominance during and after the second war). The danger, in this situation, is to affirm to be implementing a high level of regulations when the level of human conditions, industrial abilities, skills and mentalities is far (sometimes very far) to be reached for a satisfactory implementation of such requirements...

Pressured by the different actors of international aeronautical life, i.e. manufacturers, industrialists, operators, users and Governments, all decisions about regulation are taken according to the three following main criteria:

- technological control and its improvement,
- safety,
- cost of implementation.

Decision is not relevant to a barycentre but to a certain equilibrium agreed by the different partners between the three criteria above.

For several years, technologies and skills have been developed in the field of design, manufacturing, exploiting but nobody was concerned (worried by the compulsory regular evolutions) in order to set up new requirements for the best control of safety possible (as a corollary and not only a consequence, after a crash or accident).

During many years, to evolute from discovery to industrial implementation has allowed a certain progressivity in the change of habits, minds and reactions... Now it is not the same.

People ask for safety improvement whatever the cost may be! They want "zero risk level" and consider the officials and manufacturers as the first directly liable for.

Obviously, resulting from the change of behaviour and mind of all, users, industrialists, Governments, the aircraft manufacturer winner should control this evolution (in the industrial field or others...):

- the most quickly possible,
- at the lowest price,
- after proving its own "safety" (the same as the previous products or higher).

Obviously too, industrialists always have been and are still, more and more, concerned by "safety": it is a very positive marketing argument.

But is this self declaration sufficient? Of course, it is not. Notion of second and third party is now put in weight.

This means that, more and more, impartiality of decision appears clearly and pressuring groups ask Governments to commit themselves in terms of direct obligation and, therefore, liability. So, the main States or their delegates and representatives (as allowed by ICAO) are determined and:

- they are checking themselves the main points (keys) of the procedures, processes...
- they are directly involved in the demonstration of the compliance of the prototype with the basic requirements,
- they are directly involved in the checking of the conformity of materials and organizations to their requirements,
- they simultaneously issue specific requirements, implementing in the same time "novelties",
- they issue corrective requirements (airworthiness directives...).

Many examples illustrate this evolution between the manufacturer and the officials regarding statement of conformance with regulations:

- COMET —————> test of fatigue, fuselage...
- Evolution from the flight controls by cable to hydraulical, electrical ones with segregation of circuits and the simultaneous studies of adequate standards and requirements (refer the famous chapter FAR N°1306),
- Evolution of the size of the aircraft and the security —————> cutting of fuselage for depressions, electric power supply...
- Video screen devices/equipments/instruments, software arrival and standards and requirements issuance on the levels of screen transmission and reinforcement and specific training courses relative to the plane and flight control...
- Arrival of supersonic transport and the simultaneous writing up of French and U.S. specific certification regulation,
- Progress of environmental regulation (noise and pollution).

In term of liability, both States/Governments and industrialists/operators are in a very delicate situation. Are their responsibilities getting more and more shared? Who is more in charge of? Designers/manufacturers? Governments?

Are only Governments liable and committing themselves through adequate systems

and procedures of the level of safety in front of international countries.

Between the two following methods it is difficult to know which one is the more effective:

- imbrication, due to the frequent and even continuous participation of the Government to the certification processes for manufacturing and operation (where the State itself seems to be too much acting and engaged) and
- position where Government is setting up itself qualification/certification rules for products/organizations and for implementation by accredited organizations according to guidelines (instructions, directives) officially recognized by a group of States (European system E.E.C. for example),

On one hand, technological evolutions and novelties need more and more specialized human resources and materials, which undoubtedly is in the favor of the industrialists.

On the other hand, the officials, directly liable for the safe aspect of the use of those novelties, must have an adequate and qualified staff and level of materials in view to set up how to proceed with the industrialist to reach the safety goal. Of course, this is in the favor of the delegation from officials to accredited/recognized organizations. Of course, every position will tend to the other with limitations due to the environmental conditions (cost, liability restriction, feasibility) of each country in concern.

Another tendency in addition to the delegation is the fact, more and more, the number of countries having the potentiality and the national competency to design, manufacture complete aircraft and operate them will be limited. Subcontracting work for subparts will be extended to a greater number of countries worldwide (voluntary or for compensation). This should require the officials:

- to check the equivalent safety of the national methodology and requirements issuance,
- to check how they are really implemented on site,
- to continue to consider the main orderers directly liable and in charge of the safety aspect of all subcontracting (i.e. asking them to act directly in specific areas at adequate intervals).

To conclude, Safety and Regulations have been, are and will be always directly linked as Safety is the objective of the Regulations.

The difficulty has been, is and will be to find the adequate equilibrium between:

- novelties,
- feasibility,
- cost,

Keeping in mind that passengers are always and, more and more, looking for the "zero risk" and official actions must not replace the industrialists ones.

Risk Management for the Transport of Hazardous Substances

The Dutch approach

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1. Introduction

The Netherlands are one of the most densely populated industrialized countries in the world. Consequently, space for living, working, and nature is at a premium. Choices will often have to be made in which a variety of purposes will have to be served. One of the questions that need answering is whether and to what extent the handling of hazardous materials might conflict with the safety in the direct vicinity.

Depending on the volume of the transport flows and the specific hazards these involve for the surrounding areas, a certain separation between transport routes and residential areas may be desirable. In determining criteria, the interests involved must be weighed up: the transport industry as an economic factor, safety and the necessity to sometimes plan social (often even vulnerable) functions near transport routes.

Irrespective of the transport flow or the location, the result of such considerations must guarantee a certain level of safety, but it must also be feasible and affordable. The risks are charted using a figure-based approach (the risk analysis) and, if necessary, checked against the appropriate risk criteria. On the basis of the results of that check, any additional measures are taken into consideration. This approach is called the "risk approach".

The risk approach is desirable for assessing the handling (production, storage, transport and use) of hazardous materials. Such an approach ensures that the well-considered development of the industry using these materials as well as of planned developments remain possible even in the future.

2. The risk approach in general

The risk approach regarding activities involving hazardous materials is explicitly concerned with the probability of fatalities occurring in vulnerable functions, such as residential areas, shopping centres, recreational areas and offices, as a result of these materials being released into the environment. It is characteristic for such an accident that there is a relatively slight

chance of it occurring, however huge consequences may be possible while users of the vulnerable functions have no influence over this.

The aim of the risk policy is to arrive at a well-considered positioning of vulnerable functions on the one hand, and of activities involving the possibility of accidents that will affect the surrounding area on the other. For this purpose, the risks as calculated are checked against criteria and if a relatively high risk is found, measures are taken into consideration.

2.1 The risk approach in practice

For an objective assessment of risks, a figure-based approach is used that combines the probability of serious accidents and their effects. In the risk analysis, the concepts, individual risk (IR) and societal risk (SR) are used.

2.2 Individual risk

Individual risk (IR) represents the probability of a fatal situation occurring at a particular location with regard to the activity in question. As the distance to the activity in question increases, the risk of (fatal) injury decreases. On certain distances of the transport route for which a risk assessment has been made, identical so called individual risk contours can be drawn on a map (like contour lines giving height on a topographical map). This makes the IR suitable for determining a safe zone between a route and vulnerable functions such as residential areas. A certain IR value is used as a threshold limit.

2.3 Societal risk

Societal risk (SR) gives an indication of the probability of a calamity with a certain number of fatalities occurring. The number of persons present in the vicinity of a route is therefore material in determining the value of the SR. Accordingly, the SR indicates locations of importance with regard to possible "disaster situations". The aim of checking the (calculated) SR against the provisional SR value (target value) is to reduce the probability and extent of a serious accident.

The SR can also be used to compare (route) alternatives by calculating the overall societal risk of each (route) alternative and comparing the results of each. The SR is also a measure on the basis of which priorities for fighting disasters can be determined at a local level.

Societal risk is calculated per industrial activity (a plant, a storage with all the handling involved, a railroad yard etc). In the case of transport activities (free railroad track, highways, etc.) it was important to define "location". The societal risk depends on the length of the route. It was decided to use the societal risk criterium (target value) for 1 km routes. This 1 km approach fits well in the possible effect-distances of accidents and is a practical value for decision making.

2.4 Risk criteria

It is not possible to reduce every risk to nil without grave social and economic consequences. The purpose of using risk criteria is to handle risks for a specific location in a consistent manner compared with the policy for all other locations in the country. The risk criteria (a certain level of risk, i.e. safety) are based on an overall (whole country) assessment of risks of a great number of representative locations. After that a political decision has been made with respect to the consequences of risk criteria levels: costs of measures and space (the area where vulnerable dwellings would be restricted). In this respect, the criterium is a chosen reference that is used to check whether a situation is involved for which risk-reducing measures must be taken into consideration, given the fact that it is a location with relatively high risk.

The risks referred to in this case are the risks (probability of death) to persons present in the direct vicinity of transport routes for hazardous materials because of possible accidents.

2.5 Risk policy and the transport of hazardous materials

In spite of the measures in general use, hazardous materials may be released as a result of a serious traffic accident. In the event of such an accident occurring in the vicinity of e.g. a residential area, there is a chance of fatalities occurring. This affects the so-called external safety, the safety of third parties in the direct vicinity of transport routes. Therefore, the following aspects are important when assessing the safety of transport flows relative to their surroundings:

- The volume of the transport flow, which determines the probability of an accident that will affect the surrounding area;
- The type of hazardous materials involved, which determines the way in which the surrounding area will be affected;
- Road safety, which affects the probability of a large-scale accident occurring;
- The number of people living, working, recreating, etc., along the route, which determines the number of possible fatal victims.

The combination of the above-mentioned aspects determines the risk level for specific locations along transport routes. The risk policy as referred to is used to assess the risk per location and to take into consideration any location-specific measures. For each specific situation, the options (instruments) comprise measures at the source and - where necessary - effect measures (zoning).

Source measures include:

- the avoidance of vulnerable functions (routing);
- road safety measures such as speed limits, traffic control, rail conveyor systems, separation of traffic flows, safety measures at crossroads, improved infrastructure..
- screening transport routes off from residential areas.

In addition, the insight gained into the risks makes it possible to prepare effectively in anticipation of the need to counteract in the event of an accident (disaster control).

2.6 Developing criteria

Based on the assumption that the risks involved in the transport of hazardous materials with regard to vulnerable functions are generally acceptable, the criteria have been related to the present risk level.

The choice a risk level is then based on a calculation of the risk levels of a large number of locations. Naturally, such a stock-taking will show up locations with a relatively high risk level. The final choice of the criteria is determined on the one hand by the desire to provide a solution for such bottlenecks, and on the other hand by the desire, bearing in mind feasibility and affordability, to limit the number of possible future situations in which the criteria will not be met. The choice of criteria is therefore not a matter of principle, but rather a pragmatic one.

The primary purpose of setting criteria is to prevent possible high-risk situations when new developments take place. An effects study has been used as a basis to investigate whether such a set of instruments with risk criteria is and will remain feasible and affordable. Some results of the study done for transport activities are given in Table 1.

In general, the locations in the table in which the criteria are exceeded have a length of a few kilometres at most. An exception is formed by transport by sea, which involves larger areas.

Table 1. Number of locations along at least 1 km of route.

Mode of transport	Locations investigated	Exceeding IR (residential areas)	Exceeding SR
ROAD	2505	0 - 5	10 - 20
RAIL	304	0 - 5	5 - 10
WATER	238	5 - 10	0 - 5
PIPELINE	39	0 - 5	0 - 5
TOTAL	3086	25 locations max.	40 locations max.

3. Risk criteria

On the basis of the study results and the talks with the authorities and the industry involved, agreement was reached about the introduction of criteria for individual risk and societal risk.

The status (use and meaning) of the criteria is the same for stationary plants and transport activities alike. However, the criteria (specifically for societal risks) for transport activities cannot be compared as such with stationary activities, especially when taking into account the calculation method: in fact the mentioned 1 km route approach (par 2.1.2) is a pragmatic one and has an influence on the risk criterium for societal risk.

It is possible that relatively high IR will be calculated that comply with the provisional value for SR and vice versa. Therefore, relatively high risk levels for IR and SR need not go together, as IR is linked to the activity, whereas SR takes also into account the number of persons in the vicinity of the activity.

3.1 The criterium for Individual Risk

With regard to the transport of hazardous materials and to stationary activities, in principle a limiting value for the IR applies of 10^{-6} per annum (i.e. vulnerable functions will be admissible only in locations where the probability of a fatality due to an accident involving hazardous materials is no more than one in a million per annum).

For new situations (a new route, a significant change in the transport flow, new vulnerable functions), the IR criterium applies as a limiting value.

The aim for existing situations with an IR exceeding 10^{-6} per annum is to reduce the IR to the set criterium along the perimeter of vulnerable functions. For situations like this, the stand-still principle applies to new developments until the criterium is complied with. As many of these situations are historical in origin, it will not always be possible to comply with the criterium set for new situations. Opportunities for reducing risks could in such cases be presented by infrastructural alterations that were planned for quite different reasons. In other words: it is not the intention to carry out an isolated reorganization policy. For existing situations this IR criterium is a target value.

For existing situations, urgent reorganization will be required only when vulnerable functions lie within an area with an IR in excess of 10^{-5} per annum. (This IR criterium is a limiting value). No such situation has been found in the course of the study, but this does not preclude the possibility of one presenting itself.

3.2 Using the IR criterium

For new developments, an improvement of the situation can be anticipated. However, such an improvement must be foreseeable within a period of no more than five years.

For special situations, the possibility is left open to deviate from the IR limit on the basis of an integrated weighing of interests. In situations like that an undesirable situation could be accepted in spite of the criterium being exceeded. The conclusion that the criterium for individual risk be deviated from on the basis of this integrated weighing of interests is presented to the relevant ministries (transport/infrastructure and environmental affairs/physical planning) for approval. Consequently, the national authorities become co-responsible for situations in which an increased individual risk is accepted. The integrated weighing of interests deals with (a combination of) possible interests and facts relating to the risk such as:

- Transport interests, mostly of supralocal importance; in some cases international connections are involved.
- The possibly disproportionate costs resulting from compliance with the criterium. In this respect, it is also important whether other arguments exist to resolve a problem location through the use of source measures.
- Interests of local and regional significance (public planning).
- Any alternatives possibly involving a higher risk which would otherwise be involved.
- The degree to which the IR limit is exceeded in a particular area, taking into

account the developments in transport.

- In situations in which a small change at the source has an extreme effect on the distance at which the limit for individual risk is complied with, and thus on space requirements.

Checking against the criterium is done on the basis of the IR calculated at the perimeter of vulnerable functions along a route. Vulnerable functions are defined in the same way for both stationary situations and transport routes. Vulnerable are: living areas, hospitals, schools, etc. Less vulnerable are: industrial activities, recreation areas, etc.

3.3 *The criterium for Societal Risk*

The provisional SR value per km of route has been determined at 10^{-4} per annum (one in ten thousand per annum) for 10 fatalities; 10^{-6} per annum (one in a million per annum) for 100 fatalities; etc.

3.4 *Using the provisional SR value*

In assessing the SR, the local and regional authorities are given the opportunity to deviate from the provisional SR value with proper motivation. The primary function of the proposed figures is to facilitate weighing at local/regional level. Interests should be considered in a public and clear manner and, based on the assumption that the provisional SR value should be complied with, the reason for deviating from that value in a specific case must be given.

The manner in which the SR is thus used implies that local and regional authorities are themselves responsible for situations in which a higher risk level is accepted. However, the decision to deviate from the provisional value is subjected to appeal.

3.5 *Possible effects for transportroutes*

It is expected that overall, the risk criteria will (possibly) be exceeded in less than five percent of the locations along transport routes. These are the locations to note for which additional measures and/or additional planning requirements will be needed.

For most (95%) of these five percent of locations, the use of the IR criterium means that, depending on the possible measures, a zone on either side of a route of less than 100 metres should be designated in which vulnerable functions cannot be realized, or only in a very limited fashion. For railroads and roads it is calculated that the maximum zone is 40 m and less then 100 m respectively.

The societal risk is calculated for the entire relevant area. "Relevant" means where there is still a lethal effect in the neighbourhood of the (part of the) route been calculated. If necessary and possible, measures are taken at the source to reduce the risk at least to the provisional value. However, where planning prerequisites are involved, for practical reasons (feasibility and affordability) the area to be considered is maximized to 200 metres from the route.

Infrastructure for road and rail transport often includes a zone as a result of noise

reduction requirements. In such cases there may be other reasons than just external safety for limiting developments along a route. However, external safety may well impose additional restrictions.

4. Calculation instruments

It is of principal importance to standardize risk assessment when using risk criteria. The Ministries of Transport/infrastructure and Environment/physical planning, together with the provincial authorities and the railroad company, developed a tool for the PC to calculate both societal and individual risk. This program is used for all kinds of purposes: to compare route alternatives, and to compare risks of a certain location with the risk criteria.

Sometimes it is necessary to go into more detail because of deviations with a standard situation and/or in the case a discussion concerning the results of a risk assessment are very tough. In that case a more specific assessment is required: protocols for risk assessment and more sophisticated analysis methods are available. The program is "free available": it was distributed to possible users, consultancies included. The program and manual will be translated into English.

5. Developments

The risk management approach as described is meant for external safety purposes only. It is an approach to manage the risks of people living or working near industrial or transport activities. The approach has proven to be a useful instrument for physical planning of both, new industrial activities and new vulnerable dwellings. However, passengers in trains and the people on the road are excluded from calculations and from this risk management proces.

There is a difference in risk perception between so called third parties (for which the external safety policy is meant) and people using traffic systems voluntary (the so called internal safety).

Until a year ago there was no particular reason to be concerned about the (low probability/high consequences) risks of these people. Although the number of people killed in "regular" traffic accidents are of great political importance.

There are however reasons nowadays to develop a QRA based risk management system for internal safety. Apart from a better understanding of the total risk involved on certain locations, QRA based risk management seemed to be a necessity in the political discussions concerning "vertical building" i.e. infrastructure underground: roads or railroads with a roof above it or a road or railroad in a tunnel.

The advantages of "vertical building" are obvious: in a crowded country as the Netherlands, space for new developments is important. Infrastructure, although a necessity, is a nuisance for living areas because of noise, air pollution and external safety. Local environmental problems which can be solved by building the infrastructure underground. An underground infrastructure means less distance between infrastructure and living areas.

even the possibility of dwellings above the infrastructure.

However, the mentioned advantages for the neighbourhood causes disadvantages within the infrastructure. A matter of concern is the possibility of a calamity because of a huge fire or because of an accident with dangerous goods (traffic jam, a lot of people involved, difficulties to help this people, no protection, difficult to evacuate).

The problem mentioned is the trigger for studies for a societal risk criterium for people in tunnels and/or people on the road or railroad posed to the risks of dangerous goods; again for locations with a relatively high risk. One of the ideas is to find out what the consequences of such a policy would be by using a societal risk criterium a factor 10 less stringent (in probability) then the criterium used for routes for the management of external safety. The individual risk is because of its definition (a risk for a person staying under standard conditions on a specific location) not useful and also not necessary.

6. Conclusions

The chosen policy of setting criteria as outlined above for risks of transport activities is based on the idea of a consistent and rationalised risk approach. This approach is used for both stationary installations (rail road yards) and transportactivities (roads, rail, waterways and pipelines).

The outlined policy will be converted as much as possible into easy to use tables in order that (additional) risk calculations may be dispensed with in most situations. The policy is already developed and accepted by parliament for external safety purposes. Studies will be carried out to develop such an approach also for internal safety.

A consultative body is necessary for obtaining and securing a uniform and as generally accepted as possible calculation method for the risks involved in the transport of hazardous materials.

To Improve Safety per Unit Distance of Mobility is to Increase Mobility per Head of Population

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1. The proposition

To improve safety per unit distance of mobility through traffic engineering technology is to increase drivers' moving speed, to increase mobility per head of population commensurably, and therefore, to have essentially no effect upon the annual traffic accident rate per capita. Conversely, to create road conditions, such as traffic calming interventions, that compel drivers to slow down if they wish to maintain the same level of accident risk, is to decrease driver's moving speed, to decrease mobility per head of population and to have essentially no effect on the annual traffic accident rate per capita. The latter depends upon the level of accident risk people are willing to accept on the road in return for the benefits they expect from the amount of mobility they achieve and the behaviours they display in traffic. Therefore, in order to be effective in reducing the accident rate per head of population, accident countermeasures must be able to reduce the level of traffic accident risk people are willing to accept. This is the basic proposition of this paper.

2. The argument

It can be argued that there are predictable relationships from year to year between the following three variables: (1) the accident rate per kilometre driven (acc/km), (2) the vehicle kilometrage per head of population (km/cap) and (3) the accident rate per head of population (acc/cap). Some of these relationships are trivial of course: $(acc/km) \times (km/cap) = acc/cap$. But why should there be an inverse relationship between acc/km and km/cap ?

According to Risk Homeostasis Theory (earlier introduced and sometimes still known as "risk compensation theory," Wilde, 1982a, 1982b, 1988, 1994), accident countermeasures successful in lowering the rate of acc/km allow drivers to proceed at a greater speed while keeping their risk of accident per hour of exposure to traffic at the same level. The underlying rationale of accident countermeasures in this category appears to be that safety can be enhanced by offering drivers protection from the consequences of risky behaviour and that this can be done by making the environment more forgiving. We will see below that, paradoxically, there is another category of technological accident countermeasures, the rationale of which appears to be that safety can be enhanced by

making the consequence of risky behaviour more severe.

Neither category of countermeasures, however, does alter the level of traffic accident risk accepted by the members of the driving population. Examples of measures that aim at protecting drivers from the consequences of risky behaviour include the manufacturing of more crashworthy cars, the installation of seatbelts, anti-lock brakes (ABS) and airbags, the widening of roads, and the construction of divided motorways. Because the accepted level of accident risk is not reduced by these measures, the perceived potential safety benefits of such interventions induce drivers to travel at higher speeds and to drive more kilometres per year (km/cap).

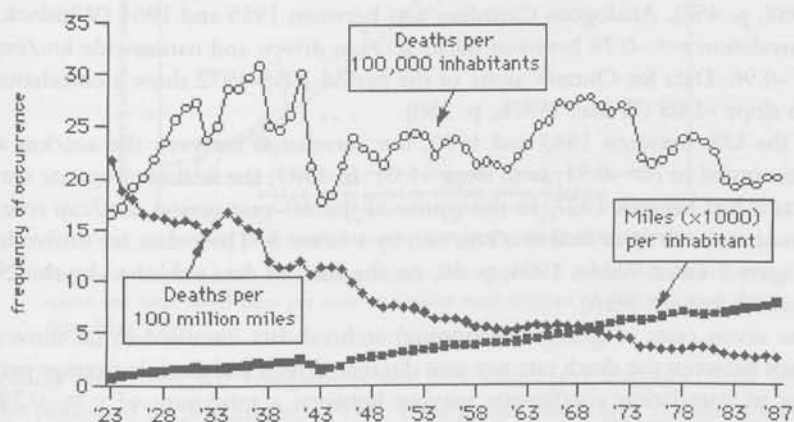


Figure 1. Traffic death rate per distance traveled, traffic death rate per capita, and the road distance traveled per capita in the U.S., 1923-1987 (Wilde, 1994).

So, if travel time budgets are stable from one time period to another, as has been argued by Zahavi and Ryan (1980), more kilometres will be driven within those time budgets and the per capita safety will not be favourably affected.

It may be inferred from the above that the provision of greater safety per km driven increases vehicular mobility in the nation in two ways: more kilometres per hour of driving and a higher rate of km/cap per annum. Therefore, instead of calling these interventions "safety measures," a more appropriate label might be "mobility promotion measures". They have the ensuing consequences of increased use of environmental resources, but no change in the rate of acc/cap. It is conceivable, however, that the increases in speed and amount of mobility of people and goods make a positive net contribution to the Gross National Product despite the attendant losses (Kamerud, 1988). This issue will not be pursued here, but it has been elsewhere (Wilde, 1994).

3. Empirical data, time series

Available archival data were inspected on the association between the accident rate per unit distance of mobility (acc/km) and the rate of km/cap. Annual Japanese statistics presented

by Koshi (1985) were subjected to further analysis. This showed that, between 1966 and 1982, the rate of acc/km of car and truck travel dropped by an annual average of 11%, and the rate of km/cap rose on average by 8% in that period (fatal accidents considered only). The product-moment correlation between the two annual rates was $r = -0.97$ (Wilde, 1994, p. 136).

Between 1973 and 1983, the rate of fatal acc/km on British motorways dropped by 10% per annum (Department of Transport, 1984). The average year-to-year increase in motorway travel likewise was 10%, while the correlation between the two variables equaled $r = -0.88$ (Wilde, 1988, p. 458). Precisely the same statistics hold for U.S. interstate highways in the period 1966-1975 (U.S. Department of Transportation, 1977, p. 89; Wilde, 1988, p. 458). Analogous Canadian data between 1955 and 1964 (Whitlock, 1971) show a correlation $r = -0.78$ between (fatal) acc/km driven and nationwide km/cap, with a slope of -0.96 . Data for Ontario alone in the period 1955-1972 show a correlation $r = -0.90$, with slope -1.05 (Wilde, 1982b, p. 250).

In the US, between 1943 and 1972, the correlation between the acc/km and the km/cap amounted to $r = -0.91$, with slope -1.01 . In 1987, the fatal acc/cap rate was about the same as it had been in 1927. In the course of this 60-year period, km/cap rose by the same amount as the drop in fatal acc/km, i.e., by a factor 8. These data are shown in graph form in Figure 1 (after Wilde, 1994, p. 60, on the basis of data published by the National Safety Council, various years).

The seven cases of (partly overlapping) archival data discussed so far show inverse relationships between the death rate per unit distance driven and the kilometrage per capita, amounting to correlation coefficients varying between a minimum of $r = -0.78$ and a maximum of $r = -0.97$. The slopes in the seven cases were (-0.73 (Japan), (-1.00 , (-1.00 , -0.96 , -1.05 , -1.01 , and (-1.00 , respectively. With the exception of Japan, all slopes are close to unity, meaning that the increase in mobility per capita closely matched the decrease in the death rate per kilometre driven. The Japanese data are marked by a few other oddities as has been pointed out elsewhere (Wilde, 1988, p. 459).

4. Empirical evidence: cross-sectional

Again we will refer to archival data. The first is a study by May (1959) which investigated the relationship between the two-year accident history of 40 road and street sections in Detroit and the moving speed of vehicles traveling in these roads and streets. Accident severity was not considered, only accident numbers. For each road section, the number of vehicles was counted over a period of 48 hours and the average driving speeds were determined over 84 hours.

From the data plotted in Figure 2 it can be seen that drivers move faster in locations where the accident rate per km (million vehicle miles) driven is lower. May fitted a slightly exponential function to the data, but the data points do not deviate significantly from a linear function $A = k.T$, meaning that the accident loss (A) equals a constant (k) times the amount of time (T , minutes per mile) spent traveling in each section. This is equivalent to saying that the accident rate per time unit of exposure is essentially the same from road

section to road section and independent of the road geometry which varies from downtown streets to expressways. In other words, the rate of acc/km varies, but drivers adjust their speed so that acc/cap remains unaltered.

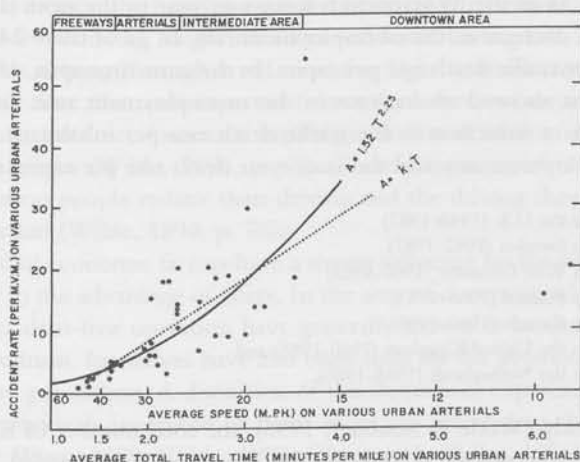


Figure 2. Accident rate per million vehicle miles (m.v.m.) driven related to average speed and total travel time per mile in various road sections of different road design (after May, 1959).

The second cross-sectional comparison involves same-year statistics from 21 different countries published by Borkenstein (1977). Data points from three countries were omitted from analysis because the reported annual driving distances per vehicle of 250,000, 200,000 and 2,000 km respectively appear unreasonably high. The correlation between (fatal) acc/km and km/cap across the remaining countries equals $r = -0.78$, with slope -0.924 . Thus, in countries where the fatal accident rate per km driven was twice as low, people drove approximately twice as much.

5. Macro-economic effects upon the fatal traffic accident rate per capita

Evidence has been offered for the proposition that the rate of km/cap depends on the rate of acc/km, both in a time-series and from a cross-sectional perspective. What has not been discussed are the major fluctuations in acc/cap from one time period to another. An example of such fluctuation may be seen in Figure 1. The traffic death rate per 100,000 inhabitants varies from not quite 20 per annum to just above 30 in the time period considered.

As these fluctuations are unlikely to be explained on the basis of traffic engineering measures, as we have argued above, the question arises as to their actual origin.

Several studies would seem to offer evidence that these fluctuations are the consequence of the business cycle: economic booms are associated with high rates of acc/cap in traffic, while economic busts are seen to lead to lower rates of traffic accidents per capita (e.g. Joksch, 1984; Partyka, 1984, 1991; Wagenaar, 1984; Adams, 1985; Sivak,

1987; Reinfurt, Stewart & Weaver, 1991; Wilde, 1991). One of these studies (Wilde, 1994) shows the relationship between the per capita death rate on the road in the U.S.A. and the rate of unemployment as an indicator of macro-economic prosperity from 1948 to 1987. During this period, 24 of the 39 transitions from one year to the next (1987 minus 1948 equals 39) showed a decrease in the unemployment rate. In 22 of these 24 transitions there was an increase in the traffic death rate per capita. In the same time span, 15 transitions from one year to the next showed an increase in the unemployment rate. In 12 of these 15 transitions, there was a reduction in the traffic death rate per inhabitant. The correlation between the unemployment rate and the same-year death rate per capita amounted to:

- $r = -0.66$ in the U.S. (1948-1987)
- $r = -0.69$ in Sweden (1962-1987)
- $r = -0.83$ in West Germany (1960-1983)
- $r = -0.86$ in Finland (1965-1983)
- $r = -0.86$ in Canada (1960-1986)
- $r = -0.88$ in the United Kingdom (1960-1985) and
- $r = -0.88$ in the Netherlands (1968-1986).

In a more recent study (Wilde & Simonet, 1996), the total number of full-time positions held was aggregated across all sectors of the economy and divided by the resident population. This employment rate was used as an indicator of the business cycle and its association with the quarterly variations from 1967 to 1994 in the traffic death rate per capita in Switzerland was investigated through an ARIMA time-series analysis. This resulted in a cross-correlation $r = 0.92$ between the two variables. When the index of industrial production was used as an indicator of the economy, a correlation $r = 0.95$ was observed on the basis of quarterly data (see Figure 3) and $r = 0.96$ on annual data. The number of jobs held, and the index of industrial production showed correlations $r = 0.87$ and 0.93 respectively, with the annual insurance claims data for property damage due to accidents, the damage being expressed in constant-value francs.

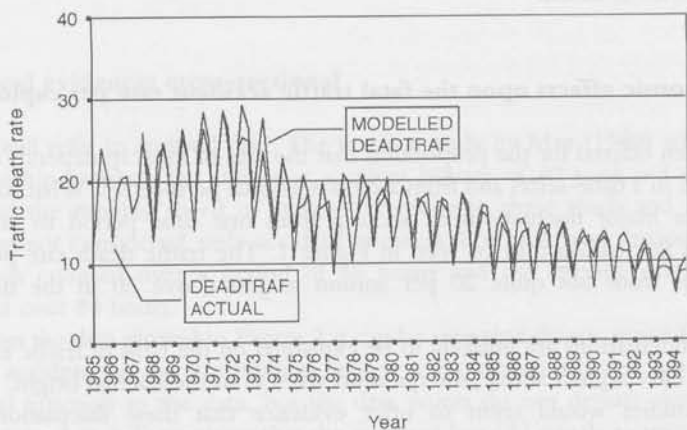


Figure 3. Actual and modeled (predicted) traffic death rate (DEADTRAF) per 100,000 residents in Switzerland, using the index of industrial production as the predictor variable in an ARIMA analysis; quarterly data (after Wilde & Simonet, 1996).

It would seem reasonable to infer that the economy has a rather firm grip on the accident rate per head of population. This may be explained by reference to the level of traffic accident risk people are willing to accept. When the economy is in a recession, and time is worth less money, the benefits expected from risky behaviour are reduced. There is less to be gained from driving longer distances and from driving fast. Similarly, there is less to be gained from driving through a red or amber light or from cutting corners in other ways. At the same time, the costs expected from risky behaviour are increased, because the costs of accidents, gasoline, insurance surcharges incurred, and of car repairs, etc., rise relative to real income (Wilde, 1994, p. 67). There is some evidence that, in periods of economic stagnation people reduce their driving and the driving they still do is at a lower accident rate per km (Wilde, 1994, p. 76).

The fact that economic factors have a strong influence on the per capita accident rate can also be used to the advantage of safety. In the area of occupational accident prevention, incentives for accident-free operation have generally shown to be the most effective form of accident prevention. Incentives have also been used for the promotion of safe driving in the general driver population. A discussion of this domain of expertise is beyond the focus of this paper. Individuals interested in these issues are referred to the available literature (e.g., McAfee & Winn, 1989; Wilde, 1994, Chapter 11; Geller, 1996).

6. What may be expected from traffic calming measures?

As noted above, there is a puzzling paradox in the safety policies that may well be pursued by one and the same accident prevention agency. The first policy aims to reduce the severity of the consequences of risky behaviour by the installation of seatbelts, airbags, reinforced doors, crashworthy vehicles, guard rails, crash barriers, wide and forgiving roads, collapsible lamp posts, and so forth. The second policy aims to increase the severity of the consequences of imprudent behaviour, and thus "to scare people into safety". Examples are speed bumps, narrow street passages, barbed wire, rumble strips, pavement undulation, speed tables, traffic throttles or pinch points. While these two policies seem logically contradictory, it has been argued above that neither policy has an effect on the fatal accident rate per head of population, but they do affect the accident rate per km driven; the first policy reduces it, and the second can be expected to increase it.

One problem in the evaluation of traffic calming measures is found in the possible shifts in traffic volumes, and thus in accident migration. In a recent paper showing crash reductions due to replacement of traffic signals by multi-way stop signs in Philadelphia, the authors noted: "At this point we can only speculate on the causes for the favourable impact on safety of the signal removals. It is possible, for example, that signal removal was followed by a diversion of traffic to other routes." (Persaud, Hauer, Retting, Vallurupalli & Mucsi, 1997). Such diversion of traffic is often one of the stated purposes of traffic calming.

It would, of course, be totally inappropriate for me, while visiting the famous town of Delft, where in 1972 the first woonerf ever was added to a city's streetscape, to suggest that the practice of traffic calming should not be pursued. As traffic safety should not be considered a summum bonum, society will be inclined to trade safety off for other benefits

such as the ones that traffic calming can bring. If safety were the highest good of all, we would not have been willing to take the risk on the road and in the air in return for the benefit of being at this conference.

References

- Adams, J.G.U. (1985). Risk and freedom. London: Transport Publishing Projects.
- Borkenstein, R.F. (1977). An overview of the problem of alcohol, drugs and traffic safety. Proceedings of the Seventh International Conference on Alcohol, Drugs and Traffic Safety, Melbourne, Jan. 23-38, pp. 3-11.
- Department of Transport, Scottish Development Department, Welsh Office, 1984, Road Accidents Great Britain 1983, London: HSMO.
- Geller, E.S. (1996). The psychology of safety. Radnor, Pennsylvania: Chilton Book Company.
- Joksch, H.C. (1984). The relationship between motor vehicle accident deaths and economic activity. *Accident Analysis and Prevention*, 16, 207-210.
- Kamerud, D.B. (1988). Evaluating the new 65 mph speed limit. In J.D. Graham (Ed.), *Preventing automobile injury*. Dover, Massachusetts: Auburn House, pp. 231-256.
- Koshi, M. (1985). Road safety measures in Japan. In L. Evans & R.C. Schwing (Eds.), *Human behavior and traffic safety*. New York: Plenum, pp. 27-41.
- May, A. (1959). A friction concept of traffic flow. Proceedings, 30th Annual Meeting of the Highway Research Board, Washington, D.C., pp. 493-510.
- McAfee, R.B., & Winn, A.R. (1989). The use of incentives/feedback to enhance work place safety: A critique of the literature. *Journal of Safety Research*, 20, 7-19.
- National Safety Council (various years). *Accident Facts*. Chicago, Illinois.
- Partyka, S.C. (1984). Simple models of fatality trends using employment and population data. *Accident Analysis and Prevention*, 16, 211-222.
- Partyka, S.C. (1991). Simple models of fatality trends revisited seven years later. *Accident Analysis and Prevention*, 23, 423-430.
- Persaud, B., Hauer, E., Retting, R., Vallurupalli, R., & Mucsi, K. (1979). Crash reductions related to traffic signal removal in Philadelphia. *Accident analysis and Prevention*, 29, 803-810.
- Reinfurt, D.W., Stewart, J.R., & Weaver, N.L. (1991). The economy as a factor in motor vehicle fatalities, suicides and homicides. *Accident Analysis and Prevention*, 23, 453-462.
- Sivak, M. (1987). A 1975 forecast of the 1985 traffic fatality situation: What did we learn from an inaccurate forecast? In J.A. Rothengatter & R.A. de Bruin (Eds.), *Road users and traffic safety*. Wolfeboro, New Hampshire: van Gorcum.
- U.S. Department of Transportation (1977). *Highway Statistics Summary to 1975*. Washington, D.C.: Government Printing Office.
- Wagenaar, A.C. (1984). Effects of macroeconomic conditions on the incidence of motor vehicle accidents. *Accident Analysis and Prevention*, 16, 191-206.
- Whitlock, F.A. (1971). *Death on the road: A study in social violence*. London: Tavistock Publications.
- Wilde, G.J.S. (1982a). The Theory of Risk Homeostasis: Implications for Safety and Health. *Risk Analysis*, 2, 209-225.
- Wilde, G.J.S. (1982b). Critical Issues in Risk Homeostasis Theory: A reply. *Risk Analysis*, 2, 249-258.
- Wilde, G.J.S. (1988). Risk homeostasis theory and traffic accidents: propositions, deductions and discussion of dissension in recent reactions: *Ergonomics*, 31, 441-468.
- Wilde, G.J.S. (1991). Economics and Accidents: A Commentary. *Journal of Applied Behavior Analysis*, 24, 81-84.
- Wilde, G.J.S. (1994). *Target risk: dealing with the danger of death, disease and damage in everyday decisions*. Toronto: PDE Publications.
- Wilde, G.J.S., & Simonet, S.L. (1996). Economic fluctuations and the traffic accident rate in Switzerland: A longitudinal perspective. Berne: Swiss Council for Accident Prevention.
- Zahavi, Y., & Ryan, J.M. (1980). Stability of travel components over time. *Transportation Research Record*, 750, 19-26.

Amsterdam-Paris High Speed Rail Link

The establishment of an on-going risk management process

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1. Introduction

This paper deals with the management of safety in the design of the Dutch section of the Amsterdam-Paris high speed rail link.

Section 2 will outline the project. Section 3 addresses safety management. Section 4 sums up the conclusions.

2. The project

2.1 A European perspective

Over the next 20 years a network of railway lines for high speed (200-350 km/h) trains will emerge, connecting the larger European cities. Its goal is to meet a substantial portion of the growing transportation needs on middle range distances (200-1000 km).

The European environmental impact assessment expects the railway's market share to grow from 15 to 25%. This means less air pollution, less energy consumption and less casualties than would be the case if the modal split would remain unchanged. The Dutch Government has decided to join in this strategic quality leap of European rail traffic. Two high speed rail links have been planned, both starting at Amsterdam, one to Germany and one to Belgium and France.

2.2 Transportation system

The Amsterdam-Paris high speed rail link project encompasses the creation of a transportation system. This means not only planning, designing and constructing the line, but also the development of stations, setting up an infrastructure controlling company and creating various business opportunities. Private investors will be invited to participate in parts or possibly the whole of the project, under terms that are currently being studied.

2.3 The Amsterdam - Paris High Speed Rail Link

The new line will run from Amsterdam, Schiphol Airport and Rotterdam to Brussels and Paris, thus connecting three capitals and two European mainports. Direct train services with high speed trains will be provided between these cities and also with The Hague (the Dutch Government Centre) and London. Travelling time from Amsterdam to Paris will drop from appr. 4 and 3/4 hours to appr. 3 hours. From Amsterdam to London, an even larger reduction in travelling time will be realised.

From Amsterdam to Schiphol trains will run on the existing, modified track. South of Schiphol a new track of some 50 km will be built, connecting to the existing track in Rotterdam. South of Rotterdam another new track stretches to Antwerp in Belgium, of which the Dutch section will be appr. 50 km long. Both new tracks are being designed to a train speed of 300 km per hour. Next to international high speed train services, the line will be used for improving national services between the West and South of the Netherlands by trains travelling at appr. 220 km/h.

2.4 Project time table

In mid 1997, the final decision to build the line was endorsed by Parliament. The plan for track layout is currently, that is end 1997, open for comment from the general public. It is expected to be fixed by the Government in the first half of 1998. Construction work should start end 1998 / beginning 1999. The southern part of the Dutch section is due to be in service on 1 June 2005 and the northern part on 31 December 2005.

2.5 Design

Design is well underway. Next to track layout, the concepts of main structures, such as tunnels and bridges, have been laid down. Quite remarkable is the appr. 7 km long drilled tunnel under open land. This land is known as Holland's Green Heart, an important nature and recreational area not far from its main city band. The Government decided to put in "some" extra money in order not to cut the heart in two. In built-up Rotterdam a cut-and-cover tunnel is planned. River crossings will consist of one large bridge and two immersed tunnels. The current design base line is a traditional ballast superstructure. Alternative designs using concrete slab are looked into. Traction energy supply will be 25 kV. Control systems will comply to standards developed in the European Train Management Systems (ERTMS) project, most likely on level 2 or 3.

3. Safety management

3.1 Introduction

The relatively high safety level of travel by train is no doubt one of its appealing features. Railway safety, as it stands today, did not come about by chance. It is the result of a culture

where safety awareness is traditionally very strong. Building on this solid foundation, the Dutch Ministry of Transport set out to make safety, which is often implicit in the design, explicit and therefore manageable. In order to do so, an innovative approach is needed, laid down in the integral safety plan.

3.2 Integral safety plan

The Integral Safety Plan is the basis for both internal safety related design decisions and external discussions about the judgement of safety risks. The following criteria for the safety policy were stipulated:

- it should be compatible with individual and societal perception of risk
- it should be socially and politically acceptable
- it should be financially and economically viable
- it should be compatible with design practice and time limits
- it should be consistent and transparent

The safety plan takes a system approach, covering all its components, i.e. track, control and command systems, rolling stock, operation, maintenance and emergency handling. Ideally, optimization of safety solutions should take place across all interfaces. The extent to which this is actually feasible is currently being studied.

The safety plan is limited to life and health risks to humans. The following groups of individuals under risk are identified:

- passengers
- train personnel
- track side workers
- people living near the track
- passers-by

3.3 Safety goals

The integral safety plan states the following safety goals:

- the safety level, both individual and societal, should be at least as good as for comparable transportation systems (in French: globalement au moins aussi bon - GAMAB)
- the risk should be as low as reasonably practicable (ALARP)
- optimal use of resources
- a safety balance among parts of the system (both functional and geographical)
- prevention is preferred above repression, intrinsic safety above added safety and safe systems above error-prone procedures
- ability for passengers, train personnel and emergency services to cope with an emergency situation

There is currently some discussion as to whether the latter three are ends in their own right or just means towards the first three.

3.4 Risk acceptance criteria

As stated in 3.3, the safety level should be at least as good as for comparable transportation systems. To substantiate this, a comparative study among existing transportation systems, both rail and other, and new projects was carried out. This showed that for passengers, train personnel and track side workers, Dutch criteria for conventional rail traffic are the most stringent. These are based on recent accident statistics and the policy to achieve some improvement for passengers and substantial improvement for track side workers. Therefore, they were adopted for this project. For people living near the track and passers-by, existing Dutch criteria coincide with those used in England by the Railway Group. Table 1 lists the individual risk acceptance criteria.

Table 1.

Individual under risk	Maximum tolerable probability of dying per annum
passenger	$4 \cdot 10^{-6}$ *
train personnel	$5 \cdot 10^{-5}$
track side worker	$5 \cdot 10^{-5}$
living near track	$1 \cdot 10^{-6}$
passer-by	$1 \cdot 10^{-6}$

* In the design a probability of $1,5 \cdot 10^{-10}$ per passenger kilometre is used. For the sake of comparison with other individuals under risk, this number is converted to a probability per annum, assuming a travel volume of 25.000 km per year per individual.

These numbers are not cast in concrete. It is currently believed that they are in accord with society's demands, regarding both risk and cost. However, if these two turn out to be incompatible, their mutual trade-off is again open to political debate. Societal risk acceptance criteria are currently being studied.

3.5 Safety management process

The first step in the safety management process, which is currently being taken, is to bring together those parties that design parts of the system or may be expected to operate it in the future.

After that, a safety assessment will be carried out periodically, the results checked against the goals of the safety plan and design changes implemented where necessary. These changes could take the form of revised and more detailed specifications as an input to the next design phase. As for rolling stock and rules of operation, influencing international standards and their national implementations would be the way to go.

Safety assessor is Railed, the Railway Safety Authority, acting as an agent for the Ministry. Basis for the assessment is the current design, together with assumptions on operation.

Since the safety assessment addresses all parts of the system simultaneously, risk apportionment is in general not necessary. This is good, because top-down risk

apportionment is often a very cumbersome process and runs the risk of just reproducing the current state of affairs, leaving little room for optimization. However, in some cases risk apportionment is needed to steer a pressing design decision and make it independent from other design decisions.

The greatest challenge in safety management is to tailor it to the various phases of the design process, i.e. have the right level of detail at the right time.

3.6 Risk assessment

As usual, risk assessment starts with hazard identification. Rather than summing up large numbers of low level hazards, a relatively small number of high level hazards, such as collision, derailment, etc. is identified and related to the various groups of individuals under risk.

Subsequently, causal analysis, typically using fault trees and consequence analysis, typically using event trees, are carried out to establish the risk determining factors. Quantification of the risk is based on component or sub-system failure data and accident statistics of an existing system plus an appreciation of the differences between these and the new project. The existing system providing the reference is conventional rail traffic in the Netherlands. It could also be high speed rail links elsewhere in the world, provided that data is available and open communication on its background is possible.

The final part of risk assessment is options analysis. This encompasses, using the risk determining factors that were established before, the generation of safety-related changes to the design that either reduce risk or save money. The most promising of these are selected and their effects assessed.

3.7 Safety report

The safety report is a key document, enabling management to make safety-related design decisions on the best information available. Its contents are:

- system description, i.e. the current design and expected operation
- hazard identification
- hazard control
- quantified risk assessment against risk acceptance criteria
- quantified assessment of costs, safety benefits and other major effects of safety measures already implied
- quantified assessment of costs, safety benefits and other major effects of possible additional safety measures
- recommendations for changing design, specifications or apportioned risks

3.8 Experience so far

Experience to date comes mainly from a study into derailment risks. It shows that it is in principle feasible to steer design decisions on the basis of quantified risk assessment and cost-benefit analysis. It has managed to materialize one of the system's important safety features,

the absence of level crossings. It has put other risk control issues, such as hot box detection and structures to guide a derailed train, in perspective. And it has exemplified the possibility of exchanging risk control across sub-systems.

4. Conclusions

One of the conditions to make high speed train travel succeed in achieving its target market share, is to retain the railway's high safety level while improving safety cost effectiveness. Optimization across technical and organisational interfaces should be promoted.

Reliable and relevant information on train accidents and incidents should travel across Europe as freely as people and cargo. Quantified risk assessment, coupled with cost-benefit analysis, can be a powerful tool in railway safety management, if well-tailored to the design process.

Aviation Safety: What Needs to be Done?

Session 3

Round Table Presentations

Over the past 10 years, the aviation industry has experienced a remarkable decline in the number of accidents. The industry has made significant progress in reducing the number of accidents, and the industry has made significant progress in reducing the number of accidents. The industry has made significant progress in reducing the number of accidents, and the industry has made significant progress in reducing the number of accidents.

It is important to recognize that while public concern and participation are important, they are not the only factors in reducing accidents. Low accident rates are encouraging, and the only thing that counts is the number of accidents. Consequently, a 20% reduction in the number of accidents, by the last of this decade, has become a realistic goal.

We know where most accidents happen. Besides what the FAA has just done, the major risk is during approach and landing. This is where 50% of all accidents occur. We also know what type of accident is causing the most loss of life. Although there are many types of accidents, all of which need to be addressed in one way or another, the most common and by far the leading cause of accidents is pilot error. During the past few years, Controlled Flight Into Terrain (CFIT) cases have risen to 10% of all commercial aviation accidents. Over the past 3 years, loss of control has also challenged CFI as a major cause of accidents.

The leading cause of accidents is pilot error, which is human error or "human factors." The FAA is currently conducting research on human factors. This is also true of the industry. Although they are not the cause of the error, it is not always the pilot. Sometimes it is a combination of the pilot, the aircraft, the weather, the traffic, the airport, the crew, or a combination of these. Consequently, with such high numbers it should be an important area for the industry to address. The FAA is currently conducting research on human factors, particularly the flight crew approach and landing CFIT, and has issued several orders on the areas that have recently been addressed by both the ICAO and FAA in a comprehensive manner.

A lot is going on at the industry to address the overall problem and there are four fundamental areas where the effort has been made. These are the aircraft, the pilot, the airport, and the operator.

Let's take a look at the aircraft first. Aircraft are becoming more and more complex, and as they become more complex, they become more difficult to operate. Aircraft have a significantly longer history than first generation aircraft, and the third generation aircraft

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Session 3

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Aviation Safety: What Needs to be Done?

Stuart Matthews

President and CEO, Flight Safety Foundation, U.S.A.

Over the years the accident rate has come tumbling down and today stands at the very low level of about 1.5 accidents per million departures. Although very low, in recent years it has more or less plateaued at a virtually constant level and is no longer continuing to decline. On the other hand traffic is rising and is anticipated to double or even treble in the next 12-15 years. Consequently unless we can make significant reductions in the accident rate, we are going to see a significant increase in the actual number of accidents. The often quoted "one major accident a week somewhere in the world" is certainly a very real possibility.

Regrettably, despite their rarity, public concerns and perceptions are heightened every time there is an aviation accident. Low accident rates are meaningless, and the only thing that counts is the number of accidents. Consequently it is imperative that we decrease the number of accidents. In the face of rising traffic, this means we must decrease the accident rate.

We know when most accidents happen. Statistics over the last ten years show that the major risk is during approach and landing. This is when 50% of all aircraft accidents occur. We also know what type of accident is causing the most loss of life. Although there are numerous types of accidents, all of which must be addressed in one way or another, the greatest concern and by far the leading cause of aviation fatalities during the past ten years is Controlled Flight into Terrain. CFIT causes more than half of all commercial aviation deaths. Over the past 5 years loss of control has also challenged CFIT as a major cause of fatalities.

The leading cause of accidents in any industry is human error or "human factors". On some 80 per cent of occasions someone has made a mistake. This is also true of the aviation industry. Although they involved most of the time, it is not always the pilot. Sometimes it is someone on the ground, a mechanic or air traffic controller. However, generally the crew is involved. Consequently with such large numbers it should be no surprise that the four primary safety concerns that we have in the aviation industry world wide are human factors, particularly the flight crew; approach and landing; CFIT; and loss of control. These factors are the ones that have recently been embraced by both the ICAO and FAA as their main safety priorities.

A lot is going on in the industry to address the overall problem and there are four fundamental areas where this effort can aimed. These are the aircraft, the system, the facilities and the operator.

Let's take a look at the airplane first. Airplanes are fundamentally rather safe and, with each successive generation, they become safer. Second generation aircraft have a significantly better record than first generation aircraft, and the third generation - those

currently being built – has a better record still.

If we take a look at the distribution of the worldwide jet fleet we can see that a small percentage of first-generation aircraft still continues in service around the world today; however, older first and second-generation aircraft still comprise almost half of the entire fleet. One simple way to improve aviation safety might be to eliminate all first and second-generation aircraft. That, of course, is totally impractical and it must be recognized that most of the existing fleet of aircraft, including many of the older generation aircraft that are currently in service today, will continue to be with us for many years.

Since we do not anticipate any radically new types of aircraft in the near future and existing aircraft types will be in service for a long time to come. Specialized equipment designed to address specific hazards continues to be developed and incremental safety improvements will be possible through the installation of this equipment in new aircraft, or by retrofitting it, where possible, in existing fleet aircraft. However, it is highly unlikely that there will be any quantum leaps in aviation safety coming from the aircraft improvements alone.

Some of the things that we can do to improve the aircraft include automated flight envelope protection systems designed to stop the pilot getting into adverse situations that could lead to loss of control and enhanced ground proximity warning systems that will provide warning of an impending CFIT threat. Full implementation of the use of transponders and TCAS will help to maintain separation and lower the risks of mid-air collisions, especially as the skies become more crowded. Ice, particularly on the ground, continues to be a problem that new detection systems could help eliminate. Although not mentioned so often, injuries due to in-flight turbulence could also be reduced by the development of clear air turbulence detection devices. Data links, rather than voice transmissions, could help to reduce errors caused by communications problems.

All of the improvements mentioned above are important in themselves as a means of enhancing safety. However, it must also be remembered that the aircraft itself is only cited as the primary cause of an accident in some 10 to 15 percent of all accidents. Consequently, even major improvements to the aircraft will not produce dramatic reductions in the overall accident rate. Comparing the accident statistics it is pertinent to note that the figures for aircraft operated outside North America are significantly higher than those of North American operators. The accident rate for non-United States carriers is somewhere between 3 and 5 times higher. Since there is little difference in the aircraft equipment – operators around the world are flying the same types of aircraft – this is a clear indication that other factors are at work besides the aircraft itself.

Worldwide, the accident rate is about 1.5 per million departures. However, closer examination of the accident rates in different parts of the world shows that there is a significant variation from region to region. In North America the rate is about 0.5 per million departures; in the developed parts of the world, Europe, Japan and Oceania, it is still well below 1.0. However, Latin America, Africa and S.E. Asia and China all have horrendous accident rates in comparison. Despite having considerably lower traffic, proportionally they have many more accidents. Significantly, over the last ten years 70 per cent of all accidents around the world have involved carriers who accounted, between them, for only 16 per cent of the total air traffic.

There's another way to look at it. In the past 10 years or so, 148 airlines have been responsible for one or more accidents and, of those, about one third have been responsible for repeated accidents. The majority of these were operators from under developed or third world countries. We expect traffic to double in the next 12-15 years. However, traffic growth varies from region to region and in some areas we expect that it will even treble. Much of the most explosive growth is in third world areas where, combined with their presently high accident rate, we can expect dramatic increases in their number of accidents locally if the rate is not reduced. This is of particular concern in Latin America, Africa, Asia and China.

It is also true, that the types of accidents experienced from region to region are different. Here we see the frequency of different types of accidents that have occurred in the different regions, firstly over the last 10 years and secondly over the last 5 years. Again it can be seen that approach and landing is a problem worldwide, particularly in those four areas I have already mentioned. Similarly with CFIT accidents, which generally occur during the approach and landing. However, the advent and installation of ground proximity warning systems (GPWS) has done much to reduce the number of CFIT events in North America. On the other hand, North America has its own problems. For instance, runway incursions, ice and snow, and in-flight fires are unusually high compared with other parts of the world and, therefore, these are particular problems that have to be addressed in this area.

I have already said some of the things that we can do to airplanes. Let us now turn our attention to what we can do about the aviation system itself. It is apparent that most aviation safety problems today lie with under-developed countries where, regrettably, the system is not always that it should be. Indeed, many countries, particularly in South America and Africa, do not have the infrastructure or capability for appropriate oversight of their air transport industries. In some cases they lack the applicable law to cover aviation or safety itself. Rules and regulations might exist but the regulatory authority may have only limited oversight or capability to ensure that its operators are conforming to the minimum ICAO standards and its obligations under the Chicago Convention. Statistics are not collected or properly analyzed and lessons learned are not implemented. We are familiar with the FAA's unilateral action to rate the regulatory authorities of individual countries under its International Aviation Safety Assessment Program, and to deny access to U.S. airspace by those carriers from countries that are not conforming properly. ICAO is also taking a more proactive stance on this matter. It is conducting its own audits and I believe that is where the main policing effort should be. One of the prime ways in which we can improve the overall safety rate is to address the safety problems of the third world. In particular we must insist that they put their regulatory systems in order and assist them if necessary.

We can also improve the facilities. As we have seen, the industry's major hazards, approach and landing, and CFIT, are even more critical in the third world. In many cases the operating environment leaves much to be desired. Limited air traffic control and radar coverage, deficient or non-existent navigation and airport landing aids all add to the problem. Ways in which we can improve the facilities include improving air traffic control to help navigation and separation. Installation of Minimum Safe Altitude Warning Systems

(MSAWS) would help significantly in preventing CFIT while the design and installation of precision approach paths, rather than non-precision step down approaches, would produce a five-fold reduction in the approach and landing risk. Upgraded and improved runway signals and lighting would help runway incursions. Improved language training should include the setting of minimum standards for English language use. This, together with the use of standard phraseology for air traffic would help reduce communication problems.

Now I would like to come to the area that is always closest to the accident - the improvements that we can make at the operating level. Historically we have achieved a significant reduction in overall accident rate by being reactive. We have examined the wreckage, analyzed the flight data recorder, the black box, examined witnesses and survivors. By all these means we have found the cause of the accident, moved to fix the problem to ensure that it does not happen again. While this has served us very well in the past, it is also the system that continues today that, as I have shown, is no longer producing any real reductions in the overall rate. If we are going to obtain significant improvements in the accident rate in the future, we will have to be pro-active. We will have to look ahead and identify potential accidents so that we can stop them before they happen. A powerful tool is available to help us do this in the digital flight data recorder (DFDR) that is fitted, by law, into virtually all commercial aircraft flying today.

The DFDR monitors the aircraft, its systems and its performance. It also monitors what the pilot or crew is doing, their control of the aircraft, if they have exceeded set operational limits, and their general conduct of the flight. The DFDR is recording all the time. Although installed originally as a means of providing information to assist in accident investigations, it not only records accident flights, it is recording every flight. In the past information from DFDRs has been used primarily only to examine accidents or serious incidents. Fortunately, accidents are relatively few and far between. However, this means that, if flight data recorders are used only in this way, the information we can get from them about normal operations is very limited. Accidents are the abnormal situations and provide only a very limited number of reference points. Indeed, if we only look at these instances alone we can hardly know what normal is!

Examination of the flight data recorder on a regular basis will show us what is normal and it can also detect adverse trends from normal operations that can then be corrected before they become a problem. Continuous analysis of the DFDR, combined with confidential reporting and non-punitive reporting systems especially by pilots, known here in the U.S. as FOQA systems, can be a very effective means of preventing accidents, reducing injuries, saving lives, equipment and costs. FOQA systems are used extensively in other parts of the world but only hesitantly are they now beginning to be used in the United States. Labor has concerns regarding job security; managements are worried about regulatory enforcing action in the event that errors are detected. There are concerns that the media, through the Freedom of Information Act (FOIA), might get hold of and publish adverse information and, of course, everyone is concerned about the plaintiffs' lawyers. Nevertheless, if we are going to be able to look ahead and identify accidents before they happen we have to address these concerns. Pilots must be assured of confidentiality and that there will be no punitive action taken against them for reporting inadvertent errors. In the event that an inadvertent error is revealed it is better to know what the mistake is, and

correct it, rather than to punish someone for making that mistake. If pilots anticipate that they might be penalized for making a mistake, either one that they have reported or one that is shown on the DFDR, they are unlikely to make any further reports. As a result and we will probably never be aware of it until someone else makes the same mistake and it results in an accident.

Consequently the Flight Safety Foundation strongly supports analysis of the flight data recorder as a means of monitoring crew behavior and performance allied with confidential non-punitive reporting programs. We also call for appropriate regulations and, if necessary, legislation to assure that FOQA programs can be fully implemented.

While accident investigations in the United States generally seek to determine the primary cause, it is well known that, rarely, is there ever one single cause of any accident. Typically, there are several contributory causes that combine together like links in a chain to create the event. If any one of the links is broken by the contributory cause being eliminated, then the accident will be prevented. There have been many contributory causes of past accidents, some of which occur repeatedly. If one tallies those contributory causes, the one that occurs most frequently is the "flying pilot's failure to follow standard operating procedures (SOPs)". The third most prevalent reason is that the "Non flying pilot failed to follow SOPs". If I have any message to leave today it is this. SOPs are an effective means of combating the human error that contributes to some 80 per cent of all accidents. Training pilots to conform to SOPs, and ensuring that they are rigidly adhered to, is one of the most powerful ways we have of eliminating almost any type of accident and hence of reducing the overall accident rate.

There are two types of failure that can contribute to accidents. These are active failures and latent failures. Active failures, or active errors, are generally mistakes made by line personnel. Latent failures are errors or mistakes that might have been made by others in the organization or in the system that might lie hidden, even for many years, waiting to combine with other circumstances and so contribute to an accident. Generally there are far more latent failures lurking in the system and seeking them out has far greater potential for safety improvement than by focussing on active (i.e. line) failures alone.

Typically, examples of latent failures are poor planning and scheduling; flawed procedures; poor training; improper allocation or lack of resources. Fixing a latent problem could also eliminate one or more active errors. For instance, improved training could mean that a pilot is less likely to make an active mistake.

Most accidents involve human error. In fact, human error is a perfectly normal phenomenon. People make mistakes all the time. I do, you do, we all do. Most mistakes are involuntary in that we do not intend to make them but, the fact is, that errors are a normal part of life. We tend to think in terms of line pilots or mechanics as being the ones who make the mistakes or active errors. However others, not line personnel, including managers also make mistakes. Generally managers do not make many active errors but they are responsible for many latent errors - errors that come to light only when they combine with others to create the incident.

It has to be recognized that management of any organization is also responsible for safety. This is a fundamental that dictates the culture of the entire company. It is the management that sets the tone for the way in which the company operates and ensures that

the environment and infrastructure is one that allows a safe operation. A company without a strong safety culture is not necessarily unsafe; however, generally speaking, a company that does have one will be a safer one and will have a safer operation.

Safety begins at the top and it is the CEO who sets the policy with safety as a core business value. Airlines are not in business to be safe; they are in business to carry passengers or cargo from one place to another at a profit. However, without safety they probably will not have many passengers or much profit for very long. Consequently safety is supportive of their business objectives. Further, especially in the aviation industry, in the long run safety is cost effective. To reduce its risk a company needs to have a culture of safety with appropriate safety programs. This means a strong, independent safety department with appropriate safety programs, including FOQA and confidential non-punitive reporting systems; standard operating procedures; proper training for all personnel and, most importantly, the provision of adequate resources such as the facilities, the equipment and the financial budget to ensure that it all works.

Such philosophies and attitudes translate into actions with aircraft that are properly maintained, well-equipped and standardized; standard operating procedures that are fully developed, implemented and strictly adhered to, and comprehensive training and checking, all of which ensure a safer operation.

We can improve the operator and, at the same time, the operating personnel by an ensuring that management is aware of its responsibilities and fully implements proper safety policies and procedures. Crew training should include programs that address the biggest industry concerns. These include CFIT awareness and education training such as that developed by the FSF industry task force over the past five year; unusual attitude recovery training; crew resource management training; and stabilized approaches. If we are to obtain the accident rate reductions we seek these standards must be imbued in all carriers worldwide. Although these philosophies and action programs apply particularly to carriers in the under developed countries, there are still companies here in the United States, as well as in other industrial nations, that might do well to heed the same advice.

In conclusion, we have to reduce the overall accident rate and I believe that it is possible by a combined assault on all fronts. It is possible to improve the aircraft itself, but only incrementally. Probably the one most important improvement we can make is to install or retrofit EGPWS to address the major hazard, CFIT, while flight envelope protection would reduce loss of control problems. However, the aircraft is a relatively small part of the overall problem.

Human factors that give rise to active failures, particularly in the cockpit, feature in 80 per cent of all accidents. Crews should adhere strictly to SOPs; they should receive CFIT, unusual attitude and CRM training. FOQA programs can identify adverse operational trends and human errors. If we are to really improve safety in the future, it is imperative that they be adopted fully in the future.

But the greatest potential for overall safety improvement lies in identifying and eliminating the latent failures that invariably contribute to accidents. Latent failures are caused, primarily, by management. The need to make managements aware of their obligations for safety is paramount. They have to understand their responsibility for the development of proper procedures and policies. They have to provide comprehensive

training for both air and ground personnel and they must ensure that strong, internal safety systems, together with adequate resources, are available to constantly monitor safety performance. Management should also understand that although safety is not necessarily cheap, it is cost effective. The regulators and civil aviation authorities must understand that they too can cause latent failures. They have a responsibility to ensure that they are capable of properly performing their oversight responsibilities, at least to the minimum ICAO standards, as well as for providing an adequate infrastructure of airport and navigation facilities.

Although everything I have said applies to all regions of the world, the major problems lie in the undeveloped world, particularly South America, Africa and large parts of Asia, where so much is lacking. These are the areas of the greatest risk and of the greatest potential growth. We need to concentrate on and provide assistance to these areas where, if we do not, the problems will only become exponentially greater. Apart from the moral necessity, the future economic viability of our industry could depend upon ensuring that these areas contribute fully to maintaining a universally safe aviation system around the globe.

In conclusion, I would like to acknowledge the assistance that I have received from both Airbus and Boeing in providing some of the statistical information used in this paper.

Railroads

Elaine Weinstein

U.S. National Transportation Safety Board, U.S.A.

1. Issues the US has in common with other countries

1. Over-reliance on automation (e.g. Shady Grove); at what point is a computer more reliable than a human and visa versa. There should be system safety - an integration of the man and the machine.
2. Corporate culture - is there a management climate that fosters safe operations?
Human factors issues - Does the work schedule permit enough time for the engineer to get sleep? fatigue, alcohol, drugs...
3. Need for a Director of Safety who reports to the President or General Manager
4. Emergency response preparedness - direct phone lines, practiced drills

Positive train separation - needed to address inattention of the crew to wayside signals - PTS is a system that can slow and stop a train when the engineer is not taking appropriate action in response to a signal indication

(1987 rec) - railroads rely on train crews to comply with the operating rules to prevent collisions; such as the meaning of the signals & proper responses. Yet 80% of crashes are a result of human error. A PTS control system automatically intercedes when an engineer does not comply with the requirements of the signal indication.

- adequacy of wayside signals to reliably capture crew attention when competing sources of attention are present; Limits of human vigilance (<1 hour); need for redundancy
- cab signal systems - provide a constant display of the governing signal indication in case the engineer doesn't see, misreads or forgets the signal indication
- automatic train control systems are capable of intervening should the engineer fail to observe a signal

2. Passenger car safety standards (Silver Spring)

- emergency egress was impeded because there emergency doors release handles were either missing or inaccessible (T-handles were missing)
- no emergency interior lighting
- difficulty pushing out windows because the lubricant hardened - no maintenance/inspection

- interior materials did not meet flammability and smoke standards - that are 30 yrs old
- structural crashworthiness of the cab control car - need for stronger collision posts

Locomotive fuel tank integrity - the fuel tanks on freight and passenger trains are designed to have a minimum clearance above the rails. There are no US standards for fuel tank design, size, location or performance. In the Silver Spring accident (MARC vs Amtrak) the fuel tank in the Amtrak train ruptured and sprayed diesel fuel into the cab of the MARC train causing the train to catch on fire and 8 of the 20 passengers and all 3 crew died.

Telematics for Slow Travellers' Safety

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Abstract. The attractiveness of slow modes for personal travel is constantly challenged by a diversity of developments. One of these concerns travelling safety. Most technological improvements in road safety concentrate on motorized modes. This is the more true for the application of telematics measures to warn and control car and lorry drivers. Remote control of speeds is one of these technologies. Overall, there is a great danger that such measures are detrimental to the attractiveness of the slow modes for personal travel. The paper draws attention to the need for development of similar technologies for the slow modes in order to improve travelling conditions, especially safety, for the non-motorized travellers, to the benefit of the total transportation system.

1. The threatened slow modes

The importance of the slow modes as a part of the total transport system can be expressed at various dimensions. For the captives without access to a car the slow modes often are the only opportunity to participate in social, cultural and economic activities. But consider also life in our cities: could we imagine attractive cities without the lively crowd of pedestrians and cyclists? And thirdly the environmental concern: the slow modes succeed in substituting a considerable part of motorized travel, thus saving energy consumption and damaging exhausts.

So, it is of paramount importance that the slow modes will remain, or better will improve their attractiveness as a travelling mode in order to offer captives sufficient mobility opportunities, to restrict environmental damage and to keep our cities liveable. This is not a superfluous appeal because there is a variety of forces working that constantly threat the current market position of the slow modes relative to the motorized modes. Spatial and economic developments lead to increasing distances between activity locations that more and more go beyond the application range of the slow modes. On the other hand, a loss of relative attractiveness is due to the permanent technological and organizational improvements of the competing motorized modes. This fact leads to a negative feedback loop in the modal choices of travellers. The more travellers use the car, the more is being done for their safety, comfort, travel time, etc. And as a consequence, the more cars are on the roads, the less attractive it is to use these roads by foot or bicycle.

The question we like to address is how we can improve the travelling safety for the slow modes in order to improve the overall attractiveness of these modes as a means of travel, but at the same time to improve the overall safety of the total transportation system.

2. Telematics for slow mode safety

A lot of policies are directed towards improving safety for travellers. An important step forward are for example speed limits in residential areas. We would like however to concentrate this paper on the traffic situation outside built-up areas on rural roads. There, traffic safety is relatively bad whereas implementing the classical measures would imply enormous costs and relatively limited benefits because of the large network combined with low traffic densities.

In our opinion, telematics offers very cost-effective opportunities to improve traffic safety for slow modes, and thus also for the motorized modes, in these conditions. This assertion will be worked out using an example in which through remote control of vehicle speeds actuated by the slow mode travellers safe conditions can be created for encounters of the different traffic participants. Such conditions will not only enhance traffic safety but will at the same time improve the attractiveness of the slow modes. The paper is inspired by two developments: the world wide development and deployment of Road Traffic Information (RTI) systems; and, the plans in the Netherlands to rebuild the traffic system into a so called inherently safe system which is at least 10 times safer than the present one.

In the Netherlands the road safety institute (SWOV, 1990) initiated a masterplan towards the development of an inherently safe traffic system. One of the main points of this approach is a rigorous separation of traffic modes when they are not compatible in terms of safety. Existing examples are the motorway, separation of pedestrians and vehicles by means of side walks; separation of cyclists and cars by means of separate cycle paths, etc. When meetings of slow and fast traffic are inevitable the speed of the fast vehicles should be strictly limited to e.g. 30 km/h. This is the solution chosen in "Woonerf" and 30 km/h areas.

The realization of an inherently safe system on a larger scale will require a lot of new infrastructure or at least a rebuilding of existing facilities. This paper presents a case where the solutions of separation and speed reduction are not efficient and the application of RTI seems much more attractive. Meetings of motorised traffic at relatively high speeds with pedestrians and cyclists on single carriageway minor roads are potentially unsafe events due to the difference in speed and the vulnerability of the unprotected road users. Separate paths for slow traffic are financially unattractive and a permanent low speed for the fast traffic is also costly to achieve and will be opposed by the public. Application of modern Road Traffic Informatics can solve this dilemma in an elegant way. A system is proposed and discussed that can accomplish a civilised and appropriate speed behaviour of the motorised road users. The slogan is: only speed reduction when it is really needed. The system can make minor roads attractive again for pedestrians and cyclists. Technical details will not be treated but the desirability of the system will be argued and some aspects and potential problems will be discussed.

3. Description of the problem

Mixing of fast moving vehicles (FMV), e.g. cars, trucks, motorcycles, and slow moving vehicles (SMV), e.g. cyclists, pedestrians, wheel-chairs, horsemen, does not fit in an

inherently safe traffic system. Two directions to make the situation safe are available: separation of traffic; and, decreasing the speed of the FMV.

In residential areas inside built-up areas traffic planners have chosen to lower the speed of FMV to a safe level of 30 km/h. The lower speed is attained by means of signs and the design of the infrastructure. These measures have a positive influence on safety, see e.g. Brilon & Blanke (1993), and can possibly be made even more efficient when the low speed is obtained by means of remote controlled vehicle speed limiters.

On main arterials inside and outside built-up areas separation of FMV and SMV is applied. Sometimes this solution is difficult to apply, e.g. in old parts of cities there is not always enough space for separation. A safety problem does also exist at intersections where FMV and SMV are using the same space but these types of problems will not be considered in this paper.

Outside built-up areas separation of FMV and SMV is the preferred measure on higher order roads. However, in all countries the road length where FMV and SMV are using the same carriageway is substantial, in the order of magnitude of about half of the total paved road network length. In the Dutch guidelines the requirement of a separate cycle path is dependent on the product of the intensities of FMV and SMV. In the design manual for cycle infrastructure, CROW (1993), separation is dependent on the intensity and speed of FMV and not on the intensity of the SMV. These are both compromises and not compatible with inherently safe traffic.

We will now limit the discussion to the road type with only one lane for both directions and used by FMV and SMV. Intensities of both vehicle types are generally low on these roads and in that case the measure proposed is most relevant. However, one certainly should study the applicability to two-lane roads as well.

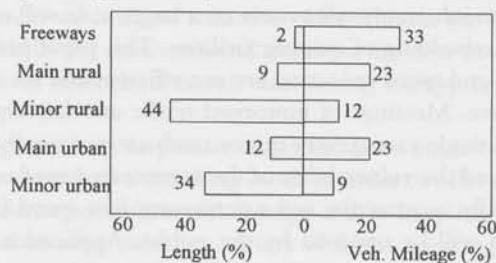


Figure 1. Distribution of road length and vehicle mileage over five main road types in the Netherlands in 1986.

We will illustrate the size of the problem with Dutch statistics in 1986. Of course the situation may be somewhat different in other countries but this does not invalidate our arguments in general. Figure 1 presents the road length and the distribution of the total vehicle mileage over several road types. One-lane roads are a subset of Minor Rural Roads and have the following statistics:

- They constitute 32% of the total road length of the country;
- 4.4% of the vehicle mileage is "produced" on these roads and about 5.5% of the vehicle hours;
- The AADT is 314 motorised vehicles.

Unfortunately no data about the use of these roads by slow traffic is available. We may however safely assume that the percentage of slow mode users on urban roads will be high and will not be negligible on the rural road categories.

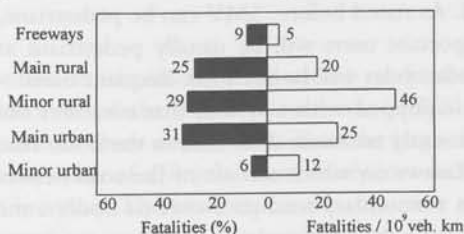


Figure 2. Distribution of number of fatalities and fatality rate over five main road types in the Netherlands in 1986.

Figure 2 presents the general safety statistics for several road types. For one-lane roads the following safety statistics are available:

- Of all people killed in traffic 14.2 percent are on these roads;
- Per vehicle distance driven and per vehicle hour spent the number of people killed is the highest of all road types;
- 7.1 percent of accidents with injuries occur on these roads;
- Considering accidents with injuries, only main roads inside built-up areas have a higher accident rate (per vehicle distance and per vehicle time).
- The number of accidents per year is only .1 per km road length.

This latter finding means that on single lane roads the accident concentration is lowest. This fact alone implies that a solution of the safety problem can be better sought in measures changing the vehicles than in changing the characteristics of the infrastructure.

Separation of fast and slow traffic on these roads is not attractive because of the high costs. Lowering the speed of the FMV is neither an attractive measure, because:

- Enforcement is difficult and costly in terms of police hours;
- Modifying the road to force low speeds (humps, etc.) is also costly;
- A RTI solution would be to reduce the speed by speed limiters in the cars that are remotely controlled from outside. This is not efficient as will be shown in the sequel.

An even more important counter argument is the acceptance by the public. The roads we are talking about are nearly always empty. A permanent speed limit is not efficient because most of the time it is useless. The extra travel time for FMV due to a permanent lower travel speed, summed over the total network, would be a substantial amount, as can be illustrated. In the Netherlands 3.6 billion vehicle km are driven annually on one-lane roads. If the average travel speed is reduced from 50 to 30 km/h, then the extra travel time will be: $(1/30 - 1/50) \times 3.6 \cdot 10^9 = 48$ million vehicle hours.

4. Outline of a possible rural road RTI safety system

In essence the proposed system consists of a moving space around a SMV and inside this space the speed of FMV is controlled in such a way that at the meeting the speed of the

FMV is as low as safety requires. Consequently the system does not only detect the presence of the SMV and signals this to the driver of the FMV, it also controls the response of the FMV; see Figure 3. The system is completely vehicle based, no central intelligence or road side equipment is needed. As stated before, SMV can be pedestrians, cyclists, wheel-chairs, horsemen, etc. Most important users will be usually pedestrians and cyclists. Regarding FMV cars, trucks and motorcycles will be the most frequent users.

All road users are equipped with a system that measures their position, speed and direction and quasi permanently transmits these data to the other road users within a certain distance. The FMV also knows on which section of the road network it is driving. This is needed for instance when a secondary road goes over or under a motorway.

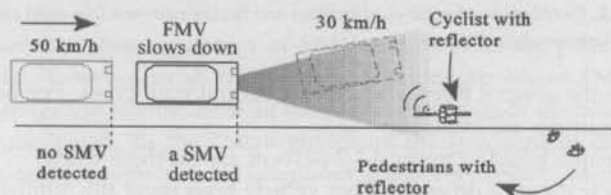


Figure 3. Illustration of how the system could function.

The RTI systems of the vehicles communicate permanently and based on this it is decided whether a meeting (either overtaking or oncoming) is imminent. The decision to take action is taken by the FMV-intelligence. It might be a feature that the SMV-user is signalled that a FMV is taking action. The response of the FMV is a controlled speed reduction to e.g. 30 km/h. The acceleration after the meeting can be left to the driver.

The situation is becoming more complex when more than two road users are in each others neighbourhood. Then there will be several areas in the road-time plane where a speed reduction is needed. The most severe restriction will then get priority. In this case the situation is also more complex with respect to the communication.

The main new point of this system is that also the SMV are provided with RTI equipment. This will bring about costs and certainly resistance from the public. To prevent this one might be inclined to develop systems where only the FMV needs RTI because this is the user who causes the problems. An example of such a system is the experimental French vehicle ProLab2; see Rombout (1995). This car is equipped with video cameras and automatic image processing and it "sees" fixed and moving obstacles, included pedestrians and cyclists. However, it is easier to develop systems where both users are active in collecting and communicating data. This will result in redundancy of information and that is certainly needed to meet reliability standards and get a high hit rate and a low false alarm rate.

A possible interesting solution in between would be a so called passive "intelligent reflector" (with transponder) on the SMV. This reflector makes it much easier to detect the presence of a SMV by means of radar or laser in a complex environment with all types of objects. The type of SMV can also be read from the reflector. This will make the equipment of the SMV much more simple, cheaper and there is no need for power.

5. Aspects of the proposed system

In order to judge the abilities of the proposed system some of its aspects will be discussed in the sequel.

- Costs

Before any estimation of costs involved can be made, the system must be worked out much further. However, if the trend towards more RTI equipment on FMV is continuing, the extra costs for these road users will not be large. For the SMV this is really a problem. Sometimes the value of a bicycle is extremely low and then the RTI equipment would be much more in value. Therefore it is more attractive to design a system that is human bound. This is anyhow needed for pedestrians and some other types of SMV. One could imagine that it could be part of a hand held telephone or, when it can be made small enough, even part of a watch.

- Failure of the system

When the system fails somehow this could lead to unsafe situations. However, one should compare the situation with that without any measure and we know that that is pretty unsafe, both in terms of accidents happening and also in terms of subjective unsafety for the slow traffic.

- Effect on level of attention of the FMV driver

It should be investigated if the drivers after some time rely so much on the system that they become less alert. This is a point for every RTI system that assists the driver in his task, e.g. an automatic anti collision system. At first thought this point does not seem to be that important on one-lane roads. The road characteristics are generally such that they require the driver to be alert in order to keep his vehicle on the road.

- Liability

This aspect is a major point when replacing a part of the driver's task by an automatic system. If this point is not solved the application of RTI in traffic will be limited to the supply of information. In the case considered here it seems reasonable to let the FMV driver be liable also in case of a system failure. With respect to this point one should certainly not abolish the existing safety devices of SMV, such as lights and reflectors.

- Requirements for SMV

Supposing this is the only traffic situation where SMV will need the RTI equipment, occasionally users will not be inclined to buy it. This can be solved by creating the possibility to rent the equipment. On the other hand it seems likely that the same system could promote safety for SMV in more traffic environments than one-lane rural roads only.

- The fast cyclist

Suppose a cyclist rides 35 km/h and the cars have to slow down to 30 km/h, then the FMV can not overtake the cyclist. Consequently the FMV should slow down to a speed that is dependent on the speed of the SMV.

- The slow, relatively wide and difficult to manoeuvre wheel-chair

For this SMV the speed of the FMV must be reduced even more than to 30 km/h, dependent on the road width. The same might be useful for horsemen.

- The moped

This might be a special Dutch problem. Compared to FMV the moped is a SMV,

but compared to cyclists and pedestrians it is a FMV.

- Capacity

It is a widespread belief that speed reductions go at the cost of roadway capacity. However, in general it can be stated that in the situations where capacity is at stake other measures will be taken to guarantee traffic safety, such as separation of modes. This is the case for example on freeways and urban arterials. Speed regulation is needed in those situations where traffic is mixed and jointly use the same space such as in residential areas and on rural roads. In these latter situations however capacity is not a factor of importance in the road design. The speed reduction through RTI measures has hardly any effect upon capacity.

One can even generally state that capacity is relatively insensitive to the level of the maximum speed, a fact that unfortunately is not well known. Over a large range of speed values, say between 30 and 120 km/h, capacity is relatively constant (see e.g. Schleicher-Jester, 1995, for recent theoretical and empirical evidence of this for urban roads).

6. Operational aspects

6.1 Time loss per manoeuvre

For a FMV the manoeuvre consists of slowing down, driving at a low speed during the meeting and accelerating to the free speed. To illustrate this point we will choose some parameter values. Suppose:

1. a FMV slows down to 30 km/h;
2. it decelerates with a constant deceleration of 2 m/s^2 ;
3. it drives with 30 km/h over 30 m (means during 3.6 s);
4. it accelerates with a constant acceleration of 1 m/s^2 to its free speed.

The extra travel time then only depends on the free speed and turns out to be surprisingly small; see Figure 4.

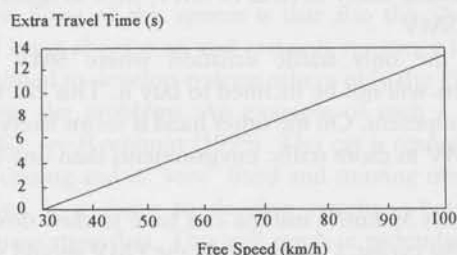


Figure 4. Extra travel time a vehicle experiences when decelerating to 30 km/h and keeping this speed during 3.6 s. Decelerating with 2 m/s^2 , accelerating with 1 m/s^2 .

The objective travel time loss may be low but subjectively it might seem large and the irritation of the drivers might be great, especially in the beginning. This frustration should be compared to the gain in safety; we do the same when installing traffic control at

intersections for reasons of safety.

In a real situation the extra travel time over a road section will depend on the intensity of SMV and it can be calculated with a relatively simple model. If this loss becomes too large, the measure to be taken is separation by means of e.g. a separate path for pedestrians and bicycles.

6.2 Example of operation

We will consider a road section with only cyclists as SMV. Parameter values have been chosen to get round numbers as results. In reality time loss will be smaller because several slow downs will partly overlap. Suppose:

1. Road section of 6 km;
2. In each direction there are 20 cyclists per hour with a speed of 20 km/h;
3. FMV maintain a speed of 60 km/h;
4. The time loss per manoeuvre equals 5 s.

Simple calculations show that a FMV will be confronted with 8 oncoming cyclists and will overtake 4 cyclists. So a FMV has to slow down 12 times and will loose at most 60 s. This leads to a reduction of the average speed of 60 km/h to 51.4 km/h.

The real time loss will be lower because of the overlap of slow downs and because there might be other FMV that lead already to a lower speed than 60 km/h.

7. Discussion

The future of our traffic system is difficult to predict and the real break through of RTI is questionable. However, nearly every drastic change in the traffic system has lead to opposition in the beginning. Even the introduction of direction indicators on cars has met with opposition long ago. Every new feature that limits the freedom of the driver will meet with fierce opposition. Cases will be found in which the new system is less safe than the original one. However, eventually the overall loss or benefit should be decisive.

The proposed type of system has to be studied and developed much more deeply. There will certainly rise technical problems, e.g. the system should also function on narrow hilly roads where communication between users might meet problems. One also has to consider the situation when not all users are already equipped with the RTI devices.

The main obstacle for the proposed type of system might be the opposition of the drivers of SMV, because until now they did not have much obligations regarding the equipment of there "vehicles". But their gain can be very valuable in terms of objective safety and in terms of feeling safe. The system might make the use of the low volume rural roads much more attractive for daily use and for recreational trips.

To accustom FMV drivers to externally controlled speed the introduction of this system for residential areas is a good start; see Ekman (1995). Such a measure will certainly lead to an even better climate in these areas, in terms of safety, noise and air quality. And it will allow a much cheaper road lay out inside those areas. A caution maybe relevant here with respect to the introduction of RTI systems in the car system. Application mostly is

motivated by the higher efficiency that can be achieved in car traffic and road use. This may be true for the short term. On the longer term however this easily may turn into its opposite. A more efficient car traffic will stimulate car mobility, will increase car travel distances, and will make long distance travel more attractive. These extra kilometers may outweigh the efficiency gains.

8. Recommendation

The development of RTI systems in road traffic has unjustly been concentrated on applications for the motorized modes. In order to improve the attractiveness of the slow modes the opportunities that RTI systems can offer need to be studied. A fruitful area is safety improvement on rural roads.

References

- Brilon, W. & Blanke, H. Extensive traffic calming: results of the accident analysis in 6 model towns. Proc. 63rd annual ITE meeting, 1993.
- CROW. Sign up for the bike. Design manual for a cycle-friendly infrastructure. Centre for Research and Contract Standardization in Civil and Traffic Engineering, CROW Record 10, Ede (NL), 1993.
- Commission of the European Communities (ed). Proc. of the DRIVE conference Brussels 1991. Elsevier 1991.
- Ekman, L. ATT systems for safety enhancement. In: Smart Vehicles. Ed. Pauwelussen & Pajek. Swets & Zeitlinger, Lisse (NL), 1995.
- Rombaut, M. A driving assistance system: the French demonstrator Prolab2. In: Smart Vehicles. Ed. Pauwelussen & Pajek. Swets & Zeitlinger, Lisse (NL), 1995.
- Schleicher-Jester, F. Leistungsfähigkeit innerörtlicher Hauptverkehrsstrassen im motorisierten Individualverkehr bei verschiedenen Geschwindigkeiten. Universität Kaiserslautern, Fachgebiet Verkehrswesen, Grüne reihe no.32, 1995.
- SWOV. Towards a sustainable safe traffic system in the Netherlands. National Road Safety Investigation 1990-2010. SWOV Institute for Road Safety research, Leidschendam (NL), 1990.

Variable Speed Influencing: The Solution?

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For a number of years already one has been philosophising about the possibilities of intelligent speed limitation devices built into passenger cars. Research surrounding this subject is being carried out on a small scale, but up until the present day there is no specific policy which is aimed at tracking down the possibilities of speed limitation and determining the process which should lead to intelligent speed limitation. In this article, a plea is being held to seriously start to consider introducing intelligent speed limitation in vehicles.

1. What is intelligent speed limitation?

The essence of speed limitation is that the speed of a vehicle is limited through alterations in the propulsion system. A car thus is simply unable to move any faster than the speed which is desirable or allowed at that specific geographic point. The simplest form is the fixed speed limitation device. This device, when fixed, ensures that a vehicle is permanently unable to drive at a higher speed than the speed which has been set beforehand. Fixed speed limitation devices are already being used in lorries.

The matter becomes much more interesting when the speed limit can be altered according to the circumstances. This means that the vehicle cannot drive faster than 30 km/h in a 30 km/h zone, and not faster than 80 km/h on a 80 km/h road. Also, there could be a limit of 15 km/h on a route and point in time when many school children are travelling, or a limit of 90 km/h in times of dense fog on motorways. This is referred to as intelligent speed limitation or Intelligent Speed Adaptation (to which we from this point onwards will refer as ISA). In this situation there should be a form of communication between the vehicle (of which the speed should be regulated) and the roadside (where signals should be emitted which provide information about the local speed limit).

ISA does not necessarily require that the speed limit cannot be exceeded at any time. Less imperative measures can be thought of, such as the method of informing the driver about the maximum speed being exceeded by means of a sound (this is, in fact, Intelligent Speed Information or ISI). An "intelligent accelerator" can be applied too. When the speed limit is reached, the driver will experience a more powerful pressure from the pedal on his foot than usual. The driver may choose to push the pedal harder, therewith continuing to drive too fast, but this will have the effect of making him tired.

2. Start Programme Durable Safety

With the signing of the intention statement about the Start Programme Durable Safety by the State, the provinces, municipalities and polders, a new phase has started in the striving towards a greater safety in traffic. A key element in the start programme is speed limitation. One seeks to achieve this speed limitation through juridical measures (such as a general speed limit of 30 km/h within the built up areas), infrastructural measures (such as roundabouts), regulation, education and communication. It is, however, striking that the Start Programme does not mention any form of action concerning vehicles as such. It is evident, however, that the limitation of the speed of vehicles offers considerable opportunities. It is not yet a suitable time to announce actions concerning the introduction of intelligent speed limitation. Yet it would have been appropriate if a point of action had been included stating the introduction of a research programme, aimed at the possibilities of speed limitation. It might be the case that we may get closer to an inherent safe traffic system if only vehicles that are simply unable to exceed speed limits are allowed on the roads.

3. The advantages and disadvantages of intelligent speed limitation

The introduction of ISA should, naturally, be considered only if the system offers clear advantages. In connection with a research programme into the feasibility of a test project with ISA by TNO Wegtransportmiddelen (Road Transport Means) and Verkeersadviesbureau (Traffic Advice Bureau) Diepens and Okkema, the possible positive and negative effects of ISA have been evaluated as well as what the amount of certainty is now that such an effect will actually take place. The major advantages of ISA might be:

1. An improvement of traffic safety
2. Less negative effects on the environment
3. A reduction of the threat of traffic and an improved mobility of people with bodily or mental limitations
4. A reduction of the problem of traffic queues
5. More municipal construction possibilities

Ad. 1: Traffic Safety

A proven connection between speed and traffic safety exists. It has been discovered that the total amount of accidents will be reduced and the severity of the accident will relatively be reduced even more. This will also apply to lower speeds as a result of ISA. The homogeneity of the stream of traffic is important too. A smaller variation in the average speeds has an effect on traffic safety. Objectively spoken, most casualties occur on 80 km/h roads outside the built up area and on major going-through roads (50 km/h) within the built up area. These, consequently, are the areas where ISA could be most effective.

Ad. 2: Environment

ISA may ensure improvements on the level of the environment. At lower speeds, the usage of energy decreases (concerning the usage of petrol, 70 to 80 km/h is the optimal speed).

ISA also decreases the differences in speed between the various vehicles so that the usage of petrol, and therewith the levels of emission, will be decreased. In addition, a lower usage of petrol has as a consequence that the costs of travelling and transport will be lower. A final point is that lower speeds reduce noise hindrance and more homogeneous speeds mean that there will be less brake dust.

Ad. 3: Threat of traffic and mobility

Lower speeds of vehicles and the knowledge that vehicles are unable to drive faster than locally allowed ensure that it becomes easier to cross roads. In addition, slow traffic does not have to feel so threatened anymore by car traffic which makes travelling by bicycle and on foot more attractive. Furthermore, the improvement concerning the crossing of roads and the reduced threat of traffic ensure also have as an advantage that more people with bodily or mental limitations can, or dare, use the traffic system. Perhaps it also means that more parents will allow their children to play outside again.

Ad. 4: Traffic Queues

ISA can also contribute to a smoother movement of car traffic and therewith to a reduction of the problem of queues. The speed checks which are being realised currently on many motorways have their basis in the idea that a lower and more constant speed ensures a larger capacity of the road. ISA can be applied to create a similar effect, although it is much better able to ensure that the speeds will indeed be lower and more constant.

Ad. 5: Possibilities of municipal construction

One of the advantages of ISA is, that a starting point is the certainty that speed limits cannot be exceeded. This means that speed limiting infrastructural measures are not necessary. However, the requirement in the Durable Safety plan that the appearance of the road meets the desired speed limit remains relevant. Yet within this requirement the possibilities for more diverse municipal building schemes will have been enlarged. On the one side, the lower speeds may lead to narrower roads, leading to more possibilities for other applications. On the other side, ISA offers the possibility to less accentuate the lanes and construct more avenue- or square-like arrangements without this leading to higher speeds.

Apart from the aforementioned positive effects, negative effects may occur. For instance, one fears that the drivers may stop checking their speeds but instead push the pedal to the floor automatically. Also, drivers may behave themselves in an undesirable manner if speed cannot be used anymore to free them from aggression and stress. It is essential to gain insight in the question as to in what ways and in what strength positive and negative effects will occur. On the basis of this knowledge, regulation concerning the introduction ISA can be developed.

4. Choosing a strategy

The question is whether the application of ISA may be a worthy substitute for other methods, or nothing more than a complement. If we start from the goal that should be reached, being speed controlling, then the essential point is to influence the behaviour of the drivers in such a manner that they will live up to the imposed speed limits. In essence there are four different possible strategies to influence behaviour in traffic:

1. The arrangement of roads: forming an infrastructure in such a way that the desired effect will be achieved (self-explaining roads)
2. Maintenance: permanent speed checks on all locations where speeding offences may or do occur
3. Education and information
4. Vehicle telematics (the intelligent car, including ISA)

At this moment, the option of road arrangements is the favourite one. This approach has a couple of disadvantages. It is, for instance, virtually impossible to enforce a desired speed anywhere and for everyone. Furthermore, the costs of speed decreasing measures are often high. There are also experiments with maintenance. Among other locations, the motorway A2 is subject to permanent speed checks. It is, however, not unlikely that permanent speed checks may be introduced everywhere, especially within the built up area. The current capacity of police and judicature, though, is insufficient and there are numerous principle objections (Big Brother is watching you). Education and information certainly are of use when influencing behaviour but they themselves will not lead to a complete subjection to the speed limits.

Vehicle telematics, such as ISA, is the only option which has the advantage that speeding is not possible anymore. This makes speed reducing measures irrelevant (although an appearance of the road that matches the desired speed remains relevant) and the maintenance can be limited to ensuring that ISA works properly. A survey done for the Project Bureau IVVS (Peeters and others, 1996) shows that the costs of the "intelligent car" strategy may be up to half the total amount lower than the (approximately equally expensive) maintenance or road arrangement strategies.

5. Support for ISA

One of the arguments which are often used against the application of speed limitation devices is that there would be insufficient support for it. It seems, however, that one's attitude towards speed limitation is not as negative as is often assumed. This is shown by, among others, a survey by the Vrije Universiteit of Amsterdam. The research done by TNO Wegtransportmiddelen and Diepens and Okkema shows that there is support for the introduction of ISA in domestic areas. Should one wish to introduce ISA in the future, then the acquisition of support should be approached actively. Two points of view are relevant in this matter.

Top-down: the government should make it clear that she strongly supports her own speed limits and will not be tolerant towards offenders. It is important that the social dilemma between the "freedom of the motorist" and the "social disadvantages of speeding" is solved. The government will have to indicate that she does not wish to intrude on the motorist's freedom but that there are limits within which this freedom is offered. She could stress that the limitation of freedom is essential on any social level.

Bottom-up: the people shall have to be effectively informed as to what the disadvantages are of the present speeding behaviour and what the advantages of ISA may be. In this light, it is useful to associate ISA with positively valued elements. The individual

citizen seems to be primarily interested in the following effects:

- a smoother traffic flow and a reduction of the amount of queues
- the possibility to determine the total travelling time more accurately
- less, and especially less severe, accidents
- no higher costs, and preferably gains

6. The process towards general introduction of ISA

The abovesaid offers enough reason for serious research into the option of applying intelligent speed limiting devices for speed control. Should (part of) the aforementioned advantages indeed occur in reality, whereas the disadvantages remain limited, then there is basically only one reason not to introduce the system and that is the possibly still limited political and/or public support. To introduce the advantages of ISA in a convincing manner, it is essential that certainty concerning the effects of ISA exists. In as far the effects of ISA have been insufficiently proven, further research will be needed to provide this certainty. Therefore, a strategic process concerning ISA is necessary, aiming at two points:

1. Increasing the knowledge about the effects of ISA
2. Increasing the support for ISA

The increase of knowledge can be achieved by executing trial projects and experimenting with ISA in various situations. In order to increase the support for ISA, it is necessary that the trial projects are arranged in such a manner that they lead to a positive (yet, naturally, fair) formation of opinions.

References

- Veenbaas, R. and E.G. Oostenbrink (ed.): *Intelligente Snelheids Adaptatie* (3 sub-reports and 1 final report). TNO Wegtransportmiddelen and Verkeersbureau Diepens and Okkema, Delft, 1996-1997.
- Peeters, P.M. and Y. van Asseldonk (ed.): *Mag het ietsje minder snel?*, main report. A survey into the social and economical costs and gains of a decrease in the speed of passenger cars. Werkgroep '2duizend, TU Delft and VU Amsterdam. By order of Project Bureau IVVS. January 1996.
- Rienstra, S.A. and P. Rietveld (ed.): *Mag het ietsje minder snel?* The public support for alterations in the regulations concerning the speed of motorised traffic. VU Amsterdam. By order of Project Bureau IVVS. October 1995.

A Simulator Study on Adaptive Cruise Control Systems and the Implications for Traffic Safety

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Abstract. This paper describes a study that is aimed at assessment of driver behaviour as a response to driving style and new technology, in particular Adaptive Cruise Control systems (ACC's). ACC's are likely to be one of the first applications of Automatic Vehicle Guidance (AVG) systems that could become available in the near future. ACC's have been engineered to improve traffic safety and efficiency, because of the constant and safe headway they keep behind a lead car. The extent to which ACC systems will realise these goals depends among other things on how they affect driving behaviour. In the present study, carried out in co-operation with the Centre for Environmental and Traffic Psychology (COV), possible benefits and drawbacks of an ACC system were assessed with participants driving in a driving simulator. The four groups of participants differed on their reported driving styles Speed (driving fast) and Focus (the ability to ignore distractions). The results show that behavioural adaptation takes place in terms of higher speeds, smaller minimal time headways, larger brake usage with an ACC. It is concluded that there are serious doubts placed on the expectation that ACC systems will lead to enhanced traffic safety, and that drivers with an "unsafe driving style" are not encouraged by the system to drive in a safer way.

1. Introduction

Adaptive Cruise Controls (ACC's) are currently in development in the automotive industry and are actually on sale in the higher market segment of passenger cars. An ACC is a system that is capable of maintaining a certain headway behind slower vehicles ahead, in addition to the conventional Cruise Control function of controlling a vehicle's speed at a driver-chosen value. This headway keeping is done by means of adjusting the speed of the car in order to prevent exceeding the programmed headway of the system. ACC's are thus assisting systems, capable of regulating both speed and following distance.

The possible advantages of ACC's are that they increase driving comfort and reduce workload. There may also be a positive effect on traffic safety, because an ACC maintains a safe headway to the vehicle in front. The system might enable driving at shorter headways and at higher speeds, which would increase roadway capacity. By means of a smoother acceleration and deceleration profile, the system could also contribute to a more stable traffic flow.

To what extent ACC's will realise these goals depends on the technical possibilities like deceleration level and headway magnitude. Another important factor in the success of these systems is the way in which drivers will use the system, their acceptance and their reaction in terms of driver behaviour. This behavioural adaptation has been identified by the OECD (1990) to be a significant issue, because "drivers employ the vehicle technology available to them in order to suit their driving purpose, motivation, driving style and current physic process."

1.1 Behavioural adaptation

A number of studies investigated the drivers' reaction to ACC's in terms of their behavioural adaptation and acceptance of the system. For instance, Nilsson (1995) found in an advanced driving simulator study that participants driving with an ACC spent more time in the left lane than participants driving without ACC. Approaching a stationary queue was found to lead to more collisions among ACC users than among unsupported drivers, possibly because of too large expectations leading to too late and abrupt interventions. Heino et al. (1995) found in a driving simulator study that driving with an ACC decreased time-headway and the variability in headway. Driving with the system also decreased (subjective) workload. Ward et al. (1995) conducted a field trial of a prototype ACC and also found behavioural adaptation reactions. Drivers set the ACC at higher speeds and at shorter headways compared to unassisted driving. Drivers were also observed to have poor lane position with ACC compared to driving without.

1.2 Acceptance

With respect to driver's acceptance of ACC systems, Becker et al. (1994) described a study in which the participants drove in real traffic with an ACC. Their results show that ACC is perceived as a comfort oriented and safety enhancing system and thus implies a high amount of user acceptance. The distance keeping behaviour of the system was experienced very positively and generally classified as acceptable, comfortable, safe and relaxing. Hogema et al. (1994) tested different forms of ACC systems in a driving simulator and found that most ACC's were considered relatively useful and comfortable. One type of ACC, the one that intervened with an acoustic feedback signal, was judged to be useless and uncomfortable. Fancher (1995) reported that participants stated after they drove a predetermined route on local highways with an ACC, that they felt safer using ACC because it maintained a safer following distance (headway) and required fewer interventions by the driver than conventional cruise control. Regarding the issue of automatic braking, participants were almost unanimous in their objection to automatic braking, because it crossed the line that dictates who controls the vehicle.

1.3 Needs and driving styles

With or without driving with an ACC, drivers have different needs and driving styles that might be important in their (behavioural) reaction to ACC. The results of a questionnaire

study about the needs and driving styles of Dutch car drivers show that drivers differ in their needs or motivations regarding driving and their reported driving styles (Hoedemaeker, 1996). In the line of reasoning of the OECD (see above), these needs and driving styles are important to take into account when investigating the effects of ACC in terms of behavioural adaptation and acceptance of the system because different needs and driving styles might lead to different reactions. Whenever ACC systems frustrate these needs or preferred driving styles, acceptance of the systems may be low and unwanted or dangerous drivers' reactions may occur.

Especially driving styles regarding speed and the degree to which drivers are easily distracted in the car by irrelevant events (focus) might be important, because of the reduced control drivers will have on speed, and the enhanced susceptibility to distractions when using the system, which will create safety hazards.

1.4 Present study

The main objective of the present study is to sort out (safety) effects of ACC systems in terms of behavioural reactions and acceptance. Needs and driving styles are taken into account by dividing the drivers into groups with different driving styles and corresponding needs, as was reported in Hoedemaeker (1996).

The ACC systems that were tested were either overrutable or not and differed in their pre-set default time headways. Two of these time headways can be found in prototypes of ACC's that are described in the literature (Morello et al., 1994; Müller & Nöcker, 1992), namely 1.5 s. and 1.0 s. The third time headway is one that is personally preferred by the participants as measured in a separate car following session.

The drivers were divided into groups based on two driving style dimensions of the Driving Style Questionnaire (DSQ, West et al, 1992). These dimensions are called Speed and Focus. The speed dimension measures whether drivers are inclined to drive fast and exceed the speed limit, and the focus dimension measures how capable drivers are of ignoring distractions. Both of these dimensions seem to be important in ACC research because speed is one of the aspects of driving that is supported by an ACC system. Moreover, driving with such a system takes away part of the control over the driving task and might have negative effects on attention and alertness.

2. Method

2.1 Participants

Thirty-eight participants (25 male, 13 female, between 25 and 60 years of age) were paid for their participation in the experiment. Non of the participants had previous experience with the simulator; they were selected from a sample of the members of the Dutch Automobile Association (ANWB) on the basis of driving experience and their answers on the (translated version of the) Driving Style Questionnaire (DSQ). The DSQ was developed and validated by West et al. (1992) and contains six dimensions of which Speed (made up

of items about driving fast and exceeding the speed limit) and Focus (driving cautiously and ignoring distractions) were the discriminating factors for the participants in the present study. Only persons who held a driving licence for at least 3 years, who were driving regularly (more than 50 km a week), and who fitted in one of the four following driving style groups were selected:

Group 1: high score on Speed (last quartile of the scores) and high score on Focus (last quartile of the scores)

Group 2: low score on Speed (first quartile) and high score on Focus (last quartile)

Group 3: high score on Speed (last quartile) and low score on Focus (first quartile)

Group 4: low score on Speed (first quartile) and low score on Focus (first quartile)

2.2 *The driving simulator*

The driving simulator of the Traffic Research Centre is a fixed-based driving simulator consisting of two integrated subsystems. The first subsystem is a conventional simulator composed of a car (a BMW 518) with a steering wheel, clutch, gear, accelerator, brake and indicators connected to a Silicon Graphics Skywriter 340VGXT computer. A car model converts driver control actions into a displacement in two-dimensional space. On a semi-circular projection screen, an image of the outside world is projected from the perspective of the driver with a horizontal angle of 150 degrees. Images are presented at a rate of 15 to 20 frames per second, resulting in a suggestion of smooth movement of the simulator car through the virtual world. The second subsystem consists of a dynamic traffic simulation with artificially intelligent cars. These cars move independently through the world according to their own decision and behaviour rules and interact with each other and with the simulator car in which the participant is seated. The simulator is described in more detail elsewhere (Van Wolffelaar & Van Winsum, 1992).

2.3 *Adaptive Cruise Control*

In the absence of a leading vehicle the ACC provides speed control, which means keeping the actual speed of the vehicle equal to the reference speed set by the driver. If a lead vehicle is detected the ACC switches automatically to headway control, which means keeping the actual time headway at the reference time headway implemented in the ACC. In the current experiment three different reference time headways are used: 1.5 s., 1.0 s. and a personally preferred headway indicated by the driver. The participants activated the ACC once at the beginning of each condition by pressing a button and releasing their foot off the gas pedal at the moment they reached the speed they wanted to set. A green LED light in the dashboard then indicates that the ACC is on. Two versions of the ACC system are used: In the "overrutable" version the drivers are able to overrule the system whenever they want. They can do this by either pressing the gas or the brake pedal. As soon as the gas or brake pedal is released the ACC system is automatically switched on again at the previous set speed. In the "non-overrutable" version of the ACC it is not possible for the drivers to overrule the system. However, when the velocity of the car gets very low (approximately < 30 km/h) participants have to switch back gears, thereby overruling the ACC. As soon

as the fourth gear is reached again the ACC takes over control. In other words: The ACC system is only active in the fourth gear. In both versions, the ACC system was always able to bring to the vehicle to a safe stop without intervention of the driver. This was done because reaction to a failing system was not subject of this study and would evoke different driver reactions.

2.4 Procedure

The driving circuit in the simulator was made up of a two by two highway with lane widths of 3.5 m. and a third emergency lane for both directions. In the middle a safety fence was visible. Before the experiment started participants practised for about 15 minutes in the normal simulator car and another 15 minutes with the ACC.

Preferred time headway was measured in a separate session, in which there was only one lead car visible, which drivers were instructed to follow at a "small but safe distance".

All participants came to the institute twice, on two separate days. They first drove a highway route without ACC and then with three of the ACC conditions. Each condition consisted of the same highway route in which several different traffic scenario's were present, including busy as well as quiet traffic, queue driving, merging into the left lane and an emergency stop when driving in a traffic queue.

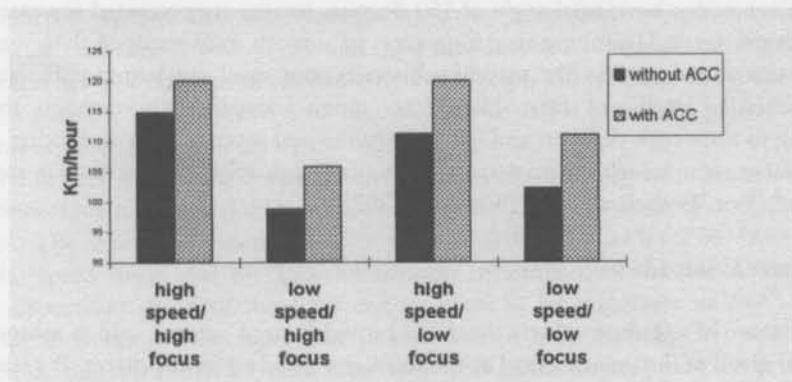


Figure 1. Mean velocity of the four driving style groups in km/hour, with and without an Adaptive Cruise Control.

3. Results

3.1 Driving behaviour with and without ACC

In quiet traffic, when participants were free to chose the speed they wanted to drive with, a main effect of ACC was found on driving speed ($F(1,1574)=30.3, p<0.0$). Mean speed without ACC was 107 km/h, with ACC it was 115 km/h (mean set speed in the ACC: 126 km/h). The four driving style groups differed significantly in their driven speeds ($F(3,1574)=30.0, p<0.0$), but there was no interaction between group and ACC. Figure 1

shows the effects on ACC and Group, indicating clearly the differences between the high and low Speed groups, driving with high and low mean velocities.

A main effect of ACC was also found on the percentage of the time that was spent in the left lane ($F(1,4)=5.6$, $p<0.02$). And when driving in the left lane the lateral position was larger with an ACC ($F(1,608)=4.7$, $p<0.03$), meaning that participants drove more close to the safety-fence compared to driving without the system. Figure 2 shows that the groups differed in the percentage they spent in the left lane ($F(3,4)=55.7$, $p<0.0$), in accordance with their high and low velocities.

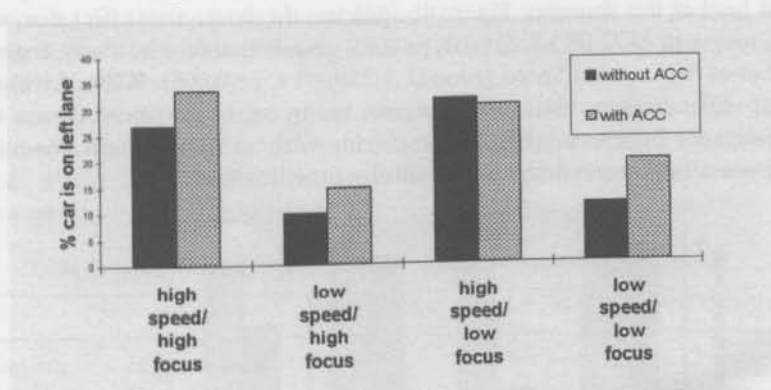


Figure 2. Percentage of the time spent in the left lane of the four driving style groups, with and without an Adaptive Cruise Control.

When driving in quiet as well as in busy traffic the standard deviation of the lateral position increased when driving with an ACC ($F(1,422)=8.4$, $p<0.05$), indicating that drivers are going to sway more compared to driving without an ACC. As Figure 3 shows there was no interaction with the driver groups.

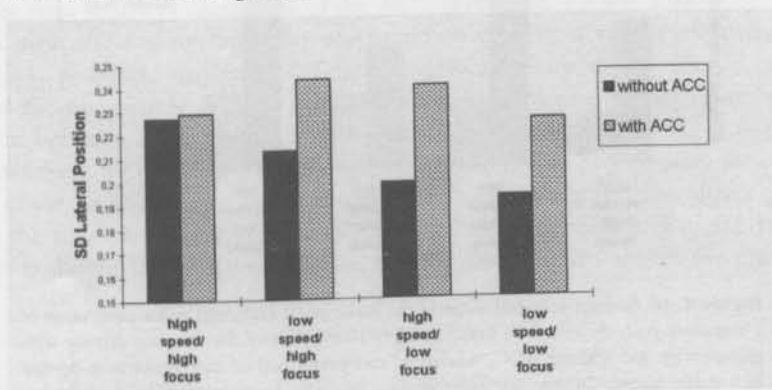


Figure 3. Standard Deviation of the lateral position on the right lane in meters in busy traffic, of the four driving style groups, with and without an Adaptive Cruise Control.

When participants had to perform an emergency stop while driving in a traffic queue, two main effects of ACC were found, indicating that the average maximal braking was larger ($F(1,255)=4.6$, $p<0.03$) and that the average minimal time headway was smaller ($F(1,255)=40.4$, $p<0.00$) when driving with an ACC compared to driving without. Figure 4a shows this effect of ACC, the main effect of Speed group ($F(1,259)=3.5$, $p<0.06$) and the interaction effect of Speed group and ACC ($F(1,255)=3.9$, $p<0.05$) on maximal braking. The effects indicate that the high speed drivers brake harder overall, but when driving with the ACC the group differences are gone; also the low speed driver groups have to brake as hard in this situation. Figure 4b indicates the interaction effect that was found between Group and ACC ($F(3,255)=3.1$, $p<0.03$) on minimal time headway, together with a main effect of ACC and of Speed group ($F(1,259)=8.1$, $p<0.005$). When driving without ACC group differences are clear, i.e. large time headways for low speed drivers and small time headways for high speed drivers, but driving with an ACC system minimises these group differences; everyone drives with a smaller time headway.

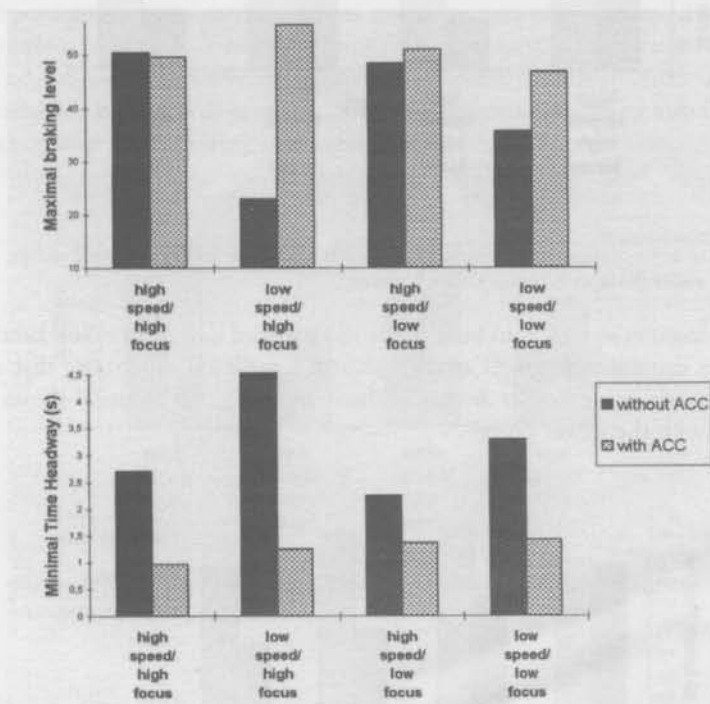


Figure 4. (a) Average maximal usage of the brake pedal expressed as the percentage of a complete push down of the brake pedal (=100%), shown for the four driving style groups with and without ACC, when lead cars performed an emergency stop driving in a traffic queue. (b) Average minimal time headway in seconds of the four driving style groups, driving with and without an Adaptive Cruise Control, when lead cars performed an emergency stop driving in a traffic queue.

In general a main effect of Focus group is found on standard deviation of the lateral position ($1,3=7.6$, $p<0.006$). When driving in quiet traffic the low focus groups show a larger

standard deviation of the lateral position than the high focus groups. Possibly due to the fact that the low focus group is driving less cautiously, being less able to ignore distractions.

A main effect of Speed group was found when participants drove in the overrutable version of the ACC. The high speed driving group overruled the system more by the using the brakes than the slow speed driving group ($F(1,2)=4.1$, $p<0.02$).

3.2 Mental load and acceptance

The answers on the Rating Scale Mental Effort (RSME, Zijlstra & van Doorn, 1985) show that the participants experienced driving with an ACC as less effortful than driving without an ACC ($F(1,1)=22.3$, $p<0.0$).

A main effect of driver group was found on the scores on the comfort ($F(3,4)=5.4$, $p<0.002$) and usefulness ($F(3,4)=4.7$, $p<0.003$) scales of the acceptance questionnaire (v.d. Laan et al., 1997). See table 1 for the mean scores on comfort and usefulness of the four driver groups.

Table 1. Perceived comfort and usefulness scores of the four driving style groups.

Group		Perceived comfort	Perceived usefulness
1. Driving fast	High focus	0.98	0.84
2. Driving slow	High focus	1.21	1.09
3. Driving fast	Low focus	0.67	0.78
4. Driving slow	Low focus	1.23	1.17

These group differences indicate that the slower driving groups perceive the Adaptive Cruise Control as more comfortable and as more useful than the fast driving groups. There was no effect of time headway condition meaning that participants had no preference for one of the time headway conditions of the ACC (preferred, 1.5 s & 1.0 s).

A main effect of overrulability was found on comfort as well as usefulness (comfort $F(1,4)=12.1$, $p<0.001$, usefulness $F(1,4)=4.8$, $p<0.03$). This means that all participants perceived the overrutable ACC as more comfortable and more useful. There was also an interaction between driver groups and overrulability on comfort ($F(3,4)=3.4$, $p<0.02$) as well as usefulness ($F(3,4)=3.8$, $p<0.01$). Indicating that all four groups score the overrutable versions of the ACC as very comfortable and very useful. Only the slow driver groups also perceive the non overrutable versions of the ACC as comfortable and useful. In Figure 5 the effect is shown for the comfort scale, but the same pattern applies for the usefulness scale.

4. Discussion and conclusions

The main objective of the present study was to sort out safety effects of ACC systems in terms of behavioural reactions and acceptance, taking into account different driving styles with respect to speed (driving fast and exceeding the speed limit) and focus (driving

cautiously and ignoring distractions). The assignment of participants to one of the driver groups was based on their own subjective reports. The present experiment, however, shows that the self reported differences in driving style are a good predictor of the actual driving styles when driving in the simulator. Drivers who score high on the factor speed of the Driving Style Questionnaire significantly drive faster than participants who score low on this factor. Also drivers who score low on the factor focus significantly sway more (they show a larger standard deviation of the lateral position) than participants who score high on this factor, which is a sign of less attention to the driving task or driving less cautiously.

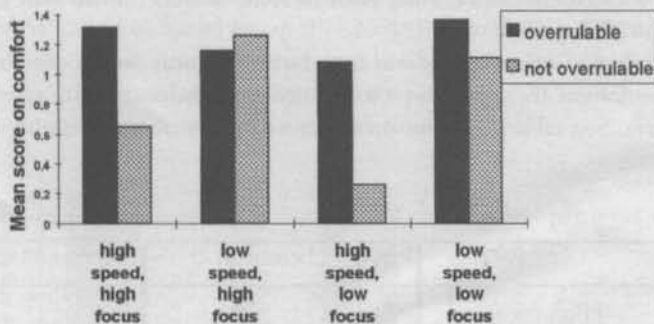


Figure 5. Interaction effect between the high and low speed driver groups and the overrutable and non-overrutable versions of the ACC on the comfort scale. The same pattern applies for the usefulness scale (not presented here).

With respect to behavioural reactions to the ACC system we can conclude that a lot of the effects that were found are the same for all the driving style groups. All drivers drove faster with an ACC compared to driving without. The differences between the groups in speed stayed, but with elevated speed levels. Also all drivers swayed more and drove more often in the left lane with an ACC, keeping the initial group differences between high and low speed drivers in tact. When drivers had to perform an emergency stop while driving in a traffic queue, they had to brake harder with the ACC, their minimal time headways decreased and the differences between the groups disappeared. Also all drivers experienced driving with an ACC as less effortful than driving without. These effects are in accordance with other behavioural adaptation studies on ACC from e.g. Nilsson (1995), Heino et al. (1995) and Ward et al. (1995), who report higher speeds, more time in the left lane, poorer lane position, decreased subjective workload, shorter headways and decreased variability in headway.

Interaction effects between driving style group and behaviour with or without an ACC were found on minimal time headway and maximal braking level. Especially the low speed drivers increased their maximum braking when they had to perform an emergency stop with an ACC. When driving without an ACC its not necessary for this group to brake that hard. Also their minimal time headway decreased much more with an ACC than the high speed drivers.

It is concluded that all drivers adapt their behaviour in a way which is not beneficial for traffic safety. But this main effect of ACC is more apparent in the low speed drivers group; their driving style gets more unsafe when driving with an ACC.

All three time headway conditions were rated as comfortable and useful when presented in an overrutable ACC, and very uncomfortable in a non overrutable ACC. Therefore it can be concluded that the perceived comfort of an Adaptive Cruise Control depends for a large part on the overrulability of the system (see also Hoedemaeker et al., 1997). This is especially true for fast drivers, because slow drivers perceive the non overrutable version not very different from the overrutable version. In other words, slow drivers don't mind if the car can take over control or not, but fast drivers do. In their acceptance of an ACC system in general, the driving style groups show differences. Drivers who like to drive fast are less positive about an ACC with respect to perceived comfort as well as perceived usefulness than drivers who like to drive slowly. The reason for this could be that fast drivers like to drive themselves and an Adaptive Cruise Control restricts them in driving the way they want, contrary to the slower driving group who don't experience driving with an Adaptive Cruise Control as restrictive, but as comfortable and useful.

In terms of traffic safety it might be more important for the high speed drivers to have some headway control support. West et al (1992) conclude from their study that there is a direct link between driving style and accident risk. People who drive fast are at higher risk to accidents caused by driving too fast. Or they may pull out into smaller gaps than other drivers or attend less to the driving task. But unfortunately these fast drivers are also the drivers who like the ACC the least. Therefore, if we would like to see An Adaptive Cruise Control as a safety system, there is a problem with the acceptance of the system by the users who could benefit the most in terms of traffic safety: drivers with a high speed driving style and a smaller preferred headway. These drivers have a lower acceptance of the system than drivers who already have a safer driving style: the low speed driving style group.

References

- Becker S, Bork M, Dorisen HT, Geduld G, Hofmann O, Naab k, Nöcker G (1994). Summary of experiences with autonomous Intelligent Cruise Control (AICC). Part 2: results and conclusions. Proceedings 1st world congress on Intelligent Vehicle Systems, Paris. Erico, Brussels. pp 1836-1843.
- Fancher, P.S., Bareket, Z., Johnson, G. & Sayer, J. (1995). Evaluation of human factors and safety performance, in the longitudinal control of headway, Proceedings 2nd world congress Intelligent Transport Systems Yokohama. VERTIS, Tokyo. pp 1732-1738.
- Heino, A., Rothengatter, J.A. & Hulst, M. v.d. (1995). Collision Avoidance Systems Safety Evaluation, DRIVE II Project V2002, Deliverable 33, Workpackage 0016. TRC, University of Groningen, The Netherlands
- Hoedemaeker, M. (1996). Drivers' Needs and Behaviour. In: Handbook of the International Conference on Traffic and Transport Psychology, 22-25 May 1996, Spain. DL: V-1787-1996. pp 147-153.
- Hoedemaeker, M., Wiethoff, M. & van Wolfelaar, P.C. (1997). Effects of differences in driving styles on acceptance of an Intelligent Cruise Control. In: From Experience to Innovation. Proceedings of the 13th Congress of the International Ergonomics Association, Tampere Finland. Vol. 6, pp 334 - 336. ISBN: 951-802-193-7.
- Hogema, J.H., van der Horst, A.R.A. & Janssen, W.H. (1994). A simulator evaluation of different forms of ICC, Report TNO-TM 1994 C-30.
- Laan, J.D. v.d., Heino, A. & Waard, D. de (1997). A simple procedure for the assessment of acceptance of advanced, transport telematics, Transportation Research -C, vol.5, no.1. Elsevier Science Ltd pp 1-10.

- Morello, E., Benz, Th. & Ludmann (1994). AICC Assessment. Proceedings 1st World Congress on Applications of Transport Telematics and Intelligent Vehicle Highway systems, Paris. pp 1900-1907.
- Müller, R. & Nöcker, G. (1992). Intelligent Cruise Control with fuzzy logic. Proceedings of the Intelligent Vehicles '92 symposium. pp 173-178.
- Nilsson, L. (1995). Safety effects of Adaptive Cruise Controls, in critical traffic situations. Proceedings 2nd world congress Intelligent Transport Systems Yokohama, VERTIS, Tokyo. pp 1254-1259.
- OECD (1990). Behavioural adaptations to changes in the road transport system. Publication service, OECD, Paris, France.
- Ward, N.J., Fairclough, S. & Humphreys, M. (1995). The effect of task automatization in the automotive context: a field study of an AICC system. Intern. Conf. on Exp. Analysis and Measurement of Situation Awareness. Florida.
- West, R., Elander, J. & French, D. (1992). Decision making, personality and driving style as correlates of individual accident risk. Contractor report 309. Transport Research Laboratory.
- Wolffelaar, van P.C. & Winsum, van W. (1992). A new driving simulator including an interactive intelligent traffic environment. Proc. 3rd intern. conference vehicle navigation & information systems. IEEE Service Center, Piscataway, NJ. pp 499-506.
- Zijlstra, F.R.H. & Van Doorn, L. (1985). The construction of a subjective effort scale. Report: Delft University of Technology, The Netherlands.

Safety Impacts of Transport Telematics in Road Traffic

An exploration of certainties and uncertainties

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Abstract. Large efforts are made to improve the intelligence of transport systems by developing and implementing a variety of telematics systems. The driving forces behind this development are the need for a more efficient use of transport infrastructure, reduction of congestion and the improvement of traffic safety and comfort of travelling. There is a widespread belief that telematics systems will have a positive impact of reaching these goals. This belief is, however, only partly supported by empirical evidence. The authors were involved in a study for the Dutch National Traffic Safety Board, aimed at analysing the state-of-the-art in knowledge about the safety aspects of new telematics systems in transport. This article discusses the mainlines of the study. It is concluded that the knowledge infrastructure on safety aspects lacks various pieces. Moreover the uncertainty about positive safety impacts is still considerable.

1. Introduction

The importance of transport telematics systems for the organisation and management of dynamic transport processes increases rapidly (Banister, 1994; Hall, 1995). On the one hand this can be explained by the increasing technical possibilities to improve the intelligence of cars and infrastructure for the support of driver behaviour and a better guidance of traffic flows. On the other hand it is generally expected that telematics will contribute significantly to public policies aimed at organising passenger and freight transport more efficiently, safer and more environmental friendly (Harvey, 1995; Shladover, 1995; Levine and Underwood, 1996). Consequently, macro economic developments will, according to this view, also gain benefits from the application of transport telematics.

The development and application of many of the transport telematics systems is to a large degree technology-driven. Unfortunately, this approach of innovation is characterised by a limited view on the complexity of transport processes. It causes a rather technocratic project view on innovations, instead of a more holistic transport systems view. This often results in optimism with respect to the positive impacts of the technology on the transport processes, and optimism with respect to the acceptance of changes by potential users. In practice however, the implementation of technological innovative transport systems on a large scale is often seriously complicated by impact uncertainties, unexpected policy

developments and social and institutional obstacles (Underwood, 1990; Van der Heijden and Marchau, 1995). Real innovations require a balanced processing of decision making since institutional, organisational, spatial and social-cultural aspects simultaneously influence the direction and speed of change.

Since the early nineties, growing awareness on this issue appears to be a driving force for transport policy makers to seek for a more active role in the field of transport telematics. At present, public authorities play a major role in the field of dynamic traffic management, simply because of the fact that as infrastructure owners they are the major stakeholder in this field. However, increasingly also policy concepts and instruments are developed and applied to influence telematics applications in relation to other aspects of the transport system, such as the development of transport needs, logistical organisation, driver behaviour and vehicle technology.

A major handicap for such an active policy approach is that a great deal of uncertainty exists about the impacts of transport telematics, irrespective the enormous amount of material being produced on this subject (Zimmer et al, 1994). As mentioned above, significant positive impacts on a variety of indicators is expected: the volume of transport need, the efficiency in transport chains, the use of scarce infrastructure capacity, the congestion probability, the traffic safety and the driver's comfort. Many of these expectations are based on theoretical considerations and optimisation on technical subsystems. To a substantial degree however, the empirical evidence for these expectations is still to be found: do the various technical systems actually deliver what they promise?

Given the need for more precise answers on impacts, the first step is to better organise the knowledge infrastructure with respect to the impacts of transport telematics. In this article, we will contribute to this step by describing the state-of-the-art knowledge with respect to the relationship between transport telematics systems and traffic safety on the road. The article is based on a study in 1996 commissioned by the Dutch National Traffic Safety Board (Marchau et al, 1996), focusing on two questions:

- which applications of transport telematics most probably have a positive or negative impact on traffic safety on the road?
- which transport telematics systems yield a large uncertainty with respect to their safety impacts?

These questions were answered by exploring the state-of-the-art knowledge on this subject in literature and by consulting experts in this field.

This article is structured as follows. In section 2, a traffic safety concept is developed based on a transport systems view. Section 3 describes the potentially related transport telematics systems. Section 4 presents an overview of the available knowledge about the traffic safety impacts of these telematics systems. The article ends up in section 5 with some points of discussion, particularly with respect to the role of public authorities in this field.

2. Traffic safety concept

Answering the question whether telematics systems actually do (or in the future will) have a significant contribution to the improvement of safety on the road, starts with the question

which concept of safety is adopted. Generally, the focus in traffic safety analysis is on accident probability multiplied with effect size, as the basic indicator for the safety level. This view on safety is increasingly considered as rather limited. Criticism stresses the lack of attention for the underlying causes of accidents, often related to interference's between a variety of factors. They influence either the probability of accidents or the size of the effects. Pleas are held for a more multi-causal and multi-level systems view (Stoop and Thissen, 1997). Traffic safety is the outcome of an interaction between variables at various levels of the transport system. To operationalise this idea for our study, the transport systems view expressed in Figure 1 is a worthy vehicle. In this view the transport system operates in terms of three markets: the transport need market, the transport service market and the traffic market.

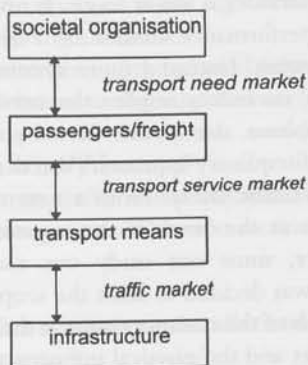


Figure 1. A transport system representation.

The transport need market represents the dynamic friction between the potential need for transport and the transport, financial and temporal possibilities to fulfil this need. The potential need for transport results from the fact that individuals are part of a specific spatial, social-cultural, economic, temporal and institutional organisation of society. Different ways of organisation generate different needs for transport: for instance a fast growing economy generates a relatively high transport growth rate. Reversely, differences between regions in terms of transport possibilities influence the societal organisation in these regions and can cause different economic growth rates between these regions. The market friction is influential by policy measures related to the social-economic profile of an area (e.g. European distribution versus high-tech telecommunication activities), price for transport (e.g. fuel taxes), household time budgets (e.g. opening hours of shops; flexible working hours) and substitution possibilities (e.g. tele-learning, tele-working, tele-shopping).

The transport service market represents the friction between the actual transport demand over space and time and the limited transport means available within the system. As such the market is the playing field for logistical service providers. Transport companies (or individuals) specify logistical services in terms of the pursued use of certain transport modes, with a certain capacity and price, at specific times and routes, in order to transport passengers or freight. This market friction between transport means and actual transport needs can be influenced by a variety of policy measures. For instance, many policy measures

aim at establishing a substantial modal shift from car and truck use to the use of more environmental friendly transport modes.

Finally, the use of specific transport services results in traffic. The traffic market represents the friction between the physical transport infrastructure and the required use of various transport means. The result is a certain amount of traffic in specific parts of specific transport networks at a specific time period. The tension at the traffic market is created by the limited availability of transport infrastructure capacity to facilitate all the required use of it. Evidently, this tension can be influenced by investments in infrastructure capacity or toll payment.

Characteristics for this systems view is that lower levels facilitate (offer services to) the processes at a higher level of the system. Reversely, processes at a higher level specify functional requirements to the processes and services at lower levels. It implies that options for improvement of the transport systems performance cannot be evaluated by merely looking at the impacts at one level of the system. Instead a more systems (multi-level or holistic) view is urgently needed. Since this inevitably implies the need for taking into account a variety of aspects and various disciplines, the systems view by consequence also implies a more multi-dimensional and multi-disciplinary approach (Van der Heijden, 1997). This also applies for policies with respect to traffic safety. From a systems point of view, dealing with safety starts as a strategic issue at the level of the organisation of society (economic, spatial, technological). However, since our study was more focusing on telematics systems for lower systems level, it was decided to limit the scope to the result of interconnected decisions at the following levels of the transport system: the transport service market, the transport means, the traffic market and the physical infrastructure.

- At the level of the transport service market, traffic safety is related to decisions in the context of *route, time and modality planning (logistics)*. In particular the organisation of the flow of hazardous materials through transport networks has to be memorised. But also important is the increasing implementation of time based production and distribution strategies (just-in-time), causing higher service requirements put upon the transport services. Practice shows that this causes more use of road transport and more stress on the driver's behaviour. Sufficient empirical evidence is available indicating that different modalities considerably differ in terms of safety records. Transport by road is the most popular way of transport of freight and passengers but also relatively the most unsafe modality. Further of importance is the choice of routes and the moment of transport: what type of roads is used (highways are safer than secondary road networks), how large is the probability of interference's with other traffic with other characteristics, are urban areas crossed (external safety problem)?
- At the level of transport means, traffic safety is related to various decisions in the context of *vehicle control and driving behaviour*. Here, choices of e.g. correct speed, lateral road position, following distance, moment of braking, obstacle passing, etc. are essential for the safety performance together with the specific vehicle characteristics. These choices are based on the drivers' subjective risk evaluation of performing preferred driving tasks within the observed traffic conditions. Next, the reliability of the technology itself (what is the probability of failure, the sensibility

for interference's between different technologies) and the complexity of the man-machine interface are here of major importance. What is the influence of the variety of in-car control en information systems on driver behaviour? Do drivers adapt their behaviour? Are drivers overloaded and becoming fatigue in situations with much information?

- The third level deals with the *characteristics of traffic flows*. Safety from this perspective is related to issues such as differences and variation in speed, steadiness in lane use, traffic density and time headway in relation to the local road capacity. Here we enter the field of dynamic traffic management. In this context we especially emphasise the issue of mixed use of roads by trucks and luxury cars, with often very different brake characteristics. In congestion sensitive areas, small incidents due to this mix, easily evolve into disasters, as has e.g. been illustrated in the last years too frequently with several large fog accidents.

Finally, the characteristics of the *physical infrastructure design* are important. How transparent is the design in relation to the intended use? Does the design invite for a too high speed? To which degree is the interaction avoided with other transport modes and traffic participants from other directions?

This view on traffic safety variables is the bases for evaluating the impacts of new transport telematics systems. The next section categorises the variety of these systems.

3. The telematics systems under discussion

The first step in our study was to categorise the relevant transport telematics systems. Referring to the elaborated traffic safety view, the three categories of telematics systems are considered relevant. They have been summarised in Table 1.

Given the potential safety impacts of logistic decisions, the societal challenge with respect to the level of logistical planning, is to reach a substantial shift towards the use of environment-friendly travel modes as well as an optimal spatial and temporal use of infrastructure networks by influencing pre-trip decision making by drivers, passengers, logistic service providers, etcetera. A substantial reduction of the use of cars and trucks implies an increase of use of safer transport modes. Various telematics systems have been developed and implemented in the past decade to contribute to these aims. Therefore, they are generally known in terms of their functionality and applicability. Pre-trip planning support systems provide the planner with information on available transport modes, optional routes, time schedules, costs, etcetera. Nowadays, a variety of information systems is available. Moreover, the individual access to these systems (using telephone or homecomputer) is improving rapidly, sometimes allowing for automatic booking. During the stage of actual transport, telecommunication-based information systems enable the logistical planner for real-time controlling and influencing the continuation of the trip. An example is the use of tracking and tracing systems for the control of freight transport.

The basic aim of telematics systems supporting driving behaviour is to improve vehicle control and optimise the interactions between the driver and the vehicle. Evidently, the public interest in this development is to reduce the probability of incidents on the roads.

Table 1. Indicative relationship between different aspects of transport, policy goals and the variety of telematics applications (not limitative).

stage	policy goals	telematics category	possible application
logistical planning	<ul style="list-style-type: none"> • modal shift and route choice in favour of safe and environment-friendly transport • improve transport efficiency 	<ul style="list-style-type: none"> • pre-trip planning support systems • systems for logistical optimisation 	<ul style="list-style-type: none"> • park and ride information • multi-modal trip reservation • public transport on call • travel matching systems • traffic inf. on radio • route planning systems • telecommunication for marketing, fleet management and control (tracking, tracing)
driver behaviour	<ul style="list-style-type: none"> • improve driver's behaviour • improve vehicle control 	<ul style="list-style-type: none"> • in car information systems • in car control systems 	<ul style="list-style-type: none"> • speed adaptation • crash recorders • reverse parking aid • tutoring systems • navigation systems • adaptive cruise control • lateral/longitudinal control • co-operative driving systems
dynamic traffic management	<ul style="list-style-type: none"> • maximise use of available infrastructure capacity • establish a smooth and safe traffic flow 	<ul style="list-style-type: none"> • real-time travel information systems • infrastructure capacity management systems • traffic flow control systems • incident management systems 	<ul style="list-style-type: none"> • dynamic route information screens • traffic information on radio • differentiated electronic payment • dynamic (directional) lane assignment • ramp metering • speed control (radar detection, camera's) • variable message sign • incident detection • aid co-ordination systems

The ultimate focus is to develop and implement driving and control-systems from the perspective of full automation of the driver's task. With respect to the control systems, in-car electronics focus on registration of the performance of vehicle subsystems in order to give auditive or visual warnings to the driver or to automatically interfere in case of bad performance. Increasing attention is paid to the possibilities to store much of this status information and information on speed and navigation in a black box to support the analysis of serious accidents. Further, assistance of the driver can be realised by a variety of in-car electronic information systems giving information or taking over partial tasks. The aim is to reduce the complexity of the driving task and to eliminate possible sources of confusion. Some of these systems focus on speed headway support, forward or side collision avoidance. Other systems focus on supporting lane keeping. Some systems give warnings in case of the approach of difficult to observe obstacles in the dead angle or in the context of reverse parking. Navigation systems, based on general positioning systems (GPs) give visual or additive advice's about the route to be followed, after specification of starting point and destination. Dynamic route information systems use real-time traffic status information received by radio signals. Finally, intelligent co-pilot systems (integration of systems within the car) and systems for cooperative driving (integration of information systems from intelligent infrastructure) are being developed for coordinating the variety of signals from the previously mentioned systems and the coordination of interventions.

Especially in situations of high traffic density, traffic managers take decisions to

actively influence traffic flow behaviour within infrastructure networks. The goal is to optimise the use of scarce infrastructure capacity and to establish a smooth and safe traffic flow (reduce congestion probability, improve incident detection and handling). To reach this goal, a variety of systems has been developed to support the guidance of road traffic with respect to route choice, access to (parts of the) networks, lane use and traffic speed. These systems deal with the translation of decisions by the road manager into signals to the road users. At present, whether the users adapt their behaviour according to these signals is basically up to the driver. In the future, it will be technologically possible to give a deterministic impact to these signals (e.g. with respect to local maximum speed level). In the mean time enforcement by road policy remains essential for yielding the pursued impacts on traffic flow behaviour. The systems used vary from general information on radio to local measures like variable lane assignment, ramp metering and local speed control. It should be noted, that the applicability of various dynamic traffic management systems is directly related to decisions related to the physical design and construction of the infrastructure network.

The specific telematics systems indicated in the table have been described in more detail in various publications (see references).

4. Reported traffic safety research related to telematics: overview

From the previously described view on traffic safety, the question arises: what do we actually know about the positive impacts of the variety of telematics systems on road traffic safety and how certain (empirically proven) is this knowledge? To find an answer to this question, an international literature search was performed. Moreover, some Dutch experts were interviewed to collect their comments on the findings of this search. The small budget for the study limited the research possibilities. Nevertheless, without having the pretension to be complete, some interesting insights were gained.

From the screening of the literature in terms of statements about the safety impacts of the variety of systems, it was found that only a limited set of the telematics systems is subject of safety discussions in literature. Further, it was found that few studies follow a systems view on safety impacts, mutually linking different telematics developments at different systems levels. Generally, these studies bear a theoretical nature and hardly discuss details. More studies can be found discussing specific telematics systems in detail, often without linking these insights to more broader points of discussion. A third observation is that a variety of research approaches is used in this field:

- theoretical reasoning;
- qualitative and quantitative data pattern analyses;
- computer simulation experiments, based on the application of mathematical models to simulate impacts of measures on traffic flow behaviour;
- driving laboratory simulation experiments, mainly focusing on man-machine interaction and driver behaviour;
- road experiments in test-sites, analysing man-machine interaction, driver behaviour and systems safety;

- experiments on public roads, focusing on a full scale impact analysis under control of conditions: man-machine interaction, driver behaviour, systems safety and traffic flow behaviour,
- monitoring and ex post evaluation of implemented systems.

As yet, this methodological variety could be an artefact of the short history and great dynamics of the technical developments. This is obstructing the cumulation of knowledge in this field.

4.1 Safety impact knowledge

Next, we come to a more detailed discussion on the findings of the literature search. Following the above elaborated safety concept, we pay attention to the aspects of logistical planning, vehicle control/driving support and traffic management.

With respect to the level of logistical decision making, it has been argued that decisions might have considerable impact on the traffic safety. Nevertheless, this issue is hardly discussed in literature on telematics systems supportive to logistical planning. Pre-trip planning support systems need reliable data about the availability of transport capacity, expected weather conditions, traffic density expectations, infrastructure maintenance planning, etcetera. Operational logistical decision making is even stronger dependent on the availability and usability of actual data about the traffic systems performance (congestion, road blockades, route alternatives). Hence, there seems to be a causal relationship between the quality of the logistical decisions (in terms of the realisation of undisturbed and safe transport) and the quality of the underlying traffic systems data (in terms of actuality, reliability and completeness). Consequently, the logistical planner is to a large degree dependent upon the quality of the data collection and data distribution activities, performed by others: traffic monitoring systems, radio, satellite systems for EDI-based tracking, tracing and fleet management. Although the causal chain of quality of performance data, quality of logistical decision making and increase/decrease of safety risks seems a plausible one, no studies have been found in literature that theoretically and empirically explore the more exact nature of these relationships.

In contrast, the literature search revealed a strong bias in studies towards telematics systems for (a) the support of vehicle control/driving and (b) dynamic traffic management. This is well understandable because of the relatively better measurable nature of the relationship between these systems and changes in traffic safety. The basic issues in relation to vehicle control/driving are: technology performance (parameter setting; failure probability) and man-machine interface. The basic issues in relation to dynamic traffic management are: technology performance and driver behaviour in the context of traffic flow participation. With respect to the level of vehicle control/driving support, Table 2 summarises the main findings with respect to the relationship between driver support systems and safety impacts. The findings have been expressed in terms of rather certain positive or negative impacts, non relevancy (no clear theoretical relationship), lack of knowledge or uncertainty about the nature of the relationship. Overall, the table indicates considerable uncertainty contrasting with the generally expected positive safety impacts of the telematics systems under consideration.

Table 2. Safety impacts of some in-car driver support systems.

telematics system	safety and technological performance	safety and man-machine interaction	safety and driver behaviour	safety and traffic flow	type of research	reference to study
enforcing speed reduction system	reliability crucial	unknown	uncertain: compensation	positive: more steady flow	theory	Marchau et al 1996
vehicle diagnose system	unknown	positive	negative: panic reactions	not relevant	theory	Gundy 1994
vehicle control system (e.g. ABS)	reliability crucial	negative: interference's	negative: compensation; skill loss	uncertain	public road experiment	Nordström 1995
telephone/fax	not relevant	negative: more stimulus	negative: less attention	negative: deviating movements	public road experiment	Brookhuis et al 1989; Petica 1995
driver tutoring	not relevant	positive	positive	more careful driving	lab simulation	V.d. Hulst 1995; De Waard 1995
head up display for visibility	unknown	uncertain: more stimuli	uncertain: compensation	positive: less accidents	driving lab simulation	Broughton 1994; Harvey 1995; Hooye 1996
dead angle warning	reliability crucial	positive	uncertain: less attention	positive	public road experiment	Echigo 1994
lateral driving support	uncertain: parameter values; interference's	positive: less working load	positive: less stress	positive: less deviating movements	driving lab simulation; road experiment	Onken 1994; Isomoto 1995
anti-collision systems	uncertain: parameter values; interference's; reliability	positive: less working load	uncertain: possibly compensation	positive: increase time headway	computer simulation; public road experiment	Nilsson 1991; Janssen & Nilsson 1993; Haervey 1995; Sue-tomi 1995; Landau 1995; Ward et al 1996
adapt. cruise control and long. control	uncertain: parameter values; interference's	positive: less working load	unknown	uncertain: depends on parameters	computer simulation; public road experiment	Morello 1994; Harvey 1995; Nilsson 1995; Watanabe 1995; Van Arem et al 1996
navigation system	uncertain; accuracy of information; interference's	positive	uncertain: less attention	uncertain: less attention	public road experiment	Verwey & Jansen 1986; Schragen 1993; Risser & Gna-vi 1994; Harvey 1995
co-operative driving	uncertain: parameter values; reliability crucial; interference's	positive	uncertain: possibly compensation; less attention	positive: less accidents	computer simulation; driving lab. simulation; road experiment	Zimmer et al 1994; Broughton 1994; Harvey 1995

These insights are based on a mix of experimental simulation studies in laboratory circumstances and small scale real world road experiments. In terms of the explanation, it is stressed in literature that the performance of various systems (e.g. speed enforcing, anti-collision, adaptive cruise control) heavily depends upon the parameter setting of the technology. Also, many of the systems still bear an experimental character and cannot be characterised as proven technology yet (e.g. lateral cruise control or intelligent co-pilot). It creates uncertainty about the reliability and accuracy of these systems. Moreover, some literature stresses the fact that hardly any knowledge exists about the interference's between

technical subsystems (Heijer, 1996). For example, discussions have recently been initiated on the safety aspects of in-car use of telephone and electronic driver support systems such as anti-collision and adaptive cruise control (e.g. Gundy, 1994). Attention is also asked for the fact that in case of automation or limitation drivers tend to adapt their behaviour. This might lead to compensatory behaviour, loss of skills and less attention in traffic participation. This could counterbalance the positive impacts of electronic driver support. Further, the more systems are used, the greater the possibility of cumulation of stimuli for the driver at particular moments, causing high peaks of task load. For instance, the telephone rings at a moment that a signal is given for a too high speed level, approaching the end of a traffic jam, and the route information system advice's you to take the secondary road at the highway junction approaching within 600 metres.

Table 3. Safety impacts of dynamic traffic management systems.

telematics system	safety and technological performance	safety and man-machine interaction	safety and driver behaviour	safety and traffic flow	type of research	reference to study
dynamic P&R info	not relevant	not relevant	unknown	positive: less traffic	public road experiment	Kempter et al 1995
route info screens	unknown	not relevant	unknown	positive: less congestion	public road experiment	Van Berkum et al 1993
information on radio	not relevant	not relevant	positive: anticipation	positive: anticipation	public road experiment	Katteler 1996
variable message sign	unknown	not relevant	negative: sudden moves/reactions	positive: lower speed	public road experiment	Kulmala and Rämä 1995
dynamic lane assignment	unknown	not relevant	unknown	positive: better flow	computer simulation	Bovy 1995
incident detection	reliability important	not relevant	unknown	positive: better handling, less congestion	computer simulation; public road experiment	Botma 1995
ramp metering	unknown	not relevant	negative: neglect sign	positive: better traffic flow at higher level	computer simulation; public road experiment	Middelham et al 1994

Table 3 summarises basic knowledge with respect to safety impacts of dynamic traffic management systems. In this table the same terms are used as in Table 2 for qualifying the available knowledge. In accordance with the aim of these systems, studies generally indicate a positive impact on the traffic flow: less congestion and a more smooth/steady traffic flow. This has positive impacts on the road safety too. Important to notice is that the knowledge about these impacts is to a considerable degree based on real world empirical observations. Hence, this knowledge can be considered as rather certain. Moreover, since these systems are increasingly applied (so far mainly at highways), the empirical bases for improving the knowledge on safety impacts grows rapidly. Nevertheless, still various pieces of knowledge seem not available yet. In particular the impact of failure or inadequate parameter setting of certain technologies on driver behaviour and traffic flow behaviour is only partially known. A key issue in this context is the acceptance of signals followed by adaptation of behaviour. Instructions forcing drivers to behave contra-natural (for instance low speed at parts of the

highway system) might yield neglecting or compensating behaviour. Recent large fog accidents at highways in the Netherlands for instance, are highly due to neglecting speed warning signals. Another problem is that wrong, non-realistic or non-actualised information (for instance overtaken congestion warnings or speed indications at a higher level than is actually possible) suggests lack of reliability of the systems and might generate a non-cooperative attitude. Finally, in the case of ramp metering there exists a trade off between improving a free flow at the entered road system and generating congestion at the underlying road system due to the ramp metering system.

5. Conclusions and discussion

The variety of telematics systems under development to improve road traffic performance is large. Many of these systems are developed separately by different industries, driven by the large competition and booming possibilities in electronics. The technology driven nature of the development yields a body of research that seems to put less emphasis on the impacts of the advanced telematics systems on the performance of the transport system as a whole. Clearly, not from an attempt to mislead potential users, but as a result of the fundamental believe that this type of systems is always good for improving driver behaviour and, consequently, also traffic flow behaviour. The leading role of industries in safety research is an explanation for the crumbled nature of the knowledge, as can be concluded from the study. The natural attitude of these industries is not to study the transport system as a whole, but to focus on those parts of the system that generates potential markets for their products.

The main finding of the analysis is that, in contrast to what is generally suggested and despite the enormous financial and research efforts in this field, still a lot of uncertainty does exist. The greatest certainty exists about the real world positive impacts of various dynamic traffic management systems. It has been possible to experiment with these systems during the last decade in real world and they seem to contribute significantly to traffic safety. The uncertainty of impacts with respect to other telematics systems might in the future also be reduced in favour of positive contributions to traffic safety. However, more than in case of dynamic traffic management systems, this seems strongly dependent upon the specific way these technologies are implemented. More than once, literature indicates that the direction of the safety impacts (positive or negative) depends on the setting of the parameters of the system, the sensitivity of the system for interference's with other systems and the lack of knowledge about the reactive behaviour of drivers.

The question is whether continuation of the presently dominating "sit, wait and react" attitude of public authorities in this situation is acceptable? It might lead to hardly to stop or to change developments. For instance full in-car (electronic) safety protection of the car driver might cause less attention for other users of the road. It becomes time to specify standards, conditions and rules for these developments from a public point of view. We argued before (Van der Heijden and Marchau, 1995) that a more pro-active role of public authorities in this respect could very well work in favour of industrial R&D efforts. For instance, the study indicated that new questions arise, among others related to legal issues

and insurance rules. The large scale use of advanced telematics systems might lead to a new type of accidents, yielding new discussions on guilt and liability. Imagine an automated guided car crashing on a special lane, causing the crashing of other cars at that lane. Who is responsible: the driver, the traffic controller, the industry that produced the technology? A lack of transparency in legal regulations might lead to hesitating stakeholders and as such delay the development and implementation of systems developed with high R&D costs. The setting of clear conditions and rules is therefore of increasing necessity.

Research in the field of transport telematics develops with high speed. The view on research with respect to the safety impacts, expressed in this article, is based on an exploration mid 1996. In the meanwhile new study results may have been published, that reduce some of the uncertainty. On the other hand, it is also not unlikely that new studies will add to uncertainty. The minimum role to play by public authorities is therefore to more explicitly and actively act as R&D manager for improving the knowledge infrastructure by stimulating research to identify and solve the remaining set of questions, lacks of knowledge, and uncertainties from a systems point of view.

References

- Banister, D. (1994): Transport planning in the U.K., U.S.A. and Europe, E&FN Spon, London.
- Botma, H. (1995): Incident management in the Netherlands, in VERTIS (eds.): Proceedings of the Second World Congress on Intelligent Transport Systems, Tokyo, pp. 1371-1376.
- Bovy, P.H.L. (1995): Advanced traveller information services in real-time traffic prediction models, *Tijdschrift Vervoerwetenschap*, vol. 31, pp. 382-393.
- Brookhuis, K.A., G. de Vries and D. de Waard (1989): De effecten van het gebruik van de auto-telefoon op het rijgedrag, Report VK 89-02, Verkeerskundig Studiecentrum, University of Groningen, Groningen, the Netherlands (in Dutch).
- Broughton, J. (1994): Assessing the safety of new driver support systems, in ERTICO (eds.): Proceedings of the First World Congress on Applications of Transport Telematics and Intelligent Vehicle Highway Systems, Paris, pp. 2110-2117.
- De Waard, D. and K. Brookhuis (1995): Een intelligent toezichtstelsel in de auto, in: *Verkeerskunde*, vol. 46, nr. 11, pp. 11-20 (in Dutch).
- Echigo, T. (1994): Relative velocity detector for vehicles travelling in other lanes, in ERTICO (eds.): Proceedings of the First world Congress on Applications of Transport Telematics and Intelligent Vehicle Highway Systems, Paris, pp. 2110-2117.
- Fincham, B. (1996): Watching how you drive, in: *IEE Review*, vol. 42, nr. 3, Institution of Electric Engineers, London, pp. 97-100.
- Gundy, C.M. (1994): Safety implications of electronic driving support systems, Report R94-85, Stichting Wetenschappelijk Onderzoek Verkeersveiligheid (SWOV), Leidschendam, The Netherlands.
- Hall, R.W. (1995): The architecture of transportation systems, *Transportation Research-C*, vol. 3, pp. 129-142.
- Harvey, S. (1995): How far will transport telematics improve transport efficiency, safety and travel environment, in VERTIS (eds.): Proceedings of the Second World Congress on Intelligent Transport Systems, Tokyo, pp. 2440-2445.
- Heijer (1996): Multiple driver support systems and traffic safety, Stichting Wetenschappelijk Onderzoek Verkeersveiligheid (SWOV), Leidschendam, the Netherlands.
- Hooey, B.L. and J.K. Caird (1996): The effects of automobile head-up displays on driver attention, in: Proceedings of the international conference on traffic and transport psychology, Valencia, pp. 173-178.
- Isomoto, K., T. Niibe, T. Suetomi and T. Butsuen (1995): Development of a lane-keeping system for lane departure avoidance, in VERTIS (eds.): Proceedings of the Second World Congress on Intelligent Transport Systems, Tokyo, pp. 1266-1271.
- Jansen, W. (1995): An extended evaluation of driving a prototype intelligent vehicle, in VERTIS (eds.):

- Proceedings of the Second World Congress on Intelligent Transport Systems, Tokyo, pp. 1771-1776.
- Janssen, W. and L. Nilsson (1993): Behavioural effects of driver support, in: A.M. Parkes & S. Franzen (eds.): *Driving future vehicles*, Taylor & Francis, London, pp. 147-155.
- Katteler, H. (1996): Verkeersinformatie op maat, *Informatie en Informatiebeleid*, vol. 14, nr. 2, pp. 41-46 (in Dutch).
- Kempter, S., P. Allee, D. Hardt, E. Wittmann and W. Grossmann (1995): Dynamic P&R information within Munich; COMFORT: system design and evaluation, in VERTIS (eds.): *Proceedings of the Second World Congress on Intelligent Transport Systems*, Tokyo, pp. 2367-2372.
- Kulmala, R. and P. Rama (1995): Safety evaluation in practice: weather warning systems, in: J.P. Pauwelussen and H.B. Pacejka (eds.): *Smart Vehicles*, Swets & Zeitlinger, Lisse, pp. 428-438.
- Landau, F.H. (1995): Human factors design of collision warning systems, in VERTIS (eds.): *Proceedings of the Second World Congress on Intelligent Transport Systems*, Tokyo, pp. 1223-1228.
- Levine, J. and S.E. Underwood (1996): A Multiattribute analysis of goals for intelligent transportation system planning, *Transportation Research-C*, vol. 4, pp. 97-111.
- Marchau, V., M. Hoedemaeker, M. Minderhoud, K. van Wees en R. van der Heijden (1996): *Veiligheid van telematica-toepassingen in het wegverkeer: zekerheden en onzekerheden*, report TRAIL Research School, Delft, the Netherlands (in Dutch).
- Middelham, F., W.J. Schouten, J. Chrisoulakis, M. Papageorgiou and H. Haj-Salem (1994): Eurocor and A10-West: coordinated ramp-metering near Amsterdam, in ERTICO (eds.): *Proceedings of the First world Congress on Applications of Transport Telematics and Intelligent Vehicle Highway Systems*, Paris, pp. 1158-1165.
- Morello, E. (1994): Evaluation framework for driver assistance applications, in ERTICO (eds.): *Proceedings of the First world Congress on Applications of Transport Telematics and Intelligent Vehicle Highway Systems*, Paris, pp. 1639-1646.
- Nilsson, L. (1995): Safety effects of adaptive cruise controls in critical traffic situations, in VERTIS (eds.): *Proceedings of the Second World Congress on Intelligent Transport Systems*, Tokyo, pp. 1254-1259.
- Nilsson, L., A. Hakan and W. Janssen (1991): Collision avoidance systems-effects of different levels of task allocation on driver behaviour, DRIVE project V1041, Report GIDS/MAN 3, Verkeerskundig Studiecentrum Groningen, Groningen, the Netherlands.
- Nordström, O. (1995): Visions of future improvements of stability, steerability and brakeability of heavy vehicle combination by use of smart technology from a Swedish point of view, in: J.P. Pauwelussen and H.B. Pacejka (eds.): *Smart Vehicles*, Swets & Zeitlinger, Lisse, pp. 29-317.
- Onken, R. (1994): DAISY, an adaptive, knowledge-based driver monitoring and warning system, in: *Conference Proceedings on Vehicle Navigation & Information Systems*, IFFF, Piscataway, U.S.A., pp. 3-10.
- Petica, S. (1995): Safety implications of in-vehicle devices: risk assessment of in-car radiotelephone use, in VERTIS (eds.): *Proceedings of the Second World Congress on Intelligent Transport Systems*, Tokyo, pp. 1713-1719.
- Risser, R. & F. Gnavi (1994): The traffic safety checklist: ITS development and recent results of analyses of some CEDs, in ERTICO (eds.): *Proceedings of the First world Congress on Applications of Transport Telematics and Intelligent Vehicle Highway Systems*, Paris, pp. 2184-2191.
- Schraagen, J.M.C. (1993): Information presentation in in-car navigation systems, in: A.M. Parkes and S. Franzen (eds.): *Driving future vehicles*, Taylor & Francis, London, pp. 171-185.
- Shladover, S.E. (1995): Review of the state of development of advanced vehicle control systems (AVCS), *Vehicle System Dynamics*, vol. 24, pp. 551-595.
- Stoop, J.A. and W.A.H. Thissen (1997): *Transport safety: trends and challenges from a systems perspective*, Safety Science, in press.
- Suetomi, T., K. Kido, Y. Yamamoto and S. Hata (1995): A study of collision warning systems using a moving-base driving simulator, in: VERTIS (eds.): *Proceedings of the Second World Congress on Intelligent Transport Systems*, Tokyo, pp. 1907-1813.
- Underwood, S.E. (1990) *Automated highway/intelligent vehicle systems: technology and socio-economic aspects*, Report 901505, Society of Automotive Engineers, Warrendale.
- Van Arem, B., J.H. Hogema, M.J. Vanderschuren and C.H. Verheul (1996): *An assessment of the impact of autonomous intelligent cruise control*, Report INRO-VVG 1995-17a, TNO-INRO, Delft, the Netherlands.
- Van Berkum, E. van and P. van der Mede (1993): *The impact of traffic information: dynamics in route and departure time choice*, Dissertation University of Technology, Delft University Press, Delft, the Netherlands.

- Netherlands.
- Van der Heijden, R.E. (1997): New challenges in transport planning: changed requirements to the education of transport planners, paper XI AESOP-Conference Planning knowledge for the European Market, may 1997, Nijmegen, Working paper Delft University of Technology, Delft, The Netherlands.
- Van der Heijden, R.E. and V.A. Marchau (1995): Automated vehicle guidance of cars: issues for public policy development, in: ISATA (eds.): Proceedings 28th International Symposium on Automotive Technology and Automation, Stuttgart, pp.161-174.
- Van der Heijden, R.E., V.A. Marchau and J.H. Baggen (1995): Technology assessment automated vehicle guidance in road traffic: towards a research agenda, in: VERTIS (eds.): Proceedings of the Second World Congress on Intelligent Transport Systems, Tokyo, pp. 2412-2417.
- Van der Hulst, M., D. De Waard, K.A. Brookhuis (1995): Automatisch verkeerstoezicht: effectiviteit, mentale belasting en acceptatie, Tijdschrift voor Ergonomie, vol. 20, pp. 7-11 (in Dutch).
- Verwey, W.B. and W.H. Jansen (1986): Route following and driving performance with in-car route guidance systems, IZF Report C86-04, TNO-IZF, Soesterberg, the Netherlands.
- Waard, N.J., M. Humphreys and S. Fairclough (1996): A field study of behavioural adaptation with an autonomous intelligent cruise control system, in: Proceedings of the International Conference on Traffic and Transport Psychology, Valencia, pp. 15-19.
- Watanabe, T., N. Kishimoto, K. Hayafune, K. Yamada, N. Maede (1995), Development of an intelligent cruise control system, in: VERTIS (eds.): Proceedings of the Second World Congress on Intelligent Transport Systems, Tokyo, pp. 2094-2099.
- Zimmer, H., M.J. Andrews, A. Kenemy and P. Hausermann (1994): PROMETHEUS, in: I. Catling (ed.): Advanced Technology for Road Transport: IVHS and ATT, Artech House Inc., London, pp. 159-222.

Traffic Flow and Safety Analysis of Longitudinal Driver Support Systems near a Freeway On-Ramp Site

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Abstract. Within the near future, the introduction of longitudinal driver support systems on the public road is expected. These in-vehicle support systems can maintain a predefined, efficient and safe distance to their leading vehicle, taking into account driving speed and speed differences. These so-called intelligent vehicles will be introduced in current roadway transportation system without additional infrastructural adaptations. Roadway capacity and safety advantages are very much likely to depend on parameter settings of the control algorithms, vehicle deceleration limitations, operational speed range and acceptability of these vehicle characteristics by the drivers. To investigate the impacts of some possible system settings on traffic flow and safety, a case study was set up.

The paper describes and discusses the traffic flow and safety impacts near an on-ramp of a freeway section. A micro-simulation model is used to study the effects of the new traffic participants. Indicators for safety and efficiency, such as Time-To-Collision and the fundamental diagram, are used to evaluate the impacts of the supported driving function.

1. Introduction

A new generation of vehicles will be apparent in the current road transportation system within a few years. These Intelligent Vehicles are equipped with technology which can support the longitudinal driving task. A short description is given about the functioning of these support systems.

A sensor in the front of the equipped vehicle measures the distance to and speed of its predecessor. Based on this information, the control unit calculates the desired acceleration. This acceleration depends on the control algorithm applied, together with the pre-set desired headway. Current prototypes (e.g. AICC, Autonomous Intelligent Cruise Control) are designed with target headways between 1.0 s and 2.0 s, which are relatively safe compared with headways encountered at Dutch freeways.

Reasons for selecting such a safe time headway is the limited acceleration and speed range of the proposed longitudinal driver support systems. Mostly, the acceleration is limited between $+1.5 \text{ m/s}^2$ and -3 m/s^2 and the operational speed ranges between 30 and 150 km/h. Impacts on traffic flow and safety are still uncertain and subject of study all over the world.

In this paper, a comparison is made between three different driver support systems and the situation without these new generation vehicles. Goal of the study is to identify benefits for traffic safety and efficiency and to gain insight in differences in AICC designs.

Section 2 discusses the model applied for the study and underlying assumptions with regard to driver support system usage. Section 3 describes the case study, including the three support systems selected for analysis. In section 4, the results are presented. Conclusions and recommendations are given in section 5.

2. The model

Assessing impacts of driver support systems on traffic flow safety and efficiency requires a microscopic model in which both human driving behaviour and supported driving behaviour (e.g. man-machine interaction) can be depicted on a detailed level. Since existing simulation models have not the features desired to analyze the mix of conventional and new generation vehicles well, a new simulation model was developed for this task. The SiMoNe (Simulation model of Motorway traffic of New generation vehicles) model is a research tool for analyzing traffic flow impacts of vehicles equipped with user-defined longitudinal driver support systems expected to be present in near future traffic.

In addition, the model can be used for capacity estimation for various geometrically different freeway configurations. For the case study, an on-ramp freeway site was selected as bottle-neck.

Some features of the model:

- vehicle positions are calculated every 0.1 s
- stochastic generation of vehicles at origins
- time delay in driving task performance
- multiple userclasses (non-supported and supported) can be present in simulation
- desired speed can be normally distributed per userclass
- desired car-following distance can be normally distributed per userclass
- car-following strategy and distance based on drivers' perception of traffic regime (congestion and non-congestion)
- mandatory and discretionary lane-change behaviour

The model was calibrated for the Dutch three lane A2 Vinkeveen site. For a detailed description of the SiMoNe model, see [1].

For the use of longitudinal driver support systems, some general assumptions are made. Firstly, it is assumed that a driver will take over the driving task when the limits of the acceleration range are reached.

Secondly, if the actual speed is below the lower speed boundary, or the actual speed is above the higher speed boundary the driver will take over the driving task. In practice, a driver will receive a warning signal indicating that the support system has reached its limits.

Another reason for a driver taking over the systems' control is a lane-change demand from a neighbour lane. If the vehicle must decelerate to let another vehicle merge in front, this implies that the driver must overrule the system. In addition, this aspect is the decisive reason that only overrutable systems can be introduced appropriately in today's road

transportation system.

Fourth assumption is that a driver tries to avoid passing vehicles on the right hand side. Although this assumption is strict for non-equipped vehicles, supported drivers do also conform to this rule, but accept more speed differences since otherwise they must overrule their system.

At last, there must be a satisfying car-following strategy applied during the approach of slower vehicles in front. Some threshold values are defined to take account of this requirement.

3. Set-up of simulation

The selected case study is an on-ramp site to a two-lane freeway. The length of the simulated freeway is 5 km. The on-ramp is located 2500 meter after the imaginary beginning of the freeway. Length of the on-ramp is 350 meter. Two detectors measure the traffic. One upstream detector is located 600 meter before the on-ramp. The downstream detector is located about 1 km after the end of the on-ramp.

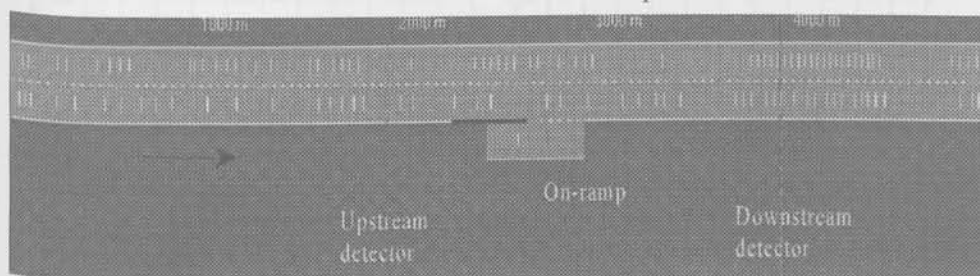


Figure 1. On-ramp site

A simulation duration of 2.5 hour was selected and included non-congested and congested traffic. Traffic demand at the two-lane origin of the freeway increased from 2500 veh/h to 4000 veh/h. The on-ramp flow rate increased from 800 veh/h to 2000 veh/h in 15 minutes after one hour, and decreased to 1000 veh/h at the end of the simulation.

Three driver support systems were selected for analysis:

1. AICC-"normal". This longitudinal driver support system is seen as the first system to be available on the market. It has a limited acceleration range and a limited speed range (30-150 km/h). A relatively safe time headway of about 1.0 second was chosen as target car-following headway. The car-following strategy is a pure imitation of human driving behaviour. It is furthermore assumed that the system must be reactivated manually after overruling the system.
2. AICC-"extended". This driver support system is similar to the AICC-normal. However, the target car-following distance was equal to the average minimal desired distance (about 0.8 s time headway). In addition to the AICC-normal, the AICC-full was equipped with an automatic re-engage functionality.
3. AICC-"special". This AICC variant is especially appropriate during congested conditions. The operational speed range is set from 0 to 50 km/h. The car-following

strategy and desired car-following distance is the same as applied in the AICC "extended". The system will automatically re-engage after human intervention.

All support systems had the same limited acceleration range (+1.5 to -3 m/s²). The manual re-engagement AICC systems are modelled on a manner that this reactivation is initiated after 8 seconds of manual driving and accelerating vehicle state.

A total of four simulation runs were conducted. Each simulation was performed with the same distribution of traffic. The reference simulation was carried out with 10% trucks and 90% passenger cars, during the other simulation runs the passenger cars were replaced by one of the described AICC systems. Other vehicle fleet distributions could be selected, however, in this preliminary study we only focus on potential benefits of the systems if these systems are implemented on a large scale in passenger cars.

4. Results

In this section we will firstly describe the impacts on traffic flow efficiency. Secondly, the safety aspects will be presented.

Figure 2 and 3 show the fundamental diagrams resulting from the simulated current traffic flow for respectively the upstream and downstream site. Lines in the figures connect consecutive speed-flow points (aggregated 15-minute counts).

Notice that the congestion branch in the fundamental diagram can not be observed at an upstream bottle-neck site. Furthermore, at a downstream measurement site, capacity flow rates may not be attained since traffic breaks down due to on-ramp traffic demand.

As can be seen in Figure 3, the capacity of the two-lane roadway is about 4300 veh/h. This value is similar to capacity values found in practice. The figure also shows a difference between the queue discharge flow rate, which is the capacity after congestion appeared (speeds below 90 km/h), and the pre-queue maximum flow rates (at speeds above 90 km/h). Obvious from Figure 3 is the congestion encountered downstream the on-ramp. The dotted curve represents the expected relationship if traffic demand on the two lane motorway was measured over the whole range.

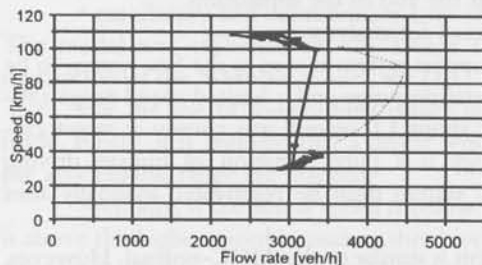


Figure 2. Reference situation - upstream

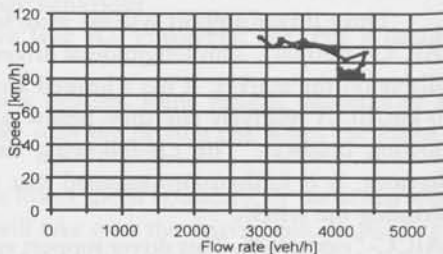


Figure 3. Reference situation - downstream

The fundamental diagrams observed with the AICC "normal" are depicted in Figure 4 and 5. It was found that capacity increased slightly. However, compared to Figure 3, there is no difference between queue discharge flow rate and pre-queue maximum flow rates. Capacity

is about 4500 veh/h at speeds above 90 km/h. The downstream detector shows congestion, similar as was observed in the reference situation.

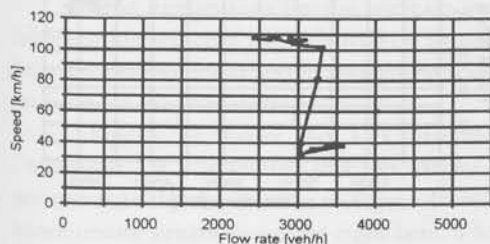


Figure 4. AICC "normal" - upstream

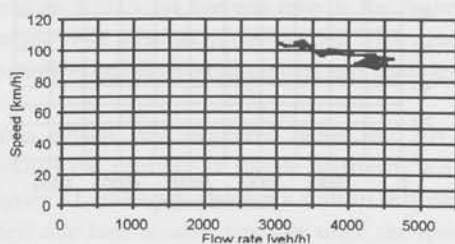


Figure 5. AICC "normal" - downstream

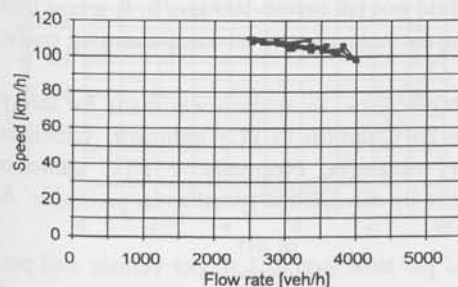


Figure 6. AICC "extended" - upstream

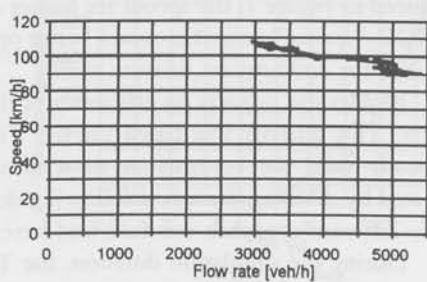


Figure 7. AICC "extended" - downstream

Figures 6 and 7 show the simulation results with the AICC "extended" support system. The system differs from the AICC "normal" by a smaller target headway and the automatic re-engagement functionality of the system after manual intervention. It is apparent that capacity increases substantially. Maximum flow rates of 5400 veh/h are observed at speeds of about 90 km/h. In addition to the capacity increase, congestion is not observed at the upstream detector (Figure 6). The freeway traffic demand is handled completely without being affected by the on-ramp traffic flow. At flow rates of about 4000 veh/h speeds drop below 100 km/h.

At last, Figures 8 and 9 show the speed-flow diagrams with the stop-and-go variant of the AICC. The system is only operational in the speed range 0-50 km/h. These low speeds are commonly observed at the on-ramp when traffic merges into the two-lane freeway. Since the system is automatically activated (and re-engaged), it will reduce human driver car-following response "errors" to a minimum.

From Figure 9 it is clear that capacity increases substantially compared with the reference situation. Flow rates above 5100 veh/h are commonly observed.

However, since the driver will take over the longitudinal driving task at speeds above 50 km/h, the difference between queue discharge flow and pre-queue is apparent. In addition, maximum flow rates are now observed at lower speeds (85 km/h) compared to the AICC-"extended".

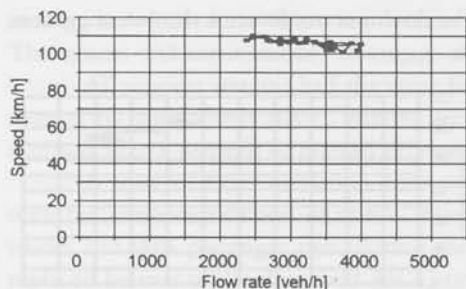


Figure 8. AICC "special" - upstream

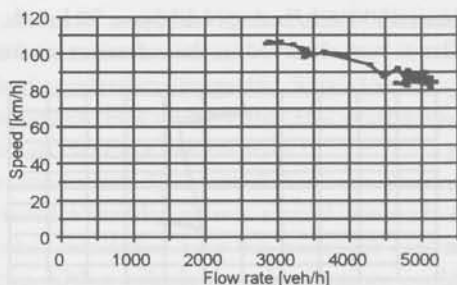


Figure 9. AICC "special" - downstream

Figure 9 shows the relationship between speed and flow rate at the downstream detector. Compared to Figure 7, the speeds are higher and do not fall below 100 km/h. It seems that the AICC-"special" variant is even a better option for reducing the on-ramp merging traffic hindrance for downstream freeway traffic.

Besides the impacts on efficiency of the traffic flow, an analysis was made for safety impacts. This analysis was based on the Time-To-Collision (TTC) indicator, which is commonly used for comparison of road safety measures. Normally, a TTC value is calculated by dividing the actual following distance by the relative speed to its predecessor. A slightly different approach was followed here.

During the simulation duration, the TTC per time step (0.1 s), per vehicle and per lane was registered. However, since we are particularly interested in a comparison of reduction of unsafe situations, we focus on the distribution of the TTC in the range 0-10 seconds. This range was divided into 40 classes of 0.25 s and the frequency of occurrence of TTC was determined. With these distributions (per lane) we can give some insight into potential safety benefits.

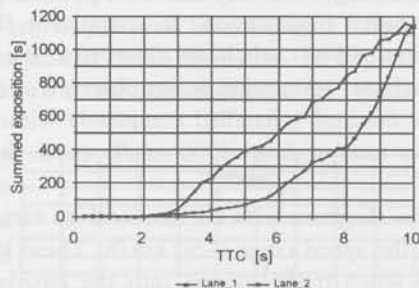


Figure 10. TTC distribution - reference

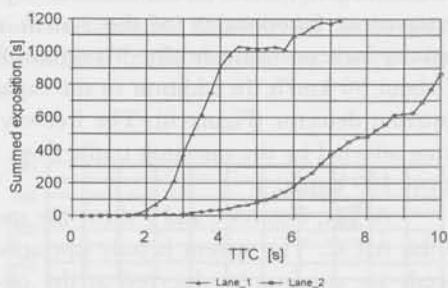


Figure 11. TTC distribution - AICC "normal"

Figure 10 shows the TTC distribution for the reference situation. Lane 1 (left lane) is relatively unsafe compared to lane 2 (right lane). Possible explanation is that the left lane is used for making lane-changes, even at high flow rates. The right lane is less utilized over the complete simulation. Since Time-To-Collisions below 3 seconds may be qualified as dangerous and undesired, the actual situation on the left lane seems not satisfying. When we compare Figure 10 to Figure 11 some major differences can be observed. After introducing

the AICC "normal", the left lane TTC distribution gets even worse compared to the reference situation. The right lane distribution has a slightly better shape.

One explanation for the increase in smaller TTC's on the left lane is the human intervention which is not followed by an automatic re-activation of the system. This results into decelerations and accelerations to reach the individual desired distances, and leading to an increase in speed differences.

Figure 12 shows the TTC distribution which was observed with the AICC "extended". It is obviously that this variant reduces the number of unsafe situations when we compare the distribution to Figure 10 or Figure 11, although there is a shift in relatively more unsafe situations on the right lane. The left side lane is safer, possibly since the speed differences are smaller, together with higher flow rates reducing the lane change probability.

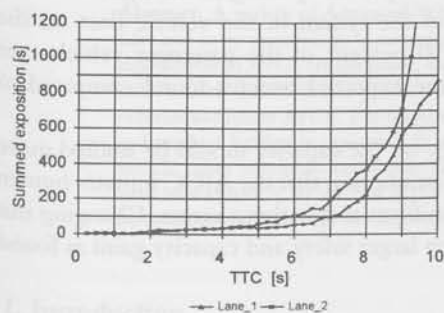


Figure 12. TTC distribution - AICC "extended"

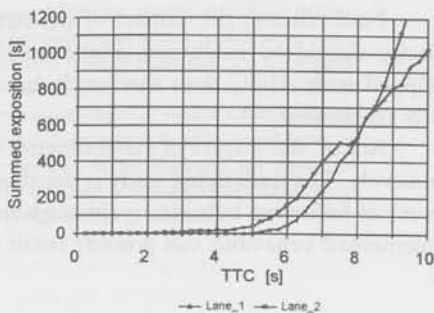


Figure 13. TTC distribution - AICC "special"

Figure 13 shows the distribution with the stop-and-go AICC. This variant is even safer than the AICC "extended". Time-To-Collisions below 4 s are very rarely observed.

5. Conclusions

In this contribution, three different longitudinal driver support systems were evaluated on two criteria: efficiency and safety impacts. In this section, the results are summarized.

- Current capacity on a two-lane freeway near an on-ramp, which is about 4300 veh/h, can be increased by introducing a driver support system on a large scale. Flow rates exceeding 5200 veh/h were observed after equipping the passenger cars with both the AICC "extended" and AICC "special". This capacity increase of at least 20%, together with a reduction of unsafe situations is surprisingly large, compared to earlier findings in literature.
- It is concluded that a driver support system that automatically re-engages performs better than manual re-engagement of the system (difference between AICC "extended" and AICC "normal").
- It is furthermore found that longitudinal support during congestion (speeds in the range 0-50 km/h) is sufficient to prevent the traffic flow breaking down. Small

disadvantage of such a system is that capacity is reached at lower speeds. In addition, over-all travel time is some what larger than in the AICC-"extended" version. Here, the capacity is reached at speeds above 90 km/h.

- The reduction of unsafe Time-To-Collisions is maximal for the AICC "special", although the AICC "extended" also performs well. The AICC "normal" results in an increase of unsafe Time-To-Collisions. This is mainly caused by the manual re-engagement functionality of the system, leading to many disturbances on the left lane.

There are some issues that should receive special attention in further research. Among others, it is questioned how people in a supported vehicle react on slower vehicles in the left neighbour lane. Is one accepting to pass vehicles on the right lane with the system switched on, or will drivers overrule their vehicle to prevent passing to the right?

Furthermore, the impact of penetration of the system in the vehicle fleet on the capacity should be examined. For example, if 50 percent of the passenger vehicles are equipped with AICC does that imply halve of the expected benefits found compared to 100% equipment?

At last, the impact of car-following strategy on the capacity should be studied more intensively. The underlying study is based on the assumption that the AICC imitates human driver car-following behaviour, although more uniform and without errors. Changing this implemented behaviour can possibly result in even larger safety and capacity gains as found yet.

References

- [1] Minderhoud, M.M. (1997) Development of the SiMoNe model, Working Paper, Delft University of Technology.

Legal Aspects of vehicle Safety and Advanced Vehicle Control Systems

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Abstract. A variety of Advanced Vehicle Control Systems, aiming at making driving safer and more convenient, is currently being developed and tested. In this paper some legal aspects of AVCS are discussed, focussed on two types of legislation, i.e. mandatory vehicle safety standards and product liability. Both type of rules relate to the safety of vehicles and future AVCS. The relationship between mandatory vehicle safety standards and product liability is examined. It is concluded that product liability, in addition to vehicle safety standards, could play an important role in stimulating a safe design of vehicles and AVCS. At the end of this paper the question whether product liability can be considered a threat for the deployment of AVCS is shortly addressed.

1. Introduction

A variety of systems actively assisting the driver in performing his driving task is rapidly being developed by the automotive industry and research institutes around the world. These systems, often called advanced vehicle control systems, driver assistance systems or driver support systems, automate – to some degree – braking, throttling or steering, aiming at making driving safer and more convenient.

Advanced Vehicle Control Systems (AVCS) currently under development include systems referred to as Adaptive Cruise Control, Collision Avoidance Systems, Lane Keeping and Lateral Control Systems. Future developments of AVCS are generally expected to be characterised by a gradual increase of automation in time, possibly leading to fully automated vehicles. For instance, Adaptive Cruise Control (ACC), expected to be introduced in Europe within the next few years, can be regarded as an enhancement of the conventional cruise control which automatically keeps a certain following headway to a leading vehicle. However, due to limited braking ability, it is necessary for the driver to intervene in cases where the braking capacity of the ACC will not be sufficient to prevent an accident or if vehicles or other objects are not being detected [1]. The driver will be able to overrule the system at any time.

Current optimism about the potential safety effects of Advanced Vehicle Control Systems, is only partly supported by empirical evidence [2]. These systems, although potentially reducing the number and severity of accidents, could also introduce some new safety issues. Safety could be threatened not only in case of technical malfunctions, but also as a result of drivers' improper understanding of the system's capabilities and limitations

leading to misunderstandings about necessary interventions and/or unjustified reliance on system performance.

AVCS raise a number of questions which go beyond their technical feasibility. For instance, lack of transparency in legal regulations, especially product liability, is subject of concern, possibly slowing down deployment of AVCS [3]. In this paper some legal aspects of AVCS are discussed, focussed on two types of legislation, i.e. mandatory vehicle safety standards and product liability. The emphasis will be on the relationship between the two types of regulation. Both vehicle safety standards and product liability relate to the safety of vehicles and future AVCS. Vehicle safety standards promote safety by prohibiting unsound vehicles to be brought on the market. Product liability enables a person who was injured by a product that did not provide the safety a person is entitled to expect, to get compensation for his damage. Both types of regulations will be shortly discussed. Secondly, vehicle safety standards and product liability are discussed in relation to each other. What relevance does compliance with safety standards have for potential product liability for AVCS. Also the question whether product liability can be considered a threat for the deployment of AVCS is shortly addressed.

In this paper mainly Dutch statutory provisions, court decisions and legal literature will be discussed. However, due to the fact that both vehicle safety standards and product liability have been harmonised to some extent, many similarities between the legal situation in the Netherlands and other European countries can be found.

2. Vehicle safety standards

First of all, a certain level of safety can be insured by setting mandatory vehicle safety standards. Extensive legislation exists, establishing all sorts of construction or performance level requirements standards for motor vehicles or vehicle equipment. To verify compliance, motor vehicles have to be examined and approved by the authorities before they can be brought into circulation. Originally dominated by national rule making, motor vehicle standards have become subject of a rapidly growing amount of European Directives. These Directives harmonise technical standards between Member States in order to remove barriers to trade and to create a single Community-wide internal market.

An important development in this context was the introduction of EC Directive 92/53. It established a Community-wide system of whole vehicle type approval for passenger cars [4]. This framework Directive contains procedures and a long list of separate Directives specifying requirements for motor vehicles, as well as for components and separate units from which vehicles are assembled. The European Directives also provide for approval certificates so that the necessary tests and examinations have to be conducted in only one of the Member States. As a result, a car that has been approved in one of the Member States could be sold everywhere in the European Community without the need for further inspection or approval.

First of all, existing mandatory vehicle standards could form an impediment for the introduction of some Advanced Vehicle Control Systems, as far as their constructional or operational characteristics will be in conflict with these standards. For instance, existing

braking legislation requires that the driver must be able to adjust the braking force at all times, without taking his hands off the steering wheel [5]. For instance, an ACC applying the brakes without the possibility for the driver to intervene at all times (non-overrutable), would be in conflict with this Directive.

Of course, new technological applications could also lead to setting new standards. For example, EEC Directive 85/647/EEC introduced special requirements for anti-locking braking systems [6]. Some current issues which merit further attention are: the need to resolve appropriate specification for partial failure performance after any failure in the anti-lock device, the need to prevent anti-lock devices from being adversely affected by electromagnetic interference, acknowledging the difficulty of checking such sophisticated systems within the Type Approval system, and the need for access by type approvers of Failure Mode Effects and Criticality Analysis (FMECA) data for the system submitted for approval [7].

It is possible, or even may be expected that some concerns about the safety of AVCS will lead to setting some new safety standards. With regard to the introduction of Adaptive Cruise Control, Scott discusses some issues that may require human factor standards in order to insure safe performance of Adaptive Cruise Control [8]. The key issues include: 1) User interface elements needed by drivers to understand the current operation mode of the system; 2) Drivers' understanding of the operating characteristics, capabilities and limitations of the system so they know what to expect and when to intervene manually; 3) Minimising differences in certain operating characteristics across vehicle manufacturers and platforms to help insure that drivers' expectations are not violated.

3. Product liability

Product liability, i.e. liability for defective products, enables the person who suffered damage caused by a defective product to get compensation for his damage. Product liability does not prevent defective products from entering the market, but it shifts the damage from the person who was injured by a defective product to the person who has brought the product into circulation.

The law on liability for defective products developed on a national level. In 1985, however, a European Council Directive on liability for defective products was introduced [9] and, as a result of this, liability for unsafe products in Europe has, to some extent, been harmonised. The Member States must bring into force the laws, regulations and administrative provisions necessary to comply with this directive (article 19) [10].

According to the Directive the producer shall be liable for damage caused by a defect in his product (article 1). A product is defective when it does not provide the safety which a person is entitled to expect, taking all circumstances into account, including:

- (a) the presentation of the product;
- (b) the use to which it could reasonably be expected that the product would be put;
- (c) the time when the product was put into circulation.

A product shall not be considered defective for the sole reason that a better product is subsequently put into circulation (article 6) [11].

A product being defective within the scope of this Directive means being unsafe rather than inadequate for its intended use. In the United States the words 'unreasonably dangerous' are used [12]. In legal literature mostly three types of defects are distinguished [13]: manufacturing defects, design defects and instruction defects.

Manufacturing defects

Vehicles, vehicle parts or vehicle equipment could first of all be considered defective if they are unsafe due to the fact that they do not comply with the manufacturer's self-imposed standards, so-called manufacturing defects. Something went wrong in the production process and as a result the product fails to meet the product specifications. This could be the result of raw materials or components containing physical flaws or the fact that some "mistake" has been made in their assembly into the final product.

Design defects

Although vehicle or vehicle equipment characteristics comply with the manufacturer's self-imposed standards they could still be considered defective if the design itself is unreasonably unsafe. A defective design implies an improper balancing of the chosen design characteristics against the likelihood and seriousness of injuries resulting from the product's use. A design defect effects a whole line of products.

First of all, design defects may result from the fact that the manufacturer simply overlooked the defect in designing a product or that foreseeable uses, applications, users and environments were not adequately considered when creating the product's design specifications. It is also possible that defects simply could not be foreseen or conducted tests did not reveal them.

Another possibility is that conducted tests did not reveal the defect. Software for instance, which is also an essential component of AVCS, is never without "bugs". It is assumed that, due to its complexity, it is impossible to design bug-free software [14]. Another complicating aspect of AVCS is that the input of the system is formed by dynamic traffic conditions which are characterised by great diversity (other vehicles, non-motorised road users, road geometry, etc.). Ideally, testing should include all possible situations. However, real world traffic will probably always be more varied than the circumstances included in the most comprehensive testing.

A defective design could also be the result of a conscious choice of the manufacturer for specific design characteristics. This choice is based on trade-offs among competing factors such as safety, utility, attractiveness, costs and consumer requirements. For instance, the first ACC's expected to be introduced, will probably not detect stationary vehicles, because the technology is not sufficiently reliable to distinguish stationary vehicles from other stationary objects and/or because technology that is sufficiently reliable is too expensive. This means that, under certain conditions, the system will not detect a queue of traffic. This could lead to dangerous situations if the system generates a false sense of security, making drivers inattentive. Such safety drawbacks could potentially lead to product liability, especially if a safer design was available at reasonable costs [15].

Instruction defects

A product could also be considered defective as a result of the failure to give adequate warning or instruction or because of the way the product is presented on the market. The producer has the duty to warn consumers for the dangers involved in (mis)using the

product. Furthermore the presentation of the product could be relevant. For example, advertising statements about safety can influence the level of safety a person is entitled to expect.

Based on case law and legal literature some important remarks about potential product liability for AVCS can be made.

- Producers must examine all possible safety aspects of AVCS

"As driver assistance systems are based on interactions between the electronic driver assistance and the human driver, however, it is not sufficient to limit the testing of such systems to the technical safety. The human side of the system has to be included into the testing" [16]. In legal literature it is assumed that manufacturers have a duty to investigate the cautiousness that can be expected from users [17]. Ideally, testing of AVCS should confront test persons with realistic traffic conditions, also checking the functional limits in critical situations. However, real world traffic will always be more varied than could be simulated in testing.

- Foreseeable careless behaviour has to be taken into account.

Manufacturers must take into account that some consumers will not always use the AVCS with the necessary care [18], especially regarding the fact that automobiles are used intensively in daily routine [19]. Foreseeable careless behaviour cannot be considered a circumstance excluding the producer's liability. For instance, the fact that an ACC will be used exceeding the maximum speed with 10 or 20 miles, will probably not be a valid defence for the manufacturer if this leads to dangerous situations. This would be an entirely foreseeable (mis)use of the system that has to be taken into account by the manufacturer [20]. The producer's defence that the accident was (also) caused by the fault of the driver will not easily be accepted. In the preamble of the Directive it is stated that the defectiveness of the product should be determined by reference not to its fitness for use but the lack of the safety which the public at large is entitled to expect, whereas the safety is assessed by excluding any misuse of the product not reasonable under the circumstances.

- Consumers must have a proper insight in system performances and limitations

Manufacturers can, to some extent, influence the safety expectations of consumers (and product liability risks), by stimulating a proper understanding of the operation characteristics. The limitations of the system must be clear to the driver. This aspect will be of great importance because consumers lack experience using AVCS. In other words, consumers lack an experience-based system reliability expectation. Misunderstandings about system performance potentially creating dangerous situations must be eliminated as much as possible. Producers must make sure that no exaggerated impression about system performances is given, for instance through advertising. Furthermore, the driver has to be aware of the limitations of the systems and the potential risks of (mis)using it, for instance through instruction manuals or warnings on or near the system itself. Inadequate presentation or instruction can make a product defective, which could otherwise be considered safe enough. However, warnings cannot neutralise the defectiveness if the unsafety could have been avoided through an alternative design (or the product should not be marketed at all) [21]. It is the producer's primary duty to market a safe product.

4. The relevance of vehicle safety standards for product liability for AVCS

Both legal safety standards and product liability deal with the safety of products. About 50 European Directives are laying down all sorts of construction and/or performance level requirements for passenger cars to insure a certain level of safety. Product liability, although primarily reactive in nature (compensation for damage) could also have a preventive effect. The possibility to be held liable not only for production defects, but also for design defects or inadequate warnings or instructions, will be an incentive for manufacturers to take all possible safety aspects into account in designing their products and introducing them on the market. This is also one of the goals listed in the preamble of the European Directive [22]. But what is the relationship between mandatory safety standards and product liability? What relevance do statutory safety standards have for determining the defectiveness of a product within the scope of art. 6:186 BW (and the European Directive on product liability)?

The European legislator consciously did not mention compliance with regulation as a circumstance relevant for determining the defectiveness of a product [23]. The answer to the question whether or not compliance with legal regulations in general (not specifically vehicle standards) influences civil liability will be dependent on the nature and rationale of the regulation in question [24]. This was stated by the "Hoge Raad" (the Dutch Supreme Court) in the context of a licence based on the Nuisance Act [25].

It can be assumed that mandatory vehicle safety standards will not exclude manufacturer's liability. Those regulations serve the need to prevent traffic safety to be threatened by unsound vehicles, not to protect the producer from liability. In this context reference could be made to the decision of the Hoge Raad in the Halcion case. In that case it was ruled by the court that the required registration (approval by the authorities) of a medicine did not exclude the producer from civil liability [26]. In his comment Brunner states, with reference to other authors, that the same must be assumed for other products.

Although statutory standards will not exclude manufacturer's liability, compliance with these standards can still be relevant in determining whether or not a vehicle or vehicle device could be considered defective. These safety standards could use the same basic assumption as the Directive: "the safety which a person is entitled to expect" [27].

To conclude this it is required that the safety standard regulates those aspects of the vehicle or vehicle device which, according to the injured person, make the vehicle unreasonably unsafe, and that it can be assumed that the defect in question was considered and judged to be acceptable by the authorities setting up the standard [28]. In that case the judge must, in principle, refrain from imposing a more strict standard based on product liability, because the defectiveness has already been judged by the authorities. For instance, it can be argued that a vehicle cannot be considered defective because an accident could have been prevented if the vehicle would have had more braking capacity than was legally required or if it had been equipped with ABS. However, compliance with a vehicle safety standard regulating the crashworthiness of the front of the vehicle will be irrelevant for the determination of the crashworthiness that may be expected from the rear end of the vehicle [29].

Although there exists a great number of vehicle safety standards laying down all sorts of requirements with regard to the construction or performance levels of motor vehicles,

they certainly do not cover all possible characteristics of a vehicle which could make it unreasonably dangerous. This is also expressed in the preamble of the framework Directive for vehicle standards [30] stating that a vehicle being in compliance with the provisions of the directive, can still possess certain characteristics potentially threatening traffic safety.

New technological applications, such as driver assisting systems, could also introduce new safety risks. These unprecedented safety risks, for example drivers' misunderstanding of operational characteristics or functional limits of an ACC creating dangerous situations, were, of course, not taken into consideration when the existing safety legislation was drafted. Compliance with existing vehicle standards will therefore be irrelevant for determining the defectiveness of these systems.

However, it is also possible that some new safety standards will be drafted, regulating AVCS specific safety issues, for instance requiring a minimum set headway for ACC. If an injured person states that an AVCS must be considered defective, and the manufacturer defends himself arguing that the system is in compliance with the legal requirements, again the question has to be answered whether or not the alleged defect can be assumed to be taken into account and judged acceptable by the authorities. Electro-magnetic compatibility requirements will not be relevant for determining the defectiveness of man-machine interaction design characteristics.

However, even if it could be assumed that the authorities setting up the standard took the defect into account and judged it acceptable, liability of the producer could still be justified. Compliance with legal standards is just one of the relevant circumstances for the determination of the defectiveness. Other circumstances could well justify imposing a more strict standard. After all, product liability is not about judging the acceptable risks in terms of general traffic safety, but about the safety a person is entitled to expect, taking all circumstances into account.

Given the fact that vehicle safety standards must be regarded as minimum standards securing a minimum of safety acceptable to admit vehicles on public roads [31], other circumstances could justify imposing a more strict standard. Such a circumstance could be, for instance, the way a vehicle is presented on the market. The presentation of the product could influence the safety a person is entitled to expect. Introducing a car as more safe than others or emphasising the safety characteristics of a vehicle or vehicle device can be an argument to assume liability, although the vehicle meets all statutory safety standards. The safety of other, but similar cars on the market will be an indication of what may be expected [32]. In general, a person is entitled to expect more safety, for instance with regard to crashworthiness, from a 50.000 dollar-car than from the lowest priced car on the market [33].

Another circumstance justifying a more strict standard could be the fact that the standard must be considered outdated or inadequate for another reason. One should bear in mind that the process of creating standards (or adjusting them) is, in most cases, a long one. "In practice the inertia of the rule-making process in Europe results in standards which at best only reflect the state of knowledge of about three years ago. Many directives have been under debate for much longer than that" [34].

The state of the art could be improved. It could also be that research shows that the standard proves to be inadequate. Especially with new technological applications like

AVCS, lacking experience of implementation on a large scale in real world traffic, one could imagine such inadequacy proven in time.

5. Is product liability a threat to the deployment of Advanced Vehicle Control Systems?

From the previous section it can be concluded that, next to mandatory safety regulations, product liability could play an important role with regard to the safe design of vehicles or vehicle equipment. Determining the defectiveness of a vehicle on the basis of product liability is not about judging the acceptable risks in terms of general traffic safety (on a certain moment in time), but about the safety the injured person was entitled to expect, taking all circumstances into account.

And, although product liability does not directly prevent unsafe products from entering the market, the threat of being held liable for unsafe vehicles or vehicle equipment will also have a preventive effect. This threat, however, should not be that strong that it will be an impediment for innovation, in particular with respect to safety improving technology. The potential safety effects of automating aspects of the driving task is often brought forward in favour of AVCS. However, liability is subject of concern. It is mentioned as a factor explicitly taken into account in the development of AVCS [35]. As some of the driver's judgements and decisions will be taken over by technology, manufacturers are confronted with certain liability risks. It could offer a new stepping stone for claims against manufacturers and could shift liability for traffic accidents from the drivers/owners to manufacturers. These (perceived) liability risks can slow down development or even outweigh the benefits of producing such systems. Especially in the United States, (presumably) due to some important differences between the civil liability systems of Europe and the United States, liability is being mentioned as an impediment for the (rapid) deployment of AVCS [36].

The question whether product liability can be regarded as a constraint for the deployment of an innovative technology in its development stage is difficult to answer. Assessment of potential product liability for such technology requires, *inter alia*, some prediction as to how well the liability risk can be managed through planning the design, production and introduction of the product. Critical factors such as system reliability and the degree to which control is transferred from the driver are as yet unknown or undecided.

It must be emphasised that it will be impossible for producers to avoid all liability claims. First of all, manufacturing defects, *i.e.* a product fails to meet the manufacturer's design specifications, can never be entirely prevented. If a product is dangerous because it deviates from the manufacturer's self-imposed standards, there will be little discussion about the products' defectiveness. The question whether or not the manufacturer will be liable will rather focus on the required causal relationship between defect and damage [37]; can this defect, in a legal sense, be considered the cause of the damage? If this requirement is also satisfied, liability will be practically inevitable. The same can be concluded for design defects, as far as they, due to the complexity of the system, could not be detected by testing (for instance, software bugs). The fact that these defects were impossible to prevent will not

be a valid defence. However, defectiveness resulting from other design defects seems less strict. The standard of responsibility is more focussed on the conduct of the producer. Did he act as a prudent manufacturer (reasonable anticipated use of the product, foreseeable careless behaviour, etc.) [38].

Of course, producers and their insurers will fear for claims being rewarded to help the injured plaintiff, easily assuming a defect, rather than based on the fact that the manufacturer was somehow negligent in producing, designing and/or introducing his product. This could make them hesitate to market innovative products like AVCS. However, as has been mentioned above, case law on the subject of product liability has been rather scarce. Based on the amount of published case law regarding product liability it appears that producers are not burdened with a great number of claims [39]. However, the small number of published cases can certainly not be regarded as the only or even most important indication whether or not product liability must be considered a serious threat to the development of innovative technology such as AVCS. It is also possible that claims are being held out of court because manufacturers concluded that defending themselves would be useless or that they prefer to settle cases out of court [40]. Another possibility is that the first cases based on the European Directive are still to come, due to the duration of legal procedures [41].

6. Concluding remarks

It can be concluded that compliance with vehicle safety standards will not exclude the product from being defective within the scope of product liability law and that product liability, in addition to vehicle safety standards, could play an important role in stimulating a safe design of vehicles and AVCS. Statutory safety standards could only be relevant for determining the defectiveness of a vehicle or vehicle equipment if they use the same basic assumption as the directive, "the safety a person is entitled to expect". This implies that the safety standard must regulate those aspects of the vehicle or vehicle device which, according to the injured person, make the vehicle unreasonably unsafe, and that it can be assumed that the defect in question was considered and judged acceptable by the legislator setting up the standard. However, compliance with safety standards is just one of the circumstances to be taken into account in determining the "safety a person is entitled to expect". Other circumstances could justify imposing a more strict standard.

Whether or not (the threat of) product liability must be regarded a serious constraint for the (rapid) development of AVCS is difficult to answer. The amount of published case law regarding product liability, although certainly not being the only or most important clue, does not indicate that manufacturers are burdened with a great number of claims and that, based on that fact, product liability must already be regarded as a serious threat to the deployment of AVCS. In this paper some remarks about potential product liability for AVCS have been made. However, more research is needed to answer the question whether this will seriously obstruct the deployment of these systems. Such research should include product liability law in other European countries, especially outside the scope of the European Directive, and aspects of product liability insurance.

Endnotes

- [1] For instance, It is unclear whether these systems will be able to detect stationary vehicles. Marchau, V. Expert opinions on future developments of driver support systems, Results of an international Delphi Study. Trail Research School, Delft/Rotterdam, December 1997, p. 12.
- [2] Marchau, V. & van der Heijden, R., Safety Impacts of Transport Telematics in Road Traffic, Proceedings of the 30th International Symposium on Automotive Technology and Automation, p. 247.
- [3] Marchau, p. 18.
- [4] Council Directive 92/53/EEC, PB EG nr. L225. Whole vehicle type approval has only been established for category M1. This category includes vehicles used for the carriage of passengers and comprising no more than eight seats in addition to the driver's seat.
- [5] ECC Directive 71/320, Pb EG L 202, Annex I, art. 2.2.1.1, 2.1.2.1 and 1.3
- [6] Council Directive 85/647/EEC, Pb EG 1985 L380.
- [7] European Transport Safety Council (ETSC), Reducing traffic injuries through vehicle safety improvements - the role of car design, technical annexes, November 1993.
- [8] Scott, S., Human Factors Standards Requirements for Adaptive Cruise Control, 4th World Congress on Intelligent Transport Systems, Berlin 1997.
- [9] Council Directive 85/374/EEC, PB EG.1985, nr. L 210.
- [10] In The Netherlands this liability for defective products has been laid down in section 6.3.3 of the Dutch Civil Code (art. 6:185 - art. 6:193 Burgerlijk Wetboek).
- [11] The formulation in the Dutch provision (art. 6:186 BW) is somewhat different, however, its meaning is the same.
- [12] L. Dommering van Rongen, Produktaansprakelijkheid, Een nieuwe Europese privaatrechtelijke regeling vergeleken met de productaansprakelijkheid in de Verenigde Staten, Deventer 1991, p. 145.
- [13] Dommering van Rongen, p. 143.
- [14] R.J.J.W. Westerdijk, Produktaansprakelijkheid voor software, diss. VU, Amsterdam, 1995, p. 225.
- [15] Van Wassenaer van Catwijk refers to a judgement of an American court. An 'earthmover' driving with a speed of 16-20 km/hour could not stop in time (5 meters) because the braking system was full of mud. The court ruled that GM could not be held liable because investments to enhance the braking system would place the product out of the market. A.J.O. van Wassenaer van Catwijk, Produktaansprakelijkheid in Europees verband, Zwolle, 1991, p. 41.
- [16] Feldges, J., Legal and Liability Aspects of Testing, 4th World Congress on Intelligent Transport Systems, Berlin 1997.
- [17] Dommering - van Rongen p.177.
- [18] HR 2 februari 1973, NJ 1973, 315.
- [19] Dommering - van Rongen, p. 320.
- [20] Dommering - van Rongen refers to a judgement of the Californian court that driving without wearing seatbelts was "an entirely foreseeable misuse of the vehicle " not excluding from liability, p. 178. Van Schellen discusses some case law on the subject from the United States in: Produktaansprakelijkheid, De onvoorzichtige consument, Tijdschrift voor Consumentenrecht, 1987 p. 3.
- [21] Dommering van Rongen p. 162, Van Wassenaer van Catwijk, p. 44.
- [22] "Whereas protection of the consumer requires that all producers involved in the production process should be made liable, in so far as their finished product, component part or any raw material supplied by them was defective".
- [23] Dommering - van Rongen, p. 186.
- [24] Consumentenrecht: een overzicht van de rechtspositie van de consument, Hondius, E (ed.), Deventer 1996. p. 282.
- [25] HR 10 maart 1972, NJ 1972, 278.
- [26] In HR 30 juni 1989, NJ 1990, 652 (Halcion).
- [27] Dommering - van Rongen, p. 191.
- [28] The fact that there are no specific standards which regulate the characteristics of a vehicle that, according to the injured person, make the vehicle unreasonably dangerous, could be an argument against a vehicle or vehicle device being regarded as defective, given the fact that they are being tolerated by the authorities. This fact, however, will be of little or no importance with regard to newly introduced products like AVCS. Verkade, et.al., Produkt in gebreke, Alphen aan de Rijn, 1990, p. 59.

- [29] Dommering - van Rongen, p. 191.
- [30] Council Directive 92/53/EEC, Pb EG 1992, nr. L225/1.
- [31] Mackay, however, points out that in practice a minimum standard can become the state of the art. "The designer no longer has the task of producing a component which reflects his perception of current knowledge. Instead his task is altered so that he aims to produce a component which most efficiently passes the legislative requirements. Hence a legal requirement, which may in concept be considered as only a minimum, in practice becomes the norm of the industry. Once a standard is fixed there is a tendency to design down to that level" Mackay, Traffic safety research, product liability and insurance industry, Second World Congress of the International Road Safety Organisation, Luxemburg, 1986. On the other hand, the increasing consumers demand for safety will be a strong incentive for manufacturers to apply higher safety standards than those required by law.
- [32] Van Wassenauer van Catwijk, *Produktenaansprakelijkheid in Europees verband* (2e druk), Zwolle 1991, p. 42.
- [33] Dommering - van Rongen, p. 161.
- [34] Mackay.
- [35] For instance Benz: "Apart from legal and liability issues there are still some technical questions about ICC (Intelligent Cruise Control, KvW)". Benz, T., Automatic Distance Keeping in a Highspeed Environment -ICC Parameter Design, 3rd World Congress on Intelligent Transport Systems, 1996.
- [36] "In the United States, the main reason for slow deployment of the ICC and SWD is concern over liability" Burris, M., Impediments to Deployment of Sensor Warning Systems in the United States. 3rd World Congress on Intelligent Transport Systems, 1996.
- [37] According to the Directive "the injured person shall be required to prove the damage, the defect, and the causal relationship between defect and damage" (article 4).
- [38] C.J.J.M. Stolker and D. I. Levine, The reasonable alternative design test, back to negligence?, *Consumer Law Journal*, 1997, p. 41 et. seq.
- [39] Castaing mentions that in 1992, Ford America faced more than 1000 liability cases, Ford Europe, however had just 1 lawsuit. Castaing, F, The effects of Product Liability on Automotive Engineer Practice, in *Product Liability and Innovation, Managing risks in an uncertain Environment*. National Academy of engineers, Washington, 1994.
- [40] Bolt, A.T. en Spier, J., De uitdeinde reikwijdte van de aansprakelijkheid uit onrechtmatige daad, *preadvies Nederlandse Juristen-Vereeniging*, Zwolle 1996, p 237.
- [41] E. Hondius, Tien jaar produktenaansprakelijkheid, *WPNR* 6184, p. 371.

Road Safety Problems and Traffic Accident Trends in Nigeria

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1. Introduction

The Road Traffic Accident (RTA) situation in Nigeria has become a great source of concern. This is because of the attendant huge human casualties, property damage and other socio-economic losses. It is the general opinion of observers and researchers that the road traffic accident (RTA) rates and fatalities in Nigeria rank amongst the highest in the world [1,4,5,6]. Available statistics show that deaths by RTA in Nigeria between 1967 and 1974 was higher than that of any other major communicable diseases in the country [5]. The contribution of RTA to total deaths rose from 38.9% in 1967 to 60.2% in 1974 [6], and this trend has been increasing up till 1982 after which it became erratic. Between 1974 and 1983, the number of accidents increased by 110.6%, total casualty increased by 57.1% while human population increased by 27.2% [7]. The pattern of RTA beyond 1983 shows similar trends.

Studies have shown that some States in Nigeria have individual fatality averages exceeding the national average put at 11 per 100,000 population [8] while the total cost of RTA to the nation is almost 2.2% of GNP by an estimate made in 1992 by the Federal Road Safety Commission.

Several genuine attempts to arrest the obviously undesirable situation have been taken by successive Nigerian Governments at both Federal and State levels. The Nigeria Police Force (NPF) has over the years been equipped with vehicles and equipment to facilitate the enforcement of traffic regulations on road users. Also the existence of Road Transport Officers (RTO) has helped to infuse a measure of sanity on the conditions of vehicles particularly commercial vehicles. All these are complemented by the setting up of the Federal Road Safety Commission to pivot the enhancement and management of road safety and traffic accident reduction in Nigeria. Government efforts in these directions are well intentioned and must be commended. However, these institutional arrangements alone are not sufficient to adequately address the multi-faced problems of road accidents.

Evolving effective RTA mitigative actions will involve understanding the accident process and the road safety problems within the immediate environment. Such an understanding will be based on two principles. The first principle is that accidents are undesirable and must be prevented at all costs. The other principle is that RTA will always occur no matter the remedial measures taken and so strategies for minimising their adverse effects must be sought. Both principles require a reliable database which should allow a

critical analysis of accident causative factors just before, during and after accident events.

This paper reviews the current RTA situation, the trends, the associated problems and the attendant combative measures in Nigeria. The findings are used to identify the strengths and weaknesses of the present system, the institutional arrangements and the administrative framework. The paper concludes with relevant recommendations which if carefully implemented will effectively reduce RTA on Nigerian roads and minimise its adverse effects.

2. Organisational framework for RTA management

Road safety activities and management in Nigeria has transcended from mere ad-hoc events to well articulated programmes directed at mitigating RTA and enhancing road safety. Traditionally, road safety activities such as RTA data collection and collation, accident rescue operations, litigation and prosecution of erring offenders, etc. were performed by the NPF. As a result of the peculiar statutory function of law enforcement of this organisation, little or no attention was placed on road user education and public enlightenment. In addition to the role played by NPF, there also exists Road Traffic Officers (RTO) formerly referred to as Vehicle Inspection Officers, whose responsibilities are to carry out vehicle inspection and certify vehicle road worthiness. As a result of the multi-faceted nature of road safety practices and management, a third governmental body - the Federal Road Safety Commission (FRSC) was set up in 1988 to complement the activities of the NPF and RTO. Through the varied activities and programmes of the FRSC, the citizenry has become more safety conscious, although there is still room for improvement.

Until recently, there has always been mutual suspicion amongst these three government organisations because of the overlap in their respective functions. This has had negative impact on the effective co-ordination of road safety activities and programmes which may have been responsible for the not too significant reduction in RTA trends from 1988 as shown in Section 5.

In the third quarter of 1997, attempt was initiated by the Federal Government of Nigeria to bring the FRSC under the administrative control of the NPF. This has generated a lot of debate and apathy from the general public who preferred the strengthening of FRSC to effectively perform its statutory function. This assertion was based on the argument that the FRSC has by its operations infused sanity into road safety issues in Nigeria. It is hoped that the matter will be promptly resolved so that the success recorded in road safety activities will not be jeopardised.

3. Traffic laws and regulations

Traffic laws and regulations which facilitate safety and security of all road users have undergone a lot of metamorphosis. The first traffic edict in Nigeria is the 1920 Road Traffic Ordinance of Lagos Colony and Southern Protectorates of Nigeria. The 1958 Constitution conferred powers on State Governments to create their own traffic laws. By 1964, the

Northern Regional Government promulgated its own traffic regulations. Since then, several traffic regulations have come into effect in different States of Nigeria. These include the Right Hand Traffic Change Over Act 1969, the Right Hand Traffic Regulations 1972 and the Federal Highways Act 1971, among others.

The multiple traffic regulations did not give room for effective road traffic management. This informed the need for the harmonisation of traffic regulations in Nigeria which consequently gave birth to recently promulgated National Road Traffic Regulation 1997. The highlights of this Regulations include among other things.

- the abrogation of the outdated 1920 Traffic Ordinance which had been in use to date
- the establishment of Directorate of Motor Vehicle Administration in all States of the Federation,
- the centralisation of vehicle registration, vehicle licensing and establishment of central vehicle data bank

4. RTA reporting and monitoring

The RTA statistics analysed in this paper were generated by the Nigeria Police Force (NPF). This is the only organisation which has the statutory mandate to collect accident records in Nigeria. These records are usually kept in a summary form with information such as census of cases reported and casualty records. Since the primary interest and focus of NPF is for litigation and prosecution of traffic offenders, the RTA records and statistics are not comprehensive enough. This is because the specific causative factors prevailing before, during and after an accident are conspicuously missing. This does not allow for meaningful interpretation and analysis of the accident process which would facilitate the planning of effective remedial measures. This notwithstanding the existing RTA data stock when analysed is useful in providing some clues to the RTA trends in Nigeria.

As a result of the RTA inherent problems with current RTA reporting system, a computer-coded format and software for accident reporting was developed by the Nigerian Building and Road Research Institute(NBRRI). Here, the various causative factors which directly or remotely contributed to the accident process before, during and after occurrence, were isolated and coded. The RTA forms were administered by the Lagos State Police Command on a pilot scale in 1989. Details of the outcome of the analysis and interpretation are presented elsewhere. Such an approach can enable better and far reaching deductions to be made about the RTA trends to facilitate carrying out appropriate mitigative actions. Previous attempts to get the NPF adopt this format for the use on a nation wide basis was not very positive. It is however gratifying to note that at the moment, this computerised format is being revised under the auspices of the FRSC, NPF and NBRRI to produce an acceptable National Road Traffic Accident Format for use in Nigeria. On completion, this is expected to be a major component of RTA Information System in Nigeria. Consequently, due consideration is being given to four areas namely, the range and quality of information to be collected; the personnel charged with data collection; the storage and retrieval of information and finally the analysis of the collected data.

Generally, as is common in most developing countries, not all RTA cases in Nigeria are reported. Some accidents not involving deaths are usually settled without involving the Police by the parties who are eager to avoid the bureaucratic bottlenecks which normally accompany litigation process. Furthermore, RTA fatality is at the moment tied to instant death at the point of accident. However, accident record update within the internationally acceptable 30-days period of accident occurrence is not usually practised in Nigeria. In addition, many casualties particularly those with slight injuries resort to treatments in the traditional or orthodox ways or privately without reference to the NPF. The implication of the above is that the official RTA cases and parameters such as casualty figures severity and fatality rates are under reported.

5. Road traffic accident trends

In spite of the deficiencies in RTA reporting system, the trend in traffic accidents in Nigeria is alarming and calls for concern. The pattern of RTA in Nigeria over a 25-year period (1971-1996) is presented in this paper. Table 1 shows the RTA statistics and their analysis in terms of severity rate, casualty rate, deaths per 100 accidents, etc. over the period. The data shows a general increase in reported accident cases, persons killed/injured and severity which peaks around 1982. Thereafter, the fatalities have been fluctuating. It is however observed in Figure 1 that a reasonable correlation exists.

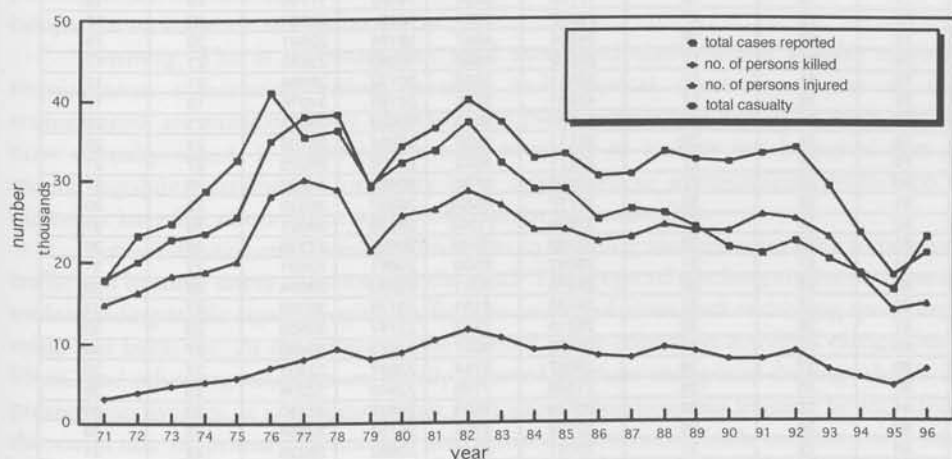


Figure 1. Road traffic accident trends in Nigeria (1971 - 1996).

Figure 2 on the other hand shows the RTA severity and fatality rates in Nigeria over the period. The severity rate refers to the total number of persons killed relative to the total casualty record while the fatality rate refers to the number of deaths per 100 accident cases. The severity ranged between 18-31% with the highest recorded in 1996. Also the deaths per 100 cases ranged between 17 and 39. Between 1981 and 1994, the recorded deaths per 100 cases ranged from 30-39 with the peak of 39 occurring in 1992. These values are very

significant. It is however important to mention that but for the mitigative actions of the Federal Road Safety Commission, the RTA situation may have been worse than its present alarming dimension.

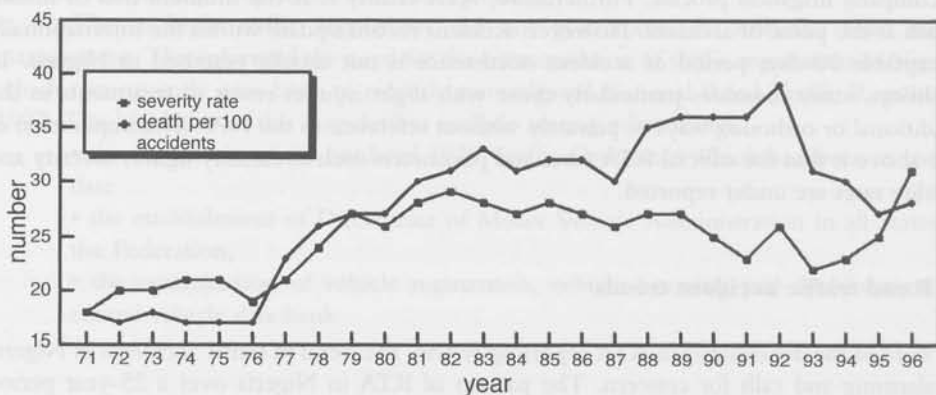


Figure 2. Road traffic accident fatality rate in Nigeria (1971 - 1996).

Table 1. Road traffic accident data and analysis (1971 - 1996).

YEAR	Severity Rate	Death per 100 Accidents	Total Cases Reported	No of Persons Killed	No of Persons Injured	Total Casualty	Severity Rate	Death per 100 Accidents
71	18	18	17745	3206	14592	17798	18	18
72	20	17	23287	3921	1616	20082	20	17
73	20	18	24844	4537	18154	22691	20	18
74	21	17	28893	4992	18660	23652	21	17
75	21	17	32651	5552	20132	25684	21	17
76	19	17	40881	6761	28155	34916	19	17
77	21	23	35351	8000	30023	38023	21	23
78	24	26	36111	9252	28854	38106	24	26
79	27	27	29271	8022	21203	29225	27	27
80	26	27	32138	8736	25484	34220	26	27
81	28	30	33777	10202	26337	36539	28	30
82	29	31	37094	11382	28539	39921	29	31
83	28	33	32109	10462	26866	37328	28	33
84	27	31	28892	8830	23861	32691	27	31
85	28	32	28976	9221	23853	33074	28	32
86	27	32	25188	8154	22176	30350	27	32
87	26	30	26215	7912	22747	30659	26	30
88	27	35	25792	9077	24413	33490	27	35
89	27	36	23987	8714	23687	32401	27	36
90	25	36	21588	7755	23449	32204	25	36
91	23	36	20724	7523	25627	33150	23	36
92	26	39	22178	8701	25154	33855	26	39
93	22	31	20141	6342	22882	29224	22	31
94	23	30	18237	5407	17890	23297	23	30
95	25	27	16217	4448	13649	18097	25	27
96	31	28	22737	6367	14431	20798	31	28

6. Road safety measures

Road safety measures are generally aimed at reducing the risk of an accident occurring. In Nigeria, the three governmental organisations mentioned earlier perform several related

road safety functions most of which overlap. The NPF not only engage in RTA data collection but also in enforcement of safety regulations and litigation. The RTO ensures that vehicles plying the road are roadworthy. The FRSC engage in several road safety measures such as safety education, public enlightenment through the print and electronic media, drama sketches, seminars and workshops, leaflets and hand bills, persuasion and limited enforcement. All the three organisations are however involved in rescue operations. Generally road safety measures can be divided into two. These are:

- **Direct Measures:** these are measures directed at improving road safety. They include road safety activities such as road user education and training, vehicle safety equipment e.g. seat belts and inspection, road safety equipment and black spot improvement; and road safety enforcement.
- **Indirect Measures:** these are primarily intended to improve the conditions of the transport system in general but with focus on safety. These measures include land use, road construction and maintenance, vehicle design and equipment; and medical care services.

6.1 Improvement of road user performance

The road user is the critical element in the road transport system. The performance and the behavioural characteristics to a large extent influence the occurrence and severity of accidents. Relevant safety measures to improve the performance of pedestrians and passengers are in place and these include screening, education training and testing, public campaigns surveillance and enforcement.

Screening: This is to ensure that road users particularly drivers acquire minimum requirements concerning vision, hearing and physical capability. Some of these requirements are mandatory for obtaining the New Improved Driving Licence which is now centrally issued. It might however be necessary to include psychological tests and mental capability particularly for heavy lorry drivers whose irresponsible conduct on the highways have become a major source of concern for road safety.

Safety Education and Training: This refers to teaching road users on how to behave in traffic and become safety conscious on the road. The scope of teaching covers such areas as understanding traffic signs, obeying traffic laws and regulations, not exceeding speed limits, using seat belts, etc. At the moment, the limited safety education activities carried out by FRSC and other organisations are usually directed at adults and special driving schools. For greater effectiveness, it is advocated that road safety education and training be included in the curricular of primary, secondary and tertiary institutions. Such measures will make pupils and students to be safety conscious, develop good knowledge of local traffic situation and impart such knowledge to their peers and families to the benefit of the society.

Road Safety Campaigns: These are usually carried out in the form of media releases, flyers, information leaflets, motor rallies, drama sketches, film shows, slogans etc. The FRSC needs to be commended as significant progress have been made in this regard.

Enforcement of Safety Regulations: This is aimed at ensuring that road users adhere to traffic rules and regulations. In the past, the time loss, procedures and the beauracatic bottlenecks associated with litigation on traffic offenders was usually cumbersome. This

often led to malpractice etc. At the moment, this has been made easier as fines are promptly imposed on traffic offenders except where deaths are involved. However, for enforcement to be rewarding to the society, the following conditions must prevail.

- The traffic regulations must be relevant to the local road user behaviour. This is to enhance enforcement. It is therefore advocated that traffic regulations be reviewed to reflect local needs.
- The mechanism of detecting violation and the penalties imposed on violations must be such that they would serve as good deterrents. Here, there are two schools of thought. The first emphasises very harsh penalties for traffic offences while the other encourages effective detection of all violations. Experience from several countries have shown that in the former case, not all traffic offences are penalised. In the latter case, the imposition of small penalties with an effective detection mechanism ensures that nearly all violations are penalised. This latter scenario is preferred as the accumulation and compounding of small penalties tend to serve as a better deterrent to traffic offenders. This appears to be the focus of the FRSC but they along with NPF need to be adequately equipped with necessary gadgets to enhance their capabilities for early detection of violators of traffic regulations.
- The enforcement strategy adopted should be scientifically derived and routinely adjusted to suit the prevailing situation and in ranking accident prone situations/areas.

Special Marshals: These are volunteers who devote their resources and time to road safety. The Special Marshal Units which are formed in all parts of Nigeria are the creation of the FRSC to complement the efforts of Regular marshals under their employment. The efforts of the Special Marshals have been commendable in traffic control, easing traffic congestion, RTA rescue operations, etc.

6.2 Vehicular safety measures

The characteristics of vehicles affect the risk and severity of accidents. To ensure a high level of safety, vehicles should be well designed, equipped and maintained. Vehicles should have good stability, effective steering and breaking performance, well functioning lights and reflectors and good visibility characteristics. Vehicle occupants can be better protected if safety accessories like head rests, seat belts, special seats for children etc. are provided and their mandatory use enforced.

The current economic situation in Nigeria has had its toll on vehicle ownership and maintenance. The preponderance of Used vehicles, popularly called "Tokunbo vehicles", which are imported into Nigeria has given cause for concern as they can be best described as scrapes. These vehicles at the time of importation are usually very old (sometimes as old as 20 years) and rickety, having outlived its usefulness. To arrest the negative effect, the Federal Government in its budget some years ago banned the importation of used vehicles which are above eight years old.

Generally, as vehicles age, various components of the vehicles such as tyres, break pads etc. wear out and would normally require replacement and maintenance. But many motorists are financially handicapped to carry out regular maintenance due to prevailing

economic constraints, thereby increasing accident risks on Nigerian roads. To arrest this negative trend, the RTOs should be adequately equipped to conduct regular vehicle inspections on a continuous basis. However, they should demonstrate absolute honesty and be of impeccable characters in the discharge of their duties.

6.3 Safety measures related to road characteristics

The risk of road accidents is greatly influenced by the Road characteristics. To ensure high level of safety, the road should be properly designed, equipped, maintained and operated to ensure smooth traffic flow and eliminate sudden elements of surprise. For this, sufficient road width, smooth alignment, suitable location and design of intersections, sufficient sight distances, clear visible signs and markings, good street lights, etc. should be provided on the road for it to perform efficiently. Roads need to be timely maintained to achieve this ideal situation.

In the recent past, the bulk of Nigeria's road network of 200,000 kilometres have undergone various degrees of deterioration due to delayed or lack of maintenance. Roads are deteriorating at a rate faster than new ones are constructed. The consequence of these is that accident risks on several roads are very high. It is however gratifying to note that most of these roads are now being rehabilitated with funds provided by the Petroleum Trust Fund (PTF).

During some road maintenance and rehabilitation activities, adequate warning signs are not installed to warn on-coming drivers. Cases abound where resulting accidents have led to preventable deaths. Closely related to this is the way objects particularly broken down vehicles and construction vehicles are abandoned on roads without adequate warning signs. This increases the risk of accidents on the highway. Appropriate legislation to check this development should be enacted and their enforcement effected by relevant agencies like FRSC. Penalties may include impounding of vehicles and payment of fines.

It is not uncommon to see many roads in Nigeria getting ripped open to install cables, pipes etc. for electricity, water and telephone. Oftentimes, these roads are not repaired to their former status, thus constituting accident risks. Appropriate legislation should be made to forestall this development. Permission should be sought from and adequate refundable deposits made to appropriate agencies before contracting companies embark on cutting up roads for the installation of services. The refund of such deposits can be based on the restoration works.

7. Integrated emergency medical services

When accidents occur, suitable medical care services are necessary to reduce their consequences. Whether an accident victim survives or dies is very much dependent on a number of factors which include:

- promptness of rescue operations and provision of first aid treatment
- the manner of handling accident victims under the attendance panicky circumstances

- the manner, speed and mode of evacuation of accident victims to medical centres which may be at the some distances away from the accident scenes.

While the prerogative for rescue operations mandatorily fall on the NPF, FRSC and the RTOs, the general citizenry often gets involved in rescue operations on humanitarian basis. The rescue operations are largely uncoordinated and ad hoc in nature. Despite the laudable efforts of these organisations and well meaning Nigerians, the lack of requisite facilities and infrastructure have hampered effectiveness in rescue operations. Furthermore since accidents can occur at anytime and anywhere, it is essential that every member of the society be trained on how best to assist accident victims. Such training can be included in the curricula of schools (primary, secondary and tertiary) and extended to members of the National Youth Service Corps Scheme. The scheme refers to the mandatory one year national service for all graduates of tertiary institutions.

It is important for Government to set up an Integrated Emergency Medical Care Services Scheme which will incorporate among other things, an effective ambulance services, a good alarm system for prompting rescue services, construction of accident clinics on major inter-city routes in Nigeria and incorporation of existing designated hospitals like teaching and orthopaedic hospitals.

8. Research development

Research and Development activities are very essential in human endeavour, the road safety sector inclusive. Generally there is a lack of interest of researchers to explore the transportation sub-sector. The reasons for this are unclear. However, NBRRI has several areas where R&D could be carried out in order to generate relevant information which will guide in appropriate policy formulation or review in respect of road safety. While NBRRI is equipped with the manpower to carry out the R&D work, some levels of technical and financial support are required.

9. Financing

Funding is a very important aspect required in road traffic accident mitigation and road safety programmes. The implementation of any of the road safety measures as well as the research and development activities earlier enumerated require funds. However the economic down turn in Nigeria and the competing demands for the scarce federal government funds exert a lot of strain on governmental budgetary allocation not only to research and development activities but also to the road safety sector. Consequently, in the face of dwindling resources to carry out the enormous tasks involved in road safety, multi-national organisations such as UNDP, UNICEF, World Bank, World Health Organisations as well as philanthropists, etc., should fund specific road safety programmes. This gesture will enhance RTA mitigation and road safety in Nigeria.

10. Conclusion

A review of the RTA trend in Nigeria was undertaken to establish the urgent need for appropriate remedial measures. The RTA trend over 25 years (1971 - 1996) presented shows that the fatality and severity rates progressively increased from 1971 and has remained high to date. This is in spite of the establishment of FRSC in 1988 to complement the efforts of NPF and the RTOs in road safety management. The activities of these three organisations in road safety management need to be properly co-ordinated for better performance.

The need for a systematic approach to road traffic accident problems in order to facilitate effective mitigative actions and road safety was highlighted. While attention is currently being paid to road safety campaigns and education, the areas needing attention such as the setting up of RTA Information Management System, establishment of an Integrated Emergency Medical Care Services, review of motor traffic regulations/acts; and enforcement strategies and practices have been mentioned. Furthermore, the need for virile research and development effort and funding of road safety programmes with support from multinational organisations was stressed.

References

- [1] Adebisi, O., 1988, Problems of road accidents in Nigeria; Effective measures to minimise its adverse effects, Keynote paper at the 10th year Anniversary Symposium of Nigerian Building and Road Research Institute, 19 pp.
- [2] Akoto, B.K.A. and Wiredu, Y.K.S., 1986, Road Accident Statistics of various States of Nigeria, Proc. of 1st Inter Conference on Road Accidents in Developing Countries, Asalor, et al (Ed), Joja Educational Research and Publishers Ltd, pp 3 - 20.
- [3] Aladesulu, S.D. and Akinyokun, O.C., 1986, A Case for Road Safety Data base in a developing nation, Proc. 1st Inter Conference on Road Accidents in Developing Countries, Asalor, et al (Ed), Joja Educational Research and Publishers Ltd, pp 21 - 35.
- [4] Department of Civil Engineering, Ahmadu Bello University, Zaria, 1982, Research progress Report on Studies undertaken for the Nigerian Building and Road Research Institute, Project No R1 - 6.
- [5] Central Bank Report, 1993, Annual Report and Statements of Accounts, pp.108-109.
- [6] Ezenwa, A.O. and Osulor, P.C, 1986, Recent developments in the control of road traffic accidents in Nigeria, Proc. Inter Conference on Road Accidents in Developing Countries Asalor, et al. (Ed), Joja Educational Research and Publishers Ltd, pp. 581-587.
- [7] Omange G.N. and Afolabi, O.T., 1990, Road Traffic Accidents in Nigeria: Case Study of Lagos State for 1989, NBRRI Report No 16, 28 pp.
- [8] Yakassai, D., 1997, Enhancing Road Safety through effective maintenance of rural and urban roads, Paper presented at the Round Table Meeting on Road Design, Construction and Maintenance, NBRRI, Abuja, 8 pp.
- [9] Olugbemi, O.A and Adebisi, O., 1986, Factors inhibiting Objective Achievement of Road Accident Monitoring Programmes in Developing a Country, Proc. Inter Conference on Road Accidents on Developing Countries, Asalor, et al (Ed), Joja Educational Research and Publishers Ltd, pp 45 - 55.
- [10] Adiuo, G.O., 1986, The Nature, Variety and Costs of Road Traffic Accidents in Nigeria, Proc. of Inter Conference on Road Accidents in Developing Countries, Asalor, et al (Ed), Joja Educational Research and Publishers Ltd, pp 3 - 20.
- [11] Sverker Almqvist and Christer Hyden, 1994, Methods of assessing traffic safety in developing countries, Building Issues, Vol. 6 National Centre for Habitat Studies, Lund university, Sweden.

Speed Control Project N216

Period under evaluation: 1993 - 1995

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Abstract. In september 1992 a speed control project was initiated on the N216 provincial road between Schoonhoven and Gorinchem. The results of the period under evaluation, 1993-1995, are reported here. The conclusions are:

- a high level of surveillance, in combination with (dynamic) notice boards and lucid information of the public generates a low percentage of offences (1,3%);
- it is essential to maintain a 80 kph limit on stretches of provincial roads (reduction of the amount of accidents with bodily injury with 80%);
- 80 kph is and remains too fast for intersections.

It may be stated with some caution that measures to control speed can play a supplementary part in the pursuit of sustained safety. Its importance might - even on relatively safe stretches - well be much higher than has been hitherto assumed in debates on the principle of sustained safety. Intersections in any case require more radical measures to achieve a situation of sustained safety. It is necessary to reduce speed there to 30 to 50 kph, for instance by constructing roundabouts.

1. Introduction

In 1992, the South Holland South Police Department, the Municipality of Liesveld and the South Holland Provincial Administration jointly agreed to participate in a road safety project where radar equipment would be used to monitor and register traffic violations along the N216 provincial road in South Holland. To this end, seven fixed surveillance points, which could be fitted with radar equipment, were set up near intersections.

The project route is divided into two sections by the traffic lights at the N216-N214 intersection. Both approaches to this intersection are lined with illuminated feedback displays. The intersection itself is not included in the measurements.

The project is supported by eye-catching notice boards along the route and has been given widespread publicity. The police are using a random rotation pattern to ensure that one or two of the seven surveillance points are continually equipped with cameras.

The Provincial Policy Document on Road Safety (June 1991) states that this speed control project is an experiment. In 1992, the Provincial Administration allocated NLG 300,000 for the realisation of this project. In addition, the Ministry of Transport, Public Works and Water Management granted a subsidy to the Municipality of Liesveld to purchase radar equipment for the police department (2 x NLG 80,000).

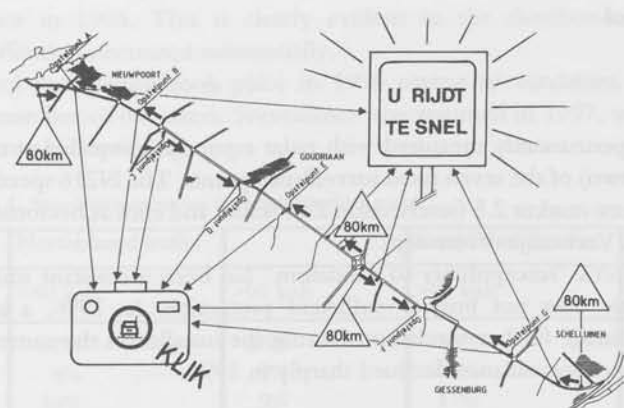


Figure 1.

2. Objectives

2.1 Strategic objective

The ultimate objective of this project is to improve road safety. In this context speed control plays a vital role. The main aim is to reduce speed peaks, rather than average speed. There is incontrovertible evidence that speed control helps to improve road safety.

It is predicted, on the basis of earlier research, that enforcement of the speed limit on 80-kph roads will reduce fatal accidents by 25-50% and injury accidents by 20-40%.

2.2 Tactical objective

The tactical objective of this project targets the driving speed of motorists, taking into account average speed as well as speed distribution. The concrete aim formulated in this regard is that, once the radar equipment has been taken into use, no more than 2% of motorists should drive faster than 90 kph.

Results of past projects have made it clear that credibility is a key factor in achieving the desired results. The credibility of enforcement is therefore central to this project. The chance of being caught should therefore be high and fines should be dealt with succinctly. Motorists must be convinced that they will be fined if they exceed the 80-kph speed limit on the project route.

2.3 Operational objective

The operational objective of this project depends upon the feasibility of the level of surveillance that ensures credibility. This ties in closely with the percentage of motorists that exceed the speed limit. In other words, the feasibility of our operational objective (the processing of fines within agreed staff parameters) is largely dependent upon accomplishment of our tactical objective (no more than 2% offenders).

3. Speed control

3.1 General

Traffic speed is permanently measured with radar equipment installed at no less than one (and sometimes two) of the seven fixed surveillance points. The N216 speed control project starts at hectometre marker 2.5 (intersection Zandkade) and ends at hectometre marker 15.0 (Provincial road/Veersedijk-Veerstoep).

The project's "susceptibility to vandalism" has been a constant source of concern. Fencing evidently does not provide sufficient protection. In 1996, a silent alarm was installed to discourage further vandalism. During the installation the camera's were not in use and the level of surveillance declined sharply in 1996.

3.2 Speed measurements "before"

Speed measurements obtained before the start of the project revealed that about 35% of motorists exceeded the legal limit of 80 kph. Every day, around 1,000 motorists drove faster than 90 kph. This amounts to an average of 20% of daily traffic volume.

The current measurements give no indication of average speed. It is assumed that the average speed is a little under 80 kph.

3.3 Speed measurements "after"

It was predicted that, upon initiation of the project, the number of motorists exceeding the speed limit would be reduced by 90%. The remaining offenders would then amount to 2% of the total traffic volume, which coincides with $\pm 30,000$ fines annually.

Project measurements indicate that violations now total 1.3%, which means the 2% target has been easily met.

The average speed in both directions has decreased from ± 80 kph to ± 73 kph, with a standard deviation of 8.3 kph.

Owing to the low percentage of offenders, it is taking longer than anticipated to fill the films in the cameras. As a result, fines are not being processed promptly. This should be a point of attention, as it affects the credibility of the project.

3.4 Speed measurements at an intermediate, invisible checkpoint

In 1992, 1995, 1996 and 1997, speed measurements in one stretch of road were obtained by means of electromagnetic detectors installed in the road surface of the N216, at hectometre marker 10.5, approximately 200 metres north of a surveillance point. Measurements were made in both directions.

At the surveillance point the camera faces south. As a result, southbound traffic is photographed from behind, while northbound traffic is photographed from the front.

Earlier measurements at hectometre marker 10.5 (in 1992) revealed that 52% of traffic exceeded 80 kph, while 24% exceeded 90 kph on that stretch of road. There was

strict surveillance in 1995. This is clearly evident in the distribution of speeds: the percentage of offenders decreased substantially.

Low level surveillance took place in 1996 owing to vandalism. This led to an increase in the number of offenders. Surveillance was resumed in 1997, which in turn led to a general decrease in speeding.

Table 1. Speed measurements at an intermediate point.

year	Northbound traffic		Southbound traffic	
	>80 kph	>90 kph	>80 kph	>90 kph
1992	52%	23%	53%	25%
1995	8%	2%	14%	4%
1996	38%	9%	17%	5%
1997	32%	8%	12%	35%

This table shows a remarkable difference between northbound and southbound traffic. When northbound traffic reaches the invisible checkpoint, it has already passed the camera, which is directed towards oncoming traffic. This means that traffic that has passed the camera cannot be photographed. This is clearly visible. Motorists therefore accelerate after passing the camera. This is borne out by the above data. It is interesting to note that this did not occur when the level of surveillance was very high (1995), but did occur when the level of surveillance was low (1996). Southbound motorists are aware that they have to pass a camera and, because they are unsure as to the exact point of surveillance, they slow down in anticipation. We may conclude that:

- driving behaviour is strongly influenced by the level of surveillance;
- high levels of surveillance also have a positive effect on driving behaviour in places where there is no surveillance (i.e. less location-specific behaviour).

4. Traffic volume

4.1 Traffic volume on the N216

Before 1 January 1993, traffic volume was periodically monitored on the N216 (then the S38). After this date the volume was permanently monitored.

- In 1987, the average workday volume was 5,906 vehicles.
- In 1990, the average workday volume was 6,785 vehicles.

The measurements revealed that volume increased $\pm 3.5\%$ annually between 1987 and 1990.

- In 1993, the average workday volume was 6,634 vehicles.
- In 1995, the average workday volume was 6,458 vehicles.

It is interesting to note that, contrary to predicted annual growth, traffic volume on the N216 decreased in the 1993-95 period compared to previous years.

4.2 Traffic volume on alternative routes

In the early 1990s, the Dyke Board carried out a major road improvement project. The road surfaces of alternative routes, were renovated. The Melkweg and Peppelweg in 1989, followed by the Gorissenweg in 1991. Owing to the smoother surface, these roads could be negotiated at higher speeds. This offered traffic an enticing alternative route from Groot-Ammers to the A27 via the Peppelweg, Melkweg, Gorissenweg and N214. This is borne out by the data.

- In 1990, average workday volume on the Melkweg was 1,438 vehicles.

A recent count on the Melkweg revealed that average workday volume had increased by more than 500 vehicles. This may partly account for the decreasing volume of traffic on the N216 south of the intersection with the Peppelweg/Melkweg.

5. Accident analysis

5.1 Accidents on the N216

To demonstrate the impact of speed control, accident data obtained before and after the installation of surveillance equipment were compared (see Table 2).

Table 2. Number of accidents on the N216 over two three-year periods (excluding intersection with the N214).

Type of accidents	"before" period: 1989-1991				"after" period: 1993-1995		
	deaths	injuries	deaths + injuries	total	deaths	injuries	total
road-stretch accidents	2	9	11	45	0	2	18
intersection accidents	0	10	10	65	0	17	61
total (excl. N214)	2	19	21	110	0	19	79

The total number of accidents on the N216 decreased by 28% after the speed control project was initiated. The total number of injury accidents decreased slightly.

Speed control had a marked effect on road-stretch behaviour; the number of injury accidents decreased by 82%. At intersections, however, the number of injury accidents increased by 70%. This increase is inconsistent with predictions based on research conducted elsewhere. With this in mind, other possible causes were assessed.

It was apparent that the traffic situation had changed in two ways:

- The Dyke Board's road improvement project gave rise to an alternative route, which resulted in a substantial increase in cross-traffic at the N216/Melkweg/Peppelweg intersection. The large volume of cross-traffic at this intersection is highly detrimental to road safety. In the "after" period, seven injury accidents occurred here, compared to two in the "before" period. This intersection therefore has been replaced in 1997 by a roundabout, to improve road safety.

• Based on perceived risk and danger, centre barriers has been installed at the N216/Nieuwpoortseweg/Graafland intersection. The Municipality of Liesveld insisted upon their installation. Although the provincial authorities initially rejected the request on the grounds of theoretical objections, they eventually acceded after the ANWB (the Dutch counterpart of the Automobile Association) advised in favour of installation. In this case, the accident figures seem to support the theoretical supposition that the separation of conflict points is detrimental to road safety. In the "after" period, six accidents occurred at the N216/Nieuwpoortseweg/Graafland intersection, three of which resulted in injuries. At least two of these accident injuries resulted from the greater complexity of crossing the intersection, which may be attributed to the centre barriers.

Because external factors were responsible for the increase in (injury) accidents at the N216/Melkweg/Peppelweg intersection and some of the accidents at the N216/Nieuwpoortseweg/-Graafland intersection, the figures for the speed control project were reassessed without the above accident data.

Table 3. Number of accidents on the N216 (excluding N214 intersection and accidents attributable to changes in the road situation).

Type of accidents	"before" period: 1989-1991				"after" period: 1993-1995		
	deaths	injuries	deaths + injuries	total	deaths	injuries	total
road-stretch accidents	2	9	11	45	0	2	18
intersection accidents	0	8	8	56	0	8	42
project route total (excl. N214/Melkweg/peppelweg and Nieuwpoortseweg/Graafland section)	2	17	19	101	0	10	60

When accidents at the N216/Melkweg/Peppelweg intersection and some of the accidents at the N216/Nieuwpoortseweg/Graafland intersection are excluded, the total number of injury accidents at intersections remains unchanged. The changing number of injury accidents at intersections gives no clear indication of the effect of speed control. The total number of accidents (including those on road stretches) decreased 41%, while the total number of injury accidents decreased 47%.

5.2 Accidents on the alternative route

Owing to the improvement project of the Dyke Board the alternative route may be negotiated at higher speeds. Accident risk has therefore increased. In addition, a "route shift" has taken place, causing a volume increase of 500 vehicles/day on the alternative route. The speed control project may have contributed to this shift.

This shift is also reflected in the changing number of accidents. There was an

increase in the number of injury accidents at the N216/Melkweg/Peppelweg intersection (included in Table 2) as well as other points along this route. The overall accident figures for the alternative route, from the intersection with the N216 to that with the N214, are listed in Table 4.

To improve safety on the alternative route, an assessment of possible supplementary measures is currently being conducted in collaboration with the Dyke Board of Alblasserwaard and Vijfheerenlanden. Options include speed control measures at intersections with the surrounding roads.

Table 4. Total number of accidents and number of injury accidents on the Melkweg and Gorissenweg.

Type of accidents	"before" period: 1989-1991		"after" period: 1993-1995	
	injuries accidents	total	injuries accidents	total
road-stretch accidents	0	3	1	1
intersection accidents	1	9	4	9
route total	1	12	5	10

6. Conclusions and recommendations

6.1 Conclusions

Project objective

The N216 speed control project has a tripartite objective:

- the strategic objective is to improve road safety;
- the tactical objective is to reduce speed;
- the operational objective is to maintain a level of surveillance that ensures credibility.

Conclusions regarding operational aspects

The project has demonstrated that it is possible to maintain a level of surveillance that ensures the credibility of speed control. The project's "susceptibility to vandalism" deserves attention and should be remedied.

Conclusions regarding speeding

The average speed on the N216 has decreased from ± 80 kph to ± 73 kph. After initiation of the speed control project, only 1.3% of motorists exceeded the speed limit. This is well below the 2% target set at the start of the project. As a result, it is taking longer than anticipated to fill the film cassettes in the surveillance cameras. This has led to a delay in the processing of fines, which should not be attributed to lack of capacity.

Conclusions regarding accident patterns

The total number of accidents decreased by 28% after installation of the surveillance equipment. There was also a slight decrease in the number of injury accidents.

It is interesting to note that the most significant safety improvements were achieved on road stretches. The 80% decrease in injury accidents on road stretches is, however, contrasted by the 70% increase in injury accidents at intersections. This increase centres around the N216/Melkweg/Peppelweg intersection and the N216/Nieuwpoortseweg/Graafland intersection. There has been a substantial increase in crossing traffic at the N216/Melkweg/Peppelweg intersection. The restructuring and improvement of the local road network gave rise to an alternative route from Groot-Ammers to the A27 via the Peppelweg, Melkweg, Gorissenweg and N214. This route can now be negotiated at higher speeds, which has led to an increase in accident risk as well as traffic volume (+ 500 vehicles/day). Permanent surveillance on the N216 may have contributed to increasing traffic volume on the alternative route, which has no such surveillance. In addition, a road-technical adjustment was made at the N216/Nieuwpoortseweg/Graafland intersection, which had a negative impact on road safety.

Exclusion of accidents at the N216/Melkweg/Peppelweg intersection and some of the accidents at the N216/Nieuwpoortseweg/Graafland intersection reveals that the speed limit of 80 kph has no effect on safety at intersections. One may therefore conclude that 80 kph is still too fast for intersections.

The following tentative conclusions may be drawn from this evaluation:

- surveillance of maximum speed on 80-kph roads primarily has a positive impact on road-stretch safety;
- enforcement of the 80-kph speed limit does not improve safety at intersections. Other factors, such as changes in traffic volume, may cancel out the positive effects of speed control at intersections;
- when imposing speed control on main routes, one should not lose sight of lower-order roads.

6.2 Recommendations

Speed control measures can contribute significantly to sustained safety, especially on road stretches. The impact of such measures - even on relatively safe roads - may be even greater than anticipated on the grounds of analyses based on the principle of sustained safety.

At intersections, however, more drastic measures are required to ensure sustained safety. The speed at intersections should be reduced to around 30-50 kph by means of roundabouts¹ and (possibly) raised intersections, in order to bring about a substantial improvement in safety. Furthermore, when striving to substantially improve road safety, one should not lose sight of the lower-order road network in the surrounding area.

¹ In 1997 a roundabout has been realised for the N216/Melkweg/Peppelweg intersection.

References

- A sustainable safe road infrastructure; the start of the realization, First World Congress on Safety of Transportation, 26-27 November 1992.
- Stability of road safety indicators for different scale levels; Verkeerskundige Werkdagen 1995, CROW, Ede 1995.
- Costs and benefits of sustainable safety, Bertus Fortuijn MSc and Gert Weijmans, MSc; Verkeerskundige Werkdagen 1995, CROW, Ede.
- Road categorisation, the relation between triptime criterion, section speed and mashwidth; Bertus Fortuijn MSc and Dick Kramer, Verkeerskundige Werkdagen 1995, CROW, Ede.
- Multi-lane roundabouts: exploring new models, Verkeerskundige Werkdagen 1997, CROW, Ede.

Traffic Flow Characteristics during Recurrent Events on Freeways

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1. Introduction

The flow of vehicles on freeways and expressways is disrupted frequently by various activities including road construction or other expected events, such as police enforcement operations. Road constructions may result from maintenance of a worn-down pavements, widening, adding lanes or building of interchanges or rail overpasses. Police enforcement, on the other hand, is usually shorter in nature, and may include speed limit or headway enforcement or just shoulder presence with an attempt of "traffic calming". The conventional level-of-service and capacity analysis for a basic freeway section is no longer valid for such situations, because of the different flow characteristics that result.

The Israel Public Work Department (PWD) is conducting continuous maintenance operations on various sections of the freeway network while the National Traffic Police (NTP) enforce the rules of the road.

This study evaluated flow conditions at a freeway work site and, at another freeway site where a police patrol car was visibly present on the shoulder. In both cases the free flow of vehicles was interrupted and unusual traffic conditions prevailed including the reduction of capacity at the work area for the duration of the interruption. This created lower level of service resulting in congestion and queues upstream of the work zone and lower speeds and shorter headway between cars when a police car was present on the shoulders of an otherwise undisturbed freeway section.

The objective of the study was to evaluate the traffic flow characteristics during events which can be predicted in advance. Specifically, it was also needed to estimate such parameters as capacity at work zones and variability of headway between vehicles when evaluating the impacts of the noticeable presence of a police car near the roadway.

2. Background of study

The Highway Capacity Manual (HCM, 1994) states that work zone capacity will change based on the type of work done, the equipment used and the number of lanes open vs. the

number of lanes blocked. Some values are provided for work-zone capacities, for example, when one lane out of two-lanes is open then the expected and recommended capacity is 1340 vph, which is about 61% of the ideal capacity. However, these values are subject to change according to the exact conditions at each site, for example the lane widths and the arrangement of the lane closures and also the local flow characteristics such as speeds and headways. Therefore, they can not provide always the necessary information for work-zone capacity and level-of-service analysis.

A similar evaluation was conducted in England by Kelleway (1985) which provides several values of reduced capacity. For example, when two out of four lanes were open then the capacity of each lane is reduced to between 1400 to 1600 vph. Additional values were provided for different numbers of open vs. closed lanes and it was further found that local merging and weaving characteristics also impact the resulted capacities.

Dixon and Hummer (1996) in North Carolina conducted a study on capacity of freeway work zones and found that advance warning and gradual closure of lanes are beneficial to capacities and safety.

The "extra-over" traffic demand, which can not be processed during a recurrent event, because of the reduced capacity, is typically "converted" to queues. These lines of cars are often diverting over time and considerable delay will ordinarily result during peak periods. When all lanes are open to traffic, or when the "external effects" such as a police vehicle presence are removed, then the recovery process begins, although some time could elapse before flow returns to normal and the original capacity values are restored.

A NCHRP study (1990) evaluated methods for freeway incident management and found that during incidents, every 1 minute delay in removing the incident creates, on the average, 4-5 minute delay for vehicles upstream of the incident. The importance of speedy response and proper enforcement is emphasized in many studies. It was also suggested that temporary use of shoulders could considerably help the recovery process.

3. Data collection

Two separate sets of data were collected for this study. One set consisted of data gathered at a work-zone on a suburban six-lane expressway south of Rishon Letsiyon, where two lanes out of three (in one direction) were closed to traffic, a few hours every day for several days, while the pavement was being repaired. The second data set consisted of flow data on a four-lane major freeway section, connecting Tel-Aviv and Haifa, where a National Traffic Police (NTP) patrol car was placed noticeably on the shoulder.

The data at the work zone (site 1), consisted of speed and headway between vehicles in the open lane. It was measured with a video camera, placed near the pavement but in a hidden location, such that the natural traffic flow will not be disturbed. Prior to the location of the work zone, a closure of a single lane took place with the aid of plastic cones that were spread along an approximate taper of 50:1. It must be noted that the lane closure was relatively surprising to most drivers who did not expect this closure to occur at this location, behind an horizontal curve and during the peak period. Considerable back-ups and queues were created upstream of the closing location.

The NTP patrol car was placed in a location (site 2) where traffic flow is sensitive and frequent breakdowns occur during peak periods, mainly because of a combination of two factors: relatively heavy flows at high speeds and adverse geometry prior and after the site. A relatively sharp compound and reverse horizontal curve, existed about 500 meters prior to the site and a busy interchange, with on and off ramps, existed at about 2 km. downstream of this site. The site itself where the patrol car was located was on a tangent section in which an increase in speed usually occurs after the reduction of speed due to the tight horizontal alignment, prior to the site. Data at this site was also collected by a video-camera which was located on a near-by elevated field, about 100 meters from the edge-of-pavement.

The intention of the observations at both sites was to study the effect, on the traffic flow characteristics, of "outside" interrupting effects such as relatively short and unexpected construction operations. At site 2, it was intended to observe the impacts on traffic flow of the presence of noticeable and marked police car on the shoulder, at a high-speed, high-volume location. Specifically, if it could exacerbate the traffic flow conditions and increase the probability of a breakdown, or alternatively improve efficiency and safety.

4. Data analysis and results

The results of the data analysis are to be presented separately for the two sites because of some distinct differences between the traffic conditions studied.

In site 1, the work-zone south of Rishon Letsiyon, several flow phenomenon were observed. First, it was found that drivers did travel at higher speeds while approaching the site than the permitted and advised speed. Two advisory speed signs of 50 km/h were installed at about 500 m. and 800 m, prior to the site. Driver, apparently, did not pay full attention to these speed advisory signs prior to the site and their average approach speed was about 95 km/h, 300 meters before the location where works began. The average speed at the site was about 55 km/h and therefore the speed differential between the approach speed and the speed at the site was about 40 km/h, greater than it should have been for safe and "efficient" speed reduction. Needless to say that this high-speed differential created some hazardous situations - observed in the field by sudden breaks, near misses etc. - and serious concerns for the safety of the Public Works Department and to the Police unit at the work zone.

The analysis was also concentrated on the distribution of flows through the work zone section. The Cumulative Distribution Function (CDF) of peak flows through a one-lane within the middle of the work-zone section, is presented in Figure 1. It can be observed that the values range between about 1,200 vph to about 2300 vph.

The observed average volume values represented capacities because of the continuous feed of vehicles due to the queues. Capacity values was about 1650 vph/lane and the observed 85th percentile was about 2050 vph/lane. Comparing these values to values found in California and reported in the HCM (1994) it was found that the average value is about 41% higher and about 55% higher respectively than pavement repair values, and observed capacities, for some typical operations (one out of three lanes open to traffic)

by the HCM 1995. The 85th percentile value observed, was higher by about 63% than the value of about 1260 vph/lane found in Texas by Dudek and Richards (1982).

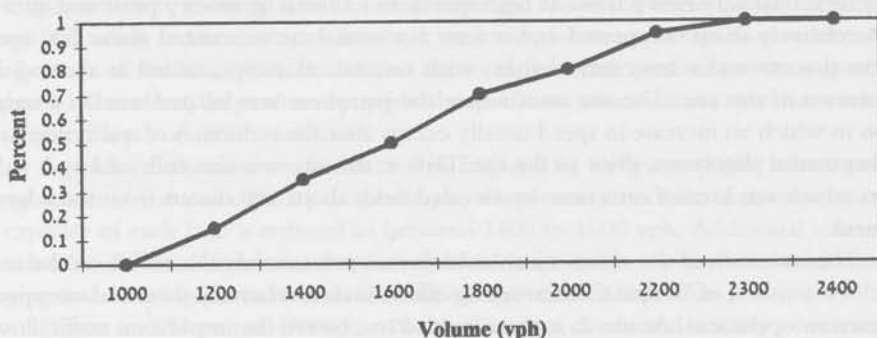


Figure 1. Cumulative distribution function of peak lane volumes through the work zone.

In site 2, where a police patrol car was present on the shoulder of a busy freeway, several observations were detected. Soon after the arrival and positioning of the police car on the southbound shoulders, a significant reduction of about 6.6% in the southbound hourly flow rate was observed. Most of the reduction occurred in the left lane where previously, before the arrival of the police vehicle, high speeds and consequently relatively long headways were observed. The lane volumes and directional flow rates are presented in Table 1.

Table 1. Lane volumes and flow rates before and during the presence of a police car.

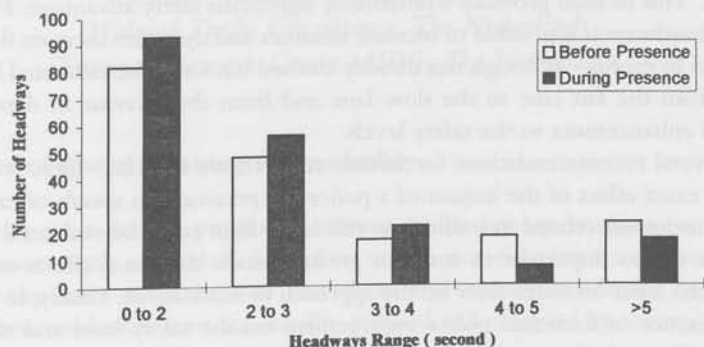
The Measurements Period	Volume at the Right Lane (half hour)	Volume at the Left Lane (half hour)	Total Volume (half hour)	Flow Rate
Before the Arrival of the Patrol Car	584	876	1460	2920
During the Presence of the Patrol Car	581	782	1363	2726
Volume Difference	-3	-94	-97	

Additional observations were conducted on the headways in the southbound direction. Because of video camera visibility and data reduction difficulties, the observations were for the right-lane only. After the arrival of the police vehicle, the average headway went down from 3.2 seconds to 2.99 seconds, a reduction of about 6.5%. The average and standard deviation of headways is presented in Table 2 for the southbound direction.

Figure 2 shows the distribution of the headways in the right-lane before and during the presence of the police vehicle on the southbound shoulder. The following observations were made.

Table 2. Right-lane headways before and during presence of a police car.

The Measurements Period	The Number of Measurements Value	Average Headway (second)	Standard Deviation
Before the Arrival of the Patrol Car	188	876	1460
During the Presence of the Patrol Car	195	782	1363

**Figure 2.** Distribution of headways in the right lane before and during the presence of a police vehicle.

The result showed some "smoothing" of traffic flow during the presence of the police car. This can be specifically observed from the reduction of the headways' standard deviation by about 6.9% from 2.04 seconds to 1.90 seconds, as presented in Table 2. It can also be observed from Figure 2, that there was an increase in the number of small headways in the right lane, during the presence of the police car on the shoulders. This phenomenon resulted from the reduction of speed and the increase in the density, while keeping the volume in the right lane about equal (581 vs. 584 vehicles per 30 minutes).

The safety effect of the increased in density and reduction in speed is not clear: lower speeds reduce risks but at the same time smaller headways resulting from higher densities, have a negative effect on safety. It must also be noted that there was a significant reduction of the volume in the left (fast) lane, after the police vehicle arrived, mainly because many drivers slowed down and moved over to the right (slow) lane.

Therefore, it could be estimated, although no data was available to fully support this conclusion, that the summed safety effect of the police car was positive: it smoothed the headways and, reduced the volume in the fast lane although it increased the density in the slow lane.

5. Conclusions and further research

Several conclusions could be drawn from this study. First, it was found that it is important to enforce the advisory speed prior to a work-zone location. This is primarily for safety reasons but also for efficient traffic flow and maximizing the capacity potentials of the opened lanes. Additionally, it is hypothesized that at a site where one lane out of 3 is kept open, it is highly preferable close initially one lane and then, after 1-2 km. to close gradually the second lane. This will minimize the interruption and distribute the interference along a longer section, thus increasing the probability of a smoother transition of flow.

Second, it was found that the presence of a police patrol car on the shoulders of a busy freeway, stabilizes the fluctuations in flow and reduces the variability between headways. This in itself provides a potentially significant safety advantage. Furthermore, by reducing headways it is possible to increase densities and therefore increase flow efficiencies. Reduction in speeds - although not directly studied but could be estimated from shifting of vehicles from the fast lane to the slow lane and from the increase in densities - provide additional enhancement to the safety levels.

Several recommendations for further research are in order: First, it is important to study the exact effect of the impact of a police car presence on speeds of cars on freeways. Several conclusions related to traffic flow efficiency than could be evaluated more precisely. Second, it is also important to study in greater details the exact effects of the slope and length of the taper on traffic flow on the approach to work zones. Finally, to study the effect of the presence of increased police enforcement on the safety level and efficiency of the flow of traffic, including capacity improvements, at the approach and through a work-zone on a high-speed, high-volume freeway.

References

- Dudek, C and S.H Richards, "Traffic Capacity Through Urban Freeway Work Zones in Texas", Transportation Research Record 869, 1982.
- Karen K. Dixon and Joseph E. Hummer, "Capacity for North Carolina Freeway Work Zones", Transportation Research Board, 75th Annual Meeting, Washington D.C 1996.
- Kelleway, R.C., C.D.White and D.H Matthews, "Delays Caused by Vehicle Incidents", PTRC Summer Annual Meeting 1985.
- NCHRP SYN 156, Freeway Incident Management, Transportation Research Board, 1990.

Sustainable Safety Focusses on Spatial Planning

Coaching townplanning and townscaping on behalf of roadsafety

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1. Importance of spatial planning for roadsafety

The Netherlands are a densely populated country which has repercussion on the traffic. Mobility has enormously expanded. Therefore we do not only need roads with a flow-function, but also have to make sure that there will be safe residential areas. In the Netherlands these residential areas are usually planned and designed by townplanning and townscaping.

By focussing on spatial planning not only road design becomes a point of interest for roadsafety, but also the structure of the road network (and therefore the number of potential blackspots) and even the choice where new residential areas should be located (and therefore mobility, the exposition to risk). It will be clear that spatial planning determines conditions for roadsafety.

In the Netherlands the communication and cooperation between the professions of townplanning and townscaping on one hand and roadplanning and traffic engineering on the other hand needs to be improved. Roadplanners and traffic engineers should have a role as coach for townplanners and townscapers.

2. Contents

This paper first deals with the relation between road planning and townplanning in general. Secondly the paper focusses on trafficplanning and townplanning on the scales of location, structure and design, indicating opportunities for roadsafety once cooperation between townscaping and traffic engineers. Road safety matters, on every scale.

Will the future Sustainable Safe isles, connected by future Sustainable Safe roads, result in better quality of life? A mechanist-approach of Sustainable Safety shall and will not lead to acceptance. The most important point of this paper may be that we should not forget about the the way Sustainable Safety affects daily life!

This paper assumes basic knowledge of Sustainable Safety. If the reader does not know about Sustainable Safety, the publication "towards safer roads" will offer the required knowledge.

3. Relation between trafficplanning and townplanning

There is a strong interaction between trafficplanning and townplanning. On the short term townplanning determines the traffic flows and the demand for traffic network. The place where school is planned, children will go; the place where industries are planned, workers will go; et cetera.

On the long run the traffic-network is a major issue for the location and structure of development areas. Once towns arose at the crossing of roads and rivers, nowadays officebuildings arise near stations and highways etcetera.

Therefore trafficplanning and townplanning cannot be seen separately, but on the other hand townplanning does not only deal with traffic. Preconditions by structures in the landscape, financial preconditions, et cetera should be dealt with as well. Sustainable Safety will seriously affect both trafficplanning and townplanning.

4. Sustainable Safety and trafficplanning

A lot of attention is paid to the function of roads in terms of Sustainable Safety, but the resulting network is only recently point of interest. The mesh of the network of roads with a flow-function and distribution-function results in different expectations for mobility and road-safety.

The mesh of the network of roads also differs for mobility: a fine mesh network of roads with a flowfunction results in an increase of mobility, but also results in an increase of roadsafety. On the same hand fitting in roads with a flow function will not be easy: disintegration, barriers, required area et cetera will call for resistance. This results in a new type of road: the light-flow-function road (in contrast with the "heavy-flow-function road", the current highway), which will be cheaper, easier to fit in, et cetera.

By fitting in distributionroads in rural areas in a smart way distributionroads can be kept to a minimum length. From the point of view of roadsafety this is positive, for these roads will allways have high risk-characterisitics. However if the mesh of roads with a flowfunction is too big, a lot of distribution roads will be necessary.

To maintain the rural areas trafficcalm but well accesible for those who reside there, fitting in traffic-calming measures on the accessroads (rural type of residential roadfunction) can be fit in in a smart way as well.

In Table 1 influence of Sustainable Safety on items like mobility, network of roads, quality of traffic flows, and road-safety are given for the rural area that was studied. These are the most important results of a recent study of Sustainable Safety on a network-level. Several consultants joined together in this study commisioned by the Transport Research Centre (AVV). This study was based on the assumption that people have a steady time-

budget for travelling when a great number of people are taken in account. Remarkable is that roadsafety does not influence quality of the trafficflow in a negative way, but the quality of flow even improves. Furthermore a medium mesh network of roads with a flow-function does not lead to an increase of mobility, but to an increase of roadsafety, even when calculations are made with current risk-characteristic.

Mobility in its essence is a quality, as people will feel the need to work, recreate, et cetera; this should be considered as a right. This right should not be threatened by arguments of road-safety. Nevertheless this should not lead to unbridled growth of mobility. The demands to make a move are not het problem, but the way the moves are made.

By making it possible to use means of transport in a functional way, people can keep developing without a strong increase of car-mobility. For short distances walking and cycling are functional, while for the longer distances public transport and the car are functional. If the growth of mobility is done by public transport, roadsafety will hardly deminish. Even if this means that there will be a lot more pedestrians or cyclists, this will not lead to severe problems for road-safety.

This demands an approach in spacial terms, which asks for cooperation between all professions like townplanning, townscaping, trafficplanning et cetera. This subject is dealt with in the next chapter.

5. Sustainable Safety and townplanning

In the previous chapter the functional use of means of transport were introduced, which demands an integrated approach. In this chapter the integrated approach is described on different scales: location, structure and design of new residential areas. The contents of this chapter are taken from a another study, commisioned by the Transportation Research Centre.

Remember that functional use of traffic can be considered as "make sure that the best traffic is also the logic one". Public transport like trains and busses is good at big bundled trafficflows over a long distance; the car is good at dispers trafficflow over a long distance; slow traffic like pedestrian and cyclists is good at short distances. Therefore in residential areas the pedestrian and the cyclist should be dealt with first. This demands a completely different approach in townplanning and townscaping!

Keep in mind that not only the healthy thirty year old man will be on the street, but also blind people, elderly people and children. Therefore either prevent conflicts or prevent big differences in speed, direction and mass; this is the basic principle of Sustainable Safety.

5.1 Location of new residential areas

Although it is hard to prove scientifically, it is common sense that the location of new residential areas will differ when related to roadsafety. A study on this topic is recently started, but until now no results are available.

Table 1.

rural study		Variate Roadnetwork			
		frame of reference	large mesh net	medium	fine mesh net
Mobility					
total number of moves					
-	local	152.000	155.000	152.000	147.000
-	external	322.000	314.000	321.000	334.000
share public transport					
-	local	3%	5%	3%	3%
-	external	9%	10%	9%	8%
car-kilometers					
-	in area studied	8.685.000	8.546.000	8.398.000	8.909.000
-	on surrounding highways	6.702.000	6.383.000	6.874.000	7.872.000
Network					
length roadnetwork		722	998	827	1124
number of crossings		104	101	88	134
required area		1518	2386	2232	3330
invested capital in 1.000.000 Hfl		3078	4457	4296	6609
Quality of traffic flow					
share of roadlength considered 'good'		88%	93%	95%	100%
Roadsafety					
accidents					
-	stretch	284	284	255	239
-	crossing	105	96	76	89
-	total	389	380	331	328
victims					
-	stretch	395	385	349	324
-	crossing	249	211	165	150
-	total	644	596	514	474
casualties					
-	stretch	17	20	20	22
-	crossing	59	49	38	32
-	total	76	69	58	54

Nevertheless it will be clear that - in general - a location of a residential area that generates more car-kilometers, shall be relatively unsafe compared to one that does not, et cetera. Simply providing required roads to connect this residential area with roads flow-function is

not only a bad start for roadsafety, it costs too much as well. The development of the network of roads and development of functions should be well balanced.

Therefore a traffic planner should coach the townplanner and provide information about generated mobility, costs, roadsafety, et cetera for several alternative locations of new residential areas.

5.2 Structure of new residential areas

The structure of a residential area can be related to roadsafety more directly. An important point is that each structure of roads has potentials for a safe environment. A residential area can be made with several structures like axis, radials, tangentials, grids, loops and forks.

Each structure has bottlenecks and the trafficplanner should provide the townplanner with information where these bottlenecks will occur, how severe they are, et cetera. Vulnerable functions, such as schools, should not be located near these bottlenecks.

5.3 Design of new residential areas

If roadsafety is considered as a matter of roaddesign only, this will result in residential areas with a lot of measures on behalf of traffic-calming like speed-bumps, trees with traffic signs, thus creating an undesired "traffic-landscape" in a residential area. This may however be unnecessary sometimes and can be done in a natural way: change the axis of a road because of a statue, make an arched bridge instead of a bump, etcetera.

Nevertheless it should be considered that these traffic-calming measures are never as effective as a good choice of the location for a residential area or a good choice of a certain structure.

5.4 Recommendations

Seven recommendations in the study for a good structure are given as follows:

- make large yet traffic calm, continuous zones where accomodation of playing, walking and cycling has the priority to accomodating car-traffic; for the Dutch situation these zones could be from 1 up to 1,5 or 2 square kilometer.

If the area chosen is too small, it will not only cost too much, but it will result in high energy-consumption by traffic and unsafety. Also the appearance (visual quality) will be negatively influenced.

If the area chosen is too big, traffic intensities in the zone will be high and the surrounding roads will be a barrier for the inhabitants. This will also lead to unsafety.

- a clear road is a safe road: if roads are "self-explaining" this will lead to the right expectations by the car-driver, such as whether or not to expect pedestrians, how sharp will the road bend and can obstacles be expected. Roads with a flow-function should be uniform; residential roads with an access-function should be diverse (the opposite) and distribution roads should be in between.

- a good structure of roads leads to clear roads: a distributionroad splits up into three residential roads. It should be avoided that a residential area ends up in an

unstructured bunch of houses. In that way search-behaviour by car-drivers can be prevented. Orientation should be made possible using water, green and of course architecture. Within the residential area a hierarchy of roads should be considered unwanted.

- Car-intensities contribute to clear roads. For dutch standards residential roads can deal with intensities up to circa 2500 (rural) or 4000 (urban) vehicles/day. Intensities up to circa 6000 or 8000 vehicles /day appear relatively unsafe as they are neither traffic calm nor appear unsafe to pedestrian and cyclists. In that case behaviour will not be adapted well, so a structure with roads with these intensities should be avoided. The road could be split up into a residentialroad combined with another road such as distributionroad. A distributionroad which is not intensively used will call for speeding by car-drivers and is unwanted as well.

- Crossings should contribute to perception of the type of road. Hierarchy between the three roadfunctions should be clear, not hierarchy within a function. Informal priority should be avoided, especially in residential areas. Roundabouts (crossings with signals if the required area is not available) refer to distributionroads, regular crossings to residential areas.

- Make changes in function and changes in built-up area clear. First of all give them a logic place in the structure of roads. The borderline for the built-up area should be between rural and urban but also near a landmark, a bridge, a line of trees at right angles to the road, et cetera.

- Pay attention to lanes for public transport. In the dutch situation quite a few buslanes have been build. Since heavy vehicles with high speed are introduced in residential areas the way these lanes are fit in are of major importance for road safety. Therefore they should be treated as distribution roads with a limited number of crossings. On the track an informal barrier (like a canal) should prevent crossing.

From these points it may be clear that roadsafety is as much influenced by townscape and townplanning as it is influenced by roadplanning and traffic engineering. Therefore an intense cooperation between these disciplines can avoid that a residential area needs to be patched up directly after it is build. Sustainable Safety can not be seen seperately from a structural approach.

6. Acceptance

We should not focuss only on roadsafety, as there is more to life than driving safe. Spatial quality deals with both functional aspects, visual aspects and future values. As roadsafety is only one of the functional aspects, a mechanist approach of roadsafety should be avoided. People will not accept a traffic calming measure if affects visual quality or future value.

This requires an approach on functions and principles, hardly on rules and design. Think in 3D images, instead of topview drawing. Think quality, not quantity. Think synthesis, not analysis. Words as atmosphere, diversity, et cetera should be introduced in education as roadplanner, traffic engineer and roaddesigner. This way participation and acceptance for roadsafety will increase.

References

- [1] "Towards safer roads, opportunities for a policy to bring about a sustainable safe traffic system" by the Transport Research Centre (AVV). This report can be ordered by telephone +31 10 2825600 or telefax +31 10 2825640.
- [2] "Duurzaam Veilig, mobiliteitsbevorderend?"(1998), written in dutch, by Zandvoort Ordening & Advies, Hofstra Verkeersadviseurs and Walraad Verkeersadvisering commissioned by the Transport Research Centre (AVV).
- [3] "Verkeersveiligheid in nieuwbouwlocaties" (1998), written in dutch, by Institute for Road safety Research (SWOV) and Walraad Verkeersadvisering, commissioned by the Transport Research Centre (AVV).

Table 1. Comparison of road traffic deaths per 100,000 population in the Province of Xishui, China, 1990-1995.

Year	Province of Xishui	Province of Xishui	Province of Xishui
1990	10.5	10.5	10.5
1991	10.5	10.5	10.5
1992	10.5	10.5	10.5
1993	10.5	10.5	10.5
1994	10.5	10.5	10.5
1995	10.5	10.5	10.5

Sustainable Safety on Rural Roads

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1. Introduction

Roads outside the build-up area can be divided in roads for through traffic and access roads. This paper focuses on one category of access roads called the rural roads: public roads, outside the build-up area, narrow and with little function for through traffic.

The main function of rural roads is (historically) giving access to farms etc. Due to the expansion of the agriculture sector, machines and vehicles have become bigger and heavier. Therefore roads have been constructed stronger, wider and more outstretched. As a result, both traffic level and speed have increased, hence traffic safety has declined.

Nevertheless traffic safety on rural roads has not become an issue. Reason behind this is the relatively small number of accidents which occur on rural roads. Compared with the total length of the roads in The Netherlands, rural roads are five times as safe as main roads outside the build-up area. However compared with the total distance made by the traffic on the roads, rural roads are five times as dangerous. In other words: the density of accidents is low, but the risk of being involved in an accident is high.

The district water boards within the Province of Zeeland are responsible for the rational road management of the rural roads. This implies that they are also responsible for the safety of the road-users. HASKONING Dutch Consulting Engineers and Architects has examined the traffic safety situation of the rural roads in the Province of Zeeland under the authority of the district water board "Zeeuwse Eilanden". Important causes of accidents have been identified. The accident potential occur depends on the characteristics of road and its surroundings, although, this influence varies. Based on these findings and fit in the Dutch philosophy of traffic engineers called "sustainable safety", rural roads have been divided into categories. Design criteria have been formulated, related to this categories. It is not possible to reconstruct all roads simultaneously. Areas in which rural roads should be reconstructed first have been placed on a priority-list. This priority-list is based on accident-rates and approximate costs.

2. Traffic safety on rural roads

36.114 accidents happened within the Province of Zeeland in the years 1990 - 1995. Out of these accidents approximately 33% (11.954) happened outside the build-up areas. 3.483 accidents happened on rural roads, which is approximately 10% of the total number of accidents within the Province of Zeeland. When considering the victims the situation on the rural roads is worse. Out of the 6.926 victims all over the Province of Zeeland in 1990

- 1995, approximately 57% (3.924) of the victims sustained their injuries outside the build-up areas, and approximately 17% (1.162) on rural roads.

Analysis of the accidents that have occurred on rural roads in the Province of Zeeland showed that often only one car was involved i.e. cars, leaving the road or colliding with trees. The analysis has also showed that many accidents occurred at curves. These types of accidents were analysed more in detail, with a method named ASPE (analyse of specific characteristics of accidents). The method searches for aspects which influence driving on the location of the accidents.

It is apparent that high speed often plays a deciding role in the circumstances which lead to the accidents. Cars can easily leave the road, on narrow carriageways particularly when the vehicular speed is high, especially at places where there are changes in the road or its surroundings. Furthermore it was mentioned that shoulders are often weak, so when a car leaves the road it is hard to get back on the road.

3. Speed and traffic safety

It is clear that reducing vehicular speed can assist in increasing safety. With lower speed there is more time to correct a driving mistake or a judgement failure. It gives also more time to react.

To lower the vehicular speed it is important to know which characteristics of the road and its surroundings have substantial influence on that speed. Documentary evidence shows that there is little knowledge concerning the interaction between these characteristics and traffic speed. The only important characteristics mentioned are the width of the carriageway and the forward visibility.

Many roads in the Province of Zeeland are constructed in concrete instead of the common macadam. HASKONING has been asked to examine whether the kind of pavement influences the traffic speed. Therefore locations have been selected on rural roads that are similar in appearance, but with different pavement types. At these locations the traffic speed has been measured. Three kinds of pavement (concrete, macadam and paving bricks) were compared. The comparison also included different widths of the roads.

The results of the comparison are listed in Table 1. It shows that there is very little difference in speed driven on concrete and macadam roads. On brick roads the speed is lower. Carriageway width rather than pavement construction is the deciding factor in traffic speed.

Table 1. Average speed (km/h) on roads with different pavements, related to the width of the road.

road width (metres)	concrete	macadam	paving bricks
6.00	75	74	-
3.50 - 4.50	58	58	53
3.00	56	54	51

4. Sustainable safety

Traffic safety has increased in The Netherlands since the early 70's. About 25 years ago the number of fatalities in road traffic was over 3000 every year. This number has decreased to about 1250 persons killed annually. In the same time traffic flow more than doubled.

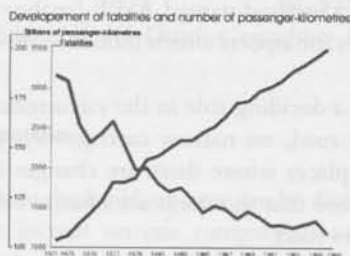


Figure 1.

Some of the successful measures implemented to increase traffic safety during these years were:

- the introduction of safety-belts in car;
- the compulsory helmet use for moped riders;
- the reconstruction/realignment of accident blackspots.

Furthermore the Dutch government formulated a national transport policy and committed construction of a complete network of highways. The local authorities created the so called "woonerven" and residential areas where speed is reduced to 30 km/h or less by road design. The safest roads related to the total distance travelled are highways and roads in residential areas with a 30 km/h speed-limit.



Figure 2.

In recent years the rate of reduction of road accidents has slowed and appeared to stop. A new philosophy to reduce accidents, injuries and fatalities in traffic has been set up in The Netherlands. This philosophy is known as "sustainable safety". The basic idea is to create an inherently safe system. This means that roads are built in such a way that the risk of an accident occurring is minimised and when they do occur there will be no serious injuries i.e. the road's course and people's behaviour on the road are predictable.

For example, on a dual carriageway you expect to drive at 100 or 120 km/h, road use is limited to cars and trucks, and there is no oncoming traffic. These expectations are different in a residential area. The driver is expected to drive 30 km/h or less. There are many kinds of vehicles on the road, going in a multitude of directions and there are pedestrians who utilise the streets such as children playing, and people taking a stroll. These

examples concern the types of roads which are the safest of the different categories as mentioned above. The other roads, also the rural roads, should be as safe as these roads.

5. Functional categories

To establish a safe road network the function of all roads should be defined. In the "sustainable safety" philosophy there are three categories of roads, both inside and outside the build-up area. Outside the build-up area these roads are:

- highways, which have a primary function for through-traffic;
- distributor roads, which have a primary function for rapid access to residential and other areas.
- local access roads; these carry traffic from distributor roads to individual properties; they also have an amenity value as they serve as a public open space within their locality.

For the purposes of this document we are considering rural roads as local access roads outside the build-up areas. The functions of the areas in which rural roads are located vary. There are many agricultural areas. Some areas have an important function for recreation, for example coastal areas, forests, moors, swamps and other areas with special natural features and may have a special environmental function. Lately more and more industrial development takes place outside the build-up area which creates areas with industrial function.

According to these functions, areas have different impact on the traffic within the area and between different areas. An inventory has been made of the functions of the areas in the Province of Zeeland. Based on this inventory the roads outside the build-up areas were divided into local access roads (in this case called the rural roads) and the other roads (distributor roads and highways).

The rural roads which have been selected still have different functions. Roads are used by people for different goals and with different modes of transport. There are for instance (heavy) trucks and machines for (agricultural) business, but also recreational bicycles and horsemen.

It is important to define more specific functions of rural roads to enable the water boards to apply rational road management. Three types of rural roads have been defined by the water boards within the Province of Zeeland:

R1: roads with predominantly a local function, but also through-traffic;

R2: roads with predominantly a residential function, a small amount of through-traffic can occur;

R3: roads with purely a residential function, with no through-traffic.

6. Design criteria

The different functions of the rural roads have consequences for the lay-out of the roads and for the rational road management. Therefore HASKONING translated the functions

into design criteria. The starting point was the goal to increase traffic safety on rural roads by decreasing the vehicular speed. A traffic speed of 60 km/h should be sufficient as an average speed. However it may be desirable to reduce vehicular velocities to less than 60 km/h at special locations. These locations are curves, junctions and places where more activity in the locality can be expected, for example a concentration of houses or farms, a camp side or swimming pool.

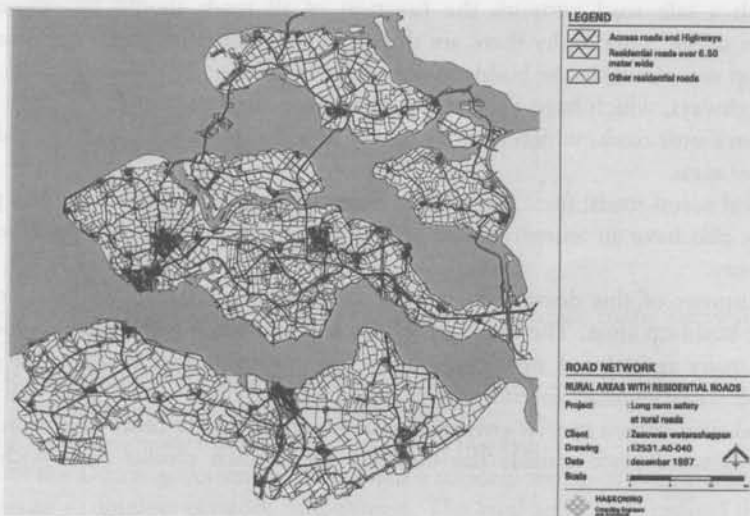


Figure 3.

As previously mentioned the width of the carriageway has an important influence on the vehicular speed. To lower the speed it may be wise to narrow the rural roads. Historically rural roads have become wider and wider, because traffic-flow has grown and trucks and machines became heavier and larger. Hence a change in convention will be needed to narrow rural roads.

In the new design criteria the width of the road is either 3.5 m for class R2 and R3 and 4.5 m for class R1. At the present time no real standard exists. In the past roads have tended to get wider, up to 6 m or even 7 m. As heavy trucks and machines must be able to pass each other, the shoulders should be strong. The shoulders have to be constructed in a way that they can (occasionally) carry the heavy trucks, but they should clearly be a part of the shoulders. The road should be perceived as being narrow by the road users, hence the vehicular speed will be reduced.

In the following tables the design criteria are summarised. The second table shows how different types of rural roads should be connected to each other and to other categories of roads at the junctions. The typical cross sections are shown schematically.

The functions of the rural roads have also consequences for the rational road management. For example on R1-roads there should be more regular inspection of the condition of the pavement and the shoulders. Besides on R1-roads there should be more periodic maintenance, while on R3-roads mainly emergency maintenance is needed. These consequences are mentioned in Table 2.

Table 3. Design of junctions.

	through-traffic (highway)	primary distributor	R1	R2	R3	cyclepath
through-traffic (highway)			No connection			
primary distributor			roundabout: cycles have no priority	connect with parallel road T-junction with road priority		
R1			roundabout: cycles have priority	T-junction with road priority traffic calming measures in R1 and R2 roads		short crossing horizontal traffic calming measures
R2				junction without road priority traffic calming measures		horizontal and vertical traffic calming measures possibility: cycles have priority ("zip-crossing")
R3						
cyclepath						

■ beyond scope of this report

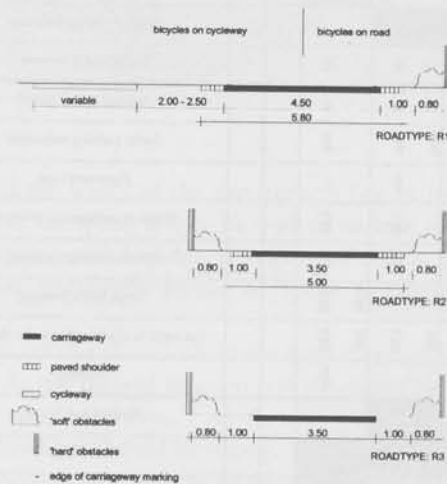


Figure 4. Typical cross sections of rural roads.

7. Priorities

To establish "sustainable safety", all rural roads should be constructed to conform to the design criteria. This will take a long time and a lot of money. As safety has to improve rapidly a transport strategy will have to be formulated. Priorities within this strategy being determined on a cost-effective basis.

Areas have to be selected in which the number of accidents can be reduced with few investments. Taking local measures at locations at which accidents have happened during the last few years is not necessarily the right way. There are hardly any accident black-spots on rural roads. Accidents may happen at one instance at a curve or junction, and the next instance at a different curve or junction. Isolated treatment of local accident black-spots, will not lead to a reduction in vehicular speed.

Measures have to be taken in a complete area, which is clearly bordered. Defined boundaries can be physical features like rivers and lakes. Other boundaries can be the highways and distributor roads. Within the Province of Zeeland the areas that are selected in this way, the rural areas, roads which are difficult to change to conform to the design criteria are excluded. In most cases these are roads over 6.5 m wide. These roads are exempted from the potential roads to redesign. They divide a rural area into smaller areas.

For the areas created in this way the costs of reconstruction are estimated by counting entries, curves, junctions and kilometres of straight road. These are the typical locations where accidents occur, and therefore measures have to be taken. The numbers of these locations are multiplied with standard-prices of simple measures to adapt these kinds of locations. The effectiveness is established by dividing the investments by the number of accidents with injuries and fatalities, that happened in the last 6 years. In this way areas are defined where traffic safety can increase considerably by relatively few investments. The result of this priority system is shown in the figure below.

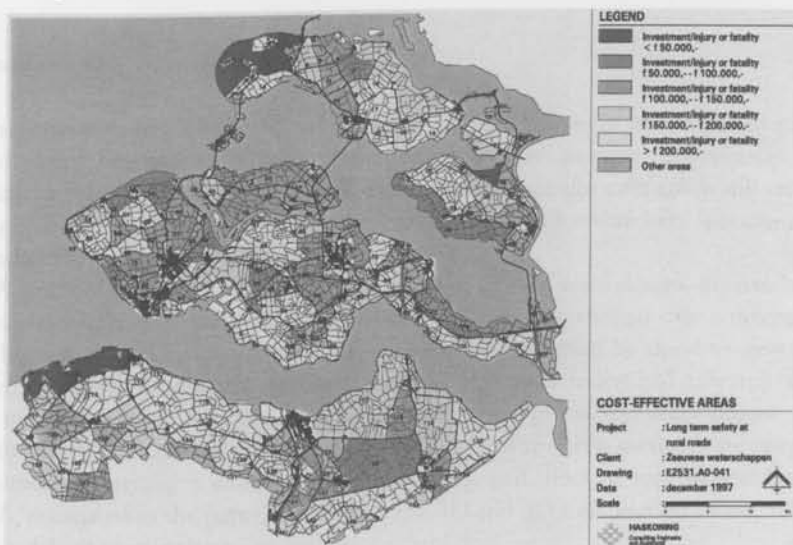


Figure 5.

8. Conclusion

On rural roads the density of accidents is low, but the risk to be involved in an accident is high. In order to create a sustainable safe road transport system, "sustainable safety", it is

important to reduce accidents on rural roads. The best way to achieve this is by a decrease in the traffic speed. 60 km/h should be sufficient as an overall speed. Therefore rural roads have to be constructed narrower. Instead of a standard width in excess of 6 m they should be constructed between 3.5 m and 4.5 m wide. Furthermore shoulders should be partly paved and measures should be taken at special locations to achieve a greater speed reduction.

Because reconstructing all rural roads is expensive priorities have to be set. Cost-effectiveness is a good way to set priorities. Costs can be estimated by counting the number of measures to be taken in an area. Effectiveness can be estimated by counting the number of accidents that happened in that area.



Figure 1. Priorities

To estimate the number of accidents that will be caused by a road network, the number of accidents that will be caused by a road network is estimated. This will be done by counting the number of accidents that will be caused by a road network. This will be done by counting the number of accidents that will be caused by a road network. This will be done by counting the number of accidents that will be caused by a road network.

Relationships between Road Aesthetics, Driving Speed and Safety Evaluation

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Abstract. The project concerns a study and a research in the area of transportation and geometric road design related to road safety. Recent and continual advancements in computer graphics, simulation and virtual reality have made it easier to develop a better understanding of the complex road environment. In order to get safer road design, the relationships between behavioral effect of the 4D road environment and the design road parameters and characteristics have to be understood and described.

This research objective is to investigate, using 3D and 4D visualization methods for road design assessment, the effect of road environment on road safety and, in particular, to describe relationships between road design and environmental parameters and characteristics that enhance road safety. The total goal is to develop a method for road safety evaluation based on a complex information from the road environment.

1. Introduction

There is a common hypothesis that an aesthetic road environment have a positive influence on road users behaviour. This hypothesis imply that positive experiences of road environment contribute to a better traffic safety. How to design safer roads still remains the fundamental question that civil engineers, practitioners and researchers specialising in the field road design are trying to investigate.

A number of unsolved problems exist in the field of road design, human behaviour and road safety.. It is advised that international research is carried out concerning road design, human behaviour and road safety, in which efforts must be done to develop a co-operative research community within Europe. Numerous individual research are being carried out in most of European countries, discussing geometric road design problems related to driver's behaviour and perception. Numerous research methods are employed in these studies, presenting a wide range of traditional and modern approaches. One of the approach, presented in the paper, is based on the 3D and 4D visualisation of alternative road designs and road view perception studies.

Drivers' behaviour is highly dependent on the way he perceive the road environment. It is estimated [4] that 90% of accidents are due to human error. Although the safety of motorists is dependent upon many factors, it depends to a very large extent upon the ease and accuracy with which they can interpret the visible evidence of their immediate surroundings. Their errors are often caused by inadequate road design which can only marginally be changed by information, rules or sanctions [2]. As a means to a safer road design, the concept of self explaining roads (SER) has been developed. In an SER

environment, drivers know how to proceed safely on the basis of the road design [3], i.e. of the road view observed.

The question „What has to be considered in establishing modern highway geometric design guidelines?” is very tempting and exciting. While several important goals for highway geometric design (like capacity, function, economy, environmental protection) are regarded today in more or less satisfying way, great deficiencies still exist when analysing and evaluating the important goal safety. Highway geometric design guidelines should guarantee the design and construction of safe roads. However, that dose not seem to be true. The laboratory experiment presented here concerns a study of subjective evaluation of road aesthetics and road safety.

2. Experimental design

The experimental research objective was to investigate the effect of the dynamic road view on the driver perception of road characteristics and in particular to:

- evaluate the effect of the road category on the perception of road and road environment,
- search for relationships between driving speed and the perception of geometric and environmental road parameters, road safety and the subjective road and road environment aesthetics,
- describe relationships between subjective safety and objective information that the driver receives from the moving road view.

2.1 Stimuli

Ten road segments were selected in southern Poland from different category roads (from I-st class freeways to V-th technical class minor roads) and represented all official road categories. They varied in four groups of parameters, as shown in Table 1.

Table 1. Design and environmental characteristics of the experimental road sections.

sect. nr.	road category	design speed (km/h)	driving speed	road characteristics			road environment		
				lane width (m)	lanes number	side markings	greenery	fields	buildings
1	I	120	110	3,50	4	yes	-	+	-
2	I	120	110	3,50	4	yes	+	-	-
3	II	90	90	3,25	4	yes	-	+	-
4	II	90	90	3,25	4	yes	+	-	-
5	III	80	70	3,25	2	yes	-	+	+
6	III	80	70	3,25	2	no	+	-	-
7	IV	60	50	3,00	2	no	-	+	+
8	IV	60	50	3,00	2	no	+	-	-
9	V	50	40	2,75	2	no	-	+	+
10	V	50	40	2,75	2	no	+	-	-

For each segment a video of the dynamic view was recorded from the driver's point of view, whilst driving with the design speed. Each stimulus was approximately 60 sec. long and covered the uniform characteristics for the road category represented. To eliminate the influence of non manipulated external factors, all sites were filmed in summer driving conditions, good light and weather and none or limited traffic on the road.

The pictures below (Figures 1, 2 and 3) are a static representation of the I-st, III-rd and V-th category road environment used as stimulus material in this experiment.



Figure 1. An example view of the I-st category road.



Figure 2. An example view of the III-rd category road.



Figure 3. An example view of the V-th category road.

2.2 Method

Independent variables constructed geometric road parameters and road environment characteristics, as well as an experimental driving speed.

The experimental dependent variables were the subjectively perceived road parameters and road view characteristics, such as road safety, road aesthetics, road environment and landscape attractiveness and choice of speed.

2.3 Rating scale

The same seven point graphical rating scale was used for six road view characteristics assessments, as in the previous authors studies (Zakowska [5,6]). The theory underlying the choice of this scales has well been documented by Heino et al. [1].

2.4 Subjects

Twenty male licensed drivers ranging in age from 20 to 45 participated in this experiment. The participants were selected to reflect different levels of driving experience, ranging from very experienced professional drivers to inexperienced drivers. Subjects were not paid for their participation in the experiment.

2.5 Procedure

The group presentations were used in the experiment (4 to 5 subjects in one group). Unlike in former experiments (Zakowska [6]) the motion road views were presented with use of a video projector on a large screen, (2m x 3m) in a laboratory environment, giving the

subjects a closer simulation of the real driving environment.

Subjects were seated in a laboratory with a good view of a screen and they were discouraged from communicating with each other. A prerecorded tape of experimental instructions and the practice film were presented as training at the start of the session. The sequences of 10 film clips were presented with 30 seconds of blank film between each picture during which time subjects recorded assessments in response booklets provided beforehand.

3. Analysis of results

The estimates were scored (from 1 for very low, to 7 for very high assessment), recorded, and analyzed using regression statistic. Individual ratings were scored with the help of the EXCEL program and statistically analysed using STATGRAFICS and EXCEL programs. For each dependant variable a separate analysis was performed, based on descriptive methods and one-way ANOVA. The most significant results are presented below.

The effect of road category (road class) on subjective assessment of two characteristics, namely: (1) road safety and (2) road aesthetics are presented in Figure 4. The comparison of subjective mean assessments of those characteristics have revealed that:

- road safety assessments increase with higher road category and these characteristics are well correlated,
- road aesthetics assessments slightly increase with an increase of road category,
- road safety and road aesthetics assessments are better correlated for higher road categories,

Interestingly, there is a relationship between road safety and road aesthetics, although these characteristics are objectively not dependant.

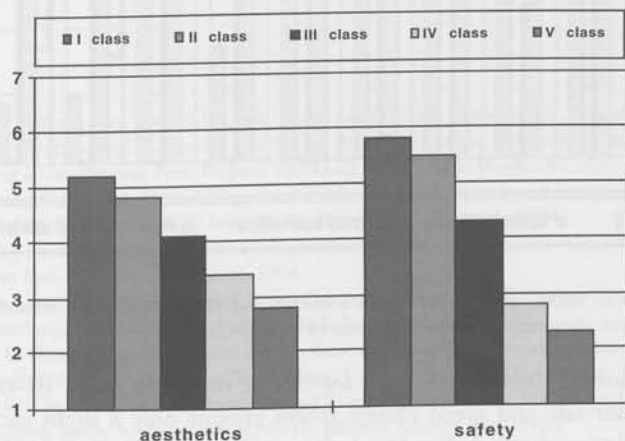


Figure 4. The relationship between subjective road aesthetics and subjective road safety for different road categories.

The effect of road category on subjective road safety and road aesthetics, as shown in Figure 4, is that the IV-th and the V-th class roads were perceived as unsafe, while their aesthetics were assessed more highly, which is probably related to the road environment factors. This is in correspondence to the results revealed for higher road categories, where better infrastructure effected a higher level of safety and aesthetics evaluation.

The way in which choice of speed is related to road characteristics, such as design speed and official road categorisation, is shown in Figure 5. The higher the road category, the faster subjects would drive, in relation to the design speed of each road category. This effect does not always correspond to the subjective road safety, which is documented in Figure 5. For speed choice assessment, score 4 means keeping the same speed (speed limit for each road category), score 1 means dramatic speed limitation, and respectively, score 7 means a high increase of driving speed in relation to design speed.

Despite the poor safety assessment of the V-th class roads, speed choice more or less corresponds to design speed. The IV-th class roads, however, although perceived as rather unsafe, unexpectedly highly scored for the speed chosen for driving (the most dramatic variation between safety and speed choice assessment exceeds two points in the seven points scale). This may explain the low level of safety at this road category, documented in a large number of accidents.

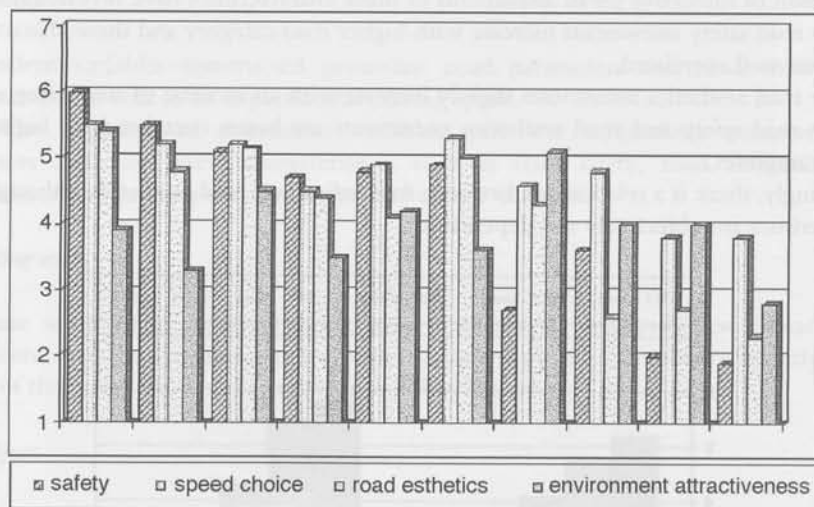


Figure 5. Safety, speed choice, road aesthetics and road environment attractiveness subjective assessments for tested segments of all road classes.

The results (Figure 5) show stabilisation for higher road categories. III-rd class roads are perceived as rather safe and speed choice scores present only a slight increase in driving speed over the designed speed. For II-nd class roads, mean speed and safety estimates are highly correlated, although scores are not the same for each road segment. This result is in corresponds to the earlier findings of Theeuwes [4] in the speed choice experiment based on static stimuli, where it was claimed, that driving speed is related to elements of the

environment. The important elements in determining the speed here, were pavement characteristics, side markings, presence of side-roads, houses, trees, the overview etc. Surprisingly, for I-st class roads, safety assessments exceed the speed assessment scores. Drivers perceive highways as very safe roads and would decide on increasing the driving speed above the speed limit, but no higher than the safety scores.

4. Discussion and conclusions

The present study indicates that road users are able, based on dynamic road-like stimuli, to discriminate between the basic road characteristics in most road categories.

Earlier road perception studies in this series, conducted by the author [5,6], were directed at the lower road categories, while here, special attention was paid to the I-st and II-nd class roads (with 120 and 90 km/h design speed). This study demonstrates that dynamic perception of road infrastructure has a very significant effect on the subjective safety assessment and on the choice of driving speed. Such a road view elements as side lines painted, gentle curves and good preview, or high quality of the pavement, result in higher assessment of road aesthetics. Especially for high road categories, choice of speed is well correlated with the proper perception of the road characteristics. The higher road category, and the higher speed of driving, though, the more attention should be put on the road aesthetics, realised in a total care for the proper road view perception. This study supports the finding of Theeuwes [4], that road behaviour is related to road design. This study furthermore demonstrated, that driving speed is strongly related to the way road users perceive road environment. To achieve safe traffic behaviour, drivers expectations, that the road environment elicits, must be in line with how road users should behave on these road. If this is realised, than one can speak of a genuine self-explaining road environment.

References

- [1] Heino A., Molen, van der, H.H. and Wilde, G.J., Risk-Homeostatic Process in Car Following Behaviour, Electrodermal Responses and Verbal Risk Estimates as Indicators of the Perceived Level of Risk During a Car-Driving Task, Report VK 90-22, VSC Traffic Research Centre, RUG Haren, 1990.
- [2] Ruyters H.G.J.C.M., Slop M. and Wegman F.C.M., Safety Effects of Road Design Standards, Report R-94-7, Leidschendam, NL: SWOV Institute for Road Safety Research, 1994.
- [3] Theeuwes J., Self-Explaining Roads: an Exploratory Study, Report TNO-TM 1994 B-18, Soeterberg, NL: Human Factors Research Institute, 1994.
- [4] Theeuwes J. and Diks G., Subjective Road Categorisation and speed choice, Report TNO-TM 1995 B-16, Soeterberg, NL: Human Factors Research Institute, 1995.
- [5] Zakowska L., Road Curve Evaluation on the Basis of Road View Perception Studies, Doctoral Thesis (unpublished), Cracow University of Technology, Civil Engineering Department, 1994.
- [6] Zakowska L., The Effect of Environmental and Design Parameters on Subjective Road Safety - a Case Study in Poland, Safety Science Journal No.19, Elsevier Science B.V., 1995.
- [7] Zakowska L., Dynamic Road View Research for Road Safety and Aesthetics Evaluation. The 7th ICECGDG Proceedings., Kraków, Fotobit Poland, Vol.I, 276-279, 1996.
- [8] Wegman, F., Road Design, Human Behaviour and Road Accidents: towards a "learning design community". International Conference "Road Safety in Europe" Proceedings, Birmingham, SWOV Report D-96-6, 1996.

- [9] Lamm R., Psarianos B. and Guenther A.K., Interrelationships between Three Safety Criteria, Modern Highway Geometric Design, as well as High Risk Target Locations and Groups. Proceedings of The Third International Conference on Safety and the Environment in the 21st Century, November 1994, Tel-Aviv, Israel, pp.439 - 449, 1994.

Road Safety

Session 4

Research Methods and Common Agenda

1. ... It is a great pleasure to have you with us today and to have you with us today. I am sure that you will find the session very interesting and that you will be able to contribute to the discussion. I am sure that you will find the session very interesting and that you will be able to contribute to the discussion.

2. ... I hope that we will have a very successful meeting and that you will find it very interesting. I am sure that you will find the session very interesting and that you will be able to contribute to the discussion.

3. ... On the basis of current figures and without change in policies, practices and behaviour, it is estimated that the EU will lose an average of 20,000 lives each year due to road accidents. In 1990, 100,000 people were killed each year as a result of road accidents, 50,000 were injured, and more than 2 million were hospitalized, resulting in 100 million additional hospital days. It is estimated that the total cost of road accidents in the EU is 100 billion ECU.

4. ... The economic cost of road accidents is estimated to be 100 billion ECU each year, or about 1% of GDP. The average cost of each person killed is 10 million ECU, and the average cost of each person injured is 1 million ECU.

5. ... There is now a growing awareness that a wide range of strategies is needed to address the problem. The traffic system has to adapt to the needs, needs and vulnerabilities of road users and to the fact that the road user is not a homogeneous group. A multi-strategy approach, with shared responsibility at local, national and European level, involving governments and other institutions as well as user organisations, provides the essential framework for road safety activity. Road safety must be considered a shared responsibility.

6. ... The EU transport policy should focus on safety. I think it is essential for the EU to bring forward practical measures to improve safety in all modes of transport and to prevent road safety in close cooperation with the Member States. The responsibility for this has to a very large degree. It is also the EU, and the Member States need to ensure the needed resources to bring a transition system from the Member States. There is a significant difference in risk between the States where the risk is higher and lower.

- (9) Lewis, R., Paulson, R., and Crowther, A. C. *Intelligence and Security: Their Role in Domestic Violence, Hate Crime, Gender Issues, as well as High Risk, Target Location, and Control*. Proceedings of The Third International Conference on going out on Assignment in the 21st Century, December 1994. *United States*, pp. 475-487. 1994.

Session 4

Research Methods and Common Agenda

The following text is extremely faint and largely illegible. It appears to be a list of abstracts or a detailed agenda for the session, containing several paragraphs of text. Due to the low contrast and blurriness of the scan, the specific content of these paragraphs cannot be accurately transcribed.

Road Safety

Pam Cornelissen

Member of the European Parliament

It is a great pleasure to be here and to have the opportunity to listen to so many distinguished experts on transport safety. It is nice to be back in Delft, where I spent 6 years studying at the technical university. I can assure you that I have the best memories of that wonderful time in this beautiful city. In my intervention I will limit myself to road safety.

1. If three aircraft were to crash every week in Europe each carrying around 300 passengers, we would shut down all air traffic in no time at all. But in the 15 member states of the European Union, 45,000 people are killed each year in traffic accidents; that means 900 every week, and more than 2 million are wounded, resulting in 0,5 million admissions to hospitals of which 25% result in invalidity.

I hope that we all agree that in a civilised world this is not acceptable. It is in fact a disgrace.

On the basis of current figures and without changes in policies, practices and behaviour 1 in 80 of today's citizens living in the EU will die on average 40 years earlier than their life expectancy as a result of a road accident and 1 in 4 of the Union's citizens will need hospital treatment in their lifetime because of serious injuries sustained in road accidents. The pain and anguish caused by these realities is beyond measure. There is, as well, a huge economic price being paid.

The economic costs arising from medical expenses, emergency services, damage to property and lost economic output amount to about 45 billion ECU a year, or almost 1% of GDP. The average economic loss of each person killed in traffic accidents amounts to 1 million ECU.

2. There is now a growing acceptance that a wide range of strategies is needed to address the problem. The traffic system has to adapt to the needs, mistakes and vulnerabilities of road users rather than the other way around. A multi-strategy approach, with shared responsibilities at local, national and European level, involving governments and other authorities as well as non governmental organisations, provides the essential framework for road safety activity. Road safety must be considered a shared responsibility.

3. The EU transport policy should focus on safety. I think it is essential for the EU to bring forward practical measures to improve safety in all modes of transport, and in particular road safety, in close cooperation with the Member States, as the subsidiarity applies here to a very large degree. Neither the EU, nor the Member States need to reinvent the wheel: we can learn a tremendous amount from one another. There is a sevenfold difference in risk between the States where the risk is highest and lowest.

As the rapporteur for the Committee on Transport and Tourism of the European Parliament on the Commission's programme for road safety for the years 1997-2001, I will elaborate on the content of this programme. My report will be on the agenda of the Committee next week and on the agenda of the March plenary session of the EP in Strasbourg.

4. The programme contains three main elements:
- gathering and disseminating information and best practice;
 - measures to prevent road accidents influencing both users and their environment;
 - measures to reduce the consequences of accidents.

In order to implement these, 65 specific measures are proposed. The following are the key ones:

- a recommendation of the Commission to take into account the costs of road accidents in a cost-benefit analysis of road safety measures;
- an integrated EU information system including accident statistics, exposure data, implementation of road safety measures, research, best practice and enforcement;
- measures to combat fatigue and the use of alcohol, medicines and drugs whilst driving;
- application of technology and telematics to ensure safer driving;
- coordination and support of safety rating systems in order to provide scientifically correct information to the consumer on the safety aspects of vehicles.

5. What I find lacking in the Commission's proposal, is the setting of an operational numerical target for fatality reduction. A headline target for the programme would illustrate beyond doubt that the EU commits itself to fostering a substantial improvement in road safety.

Numerical targets have been set in many areas such as air pollution. So why make an exception when it comes to reducing road deaths? I know the arguments against setting targets. I mention for example:

- It is unethical to accept anything other than a zero casualty target.
 - Too many players are involved to be sure that a numerical target will be reached.
- It is true that in the light of subsidiarity the actual achievement of targets cannot be the sole responsibility on the part of EU institutions given the role that member states and others have to play. In the European Union some countries have set a target - for example, the U.K., Denmark, Finland, France, Sweden and the Netherlands.

I would like to underline the relatively good achievements in the countries and regions which have set a clear target in the fight against road accidents. A target at EU level would also

- signal to Europeans that substantial action is now being taken to reduce road traffic accidents and would
- give all the players involved a target for their activity.

I would like to stress the fundamental role that non governmental organisations have to play at every level to get the safety message across.

Let us set this target for fatality reductions. It is my firm belief that we can reduce

annual deaths in the countries of the EU from the current level of 45,000 to less than 25,000 by the year 2010.

6. I would also encourage a ranking of the measures proposed according to their ability to reduce casualties.

A measure which should be a EU priority is improved protection on cars to reduce pedestrian and pedal cyclist injuries. It has been estimated that such measures could produce a reduction of 20,000 deaths and serious injuries a year. Vehicle standards are already decided at the EU level. They should be continuously updated to take account of evolving safety technology.

The ever expanding European New Car Assessment Programme - Euro NCAP - offers the prospect of huge improvements in vehicle safety. A rating system for the safety of cars should also influence the tax structure at national level. If every driver used the safest vehicle in a specific category the number of road deaths could now be cut by 15%. If the existing but not uniform car testing programmes operated by motoring organisations and by some Member States were coordinated and supported by the EU, car buyers and users would be assisted very much in making their choice.

By taking such a course we would be following the example of countries like the U.S.A., Japan and Australia where safety rating systems have been in use for several years.

The introduction of mandatory standards for safer fronts of new types of cars should also tackle the problem of bull bars. In order to reduce the severity of accidents the introduction or improvement of standards for safety equipment and devices (such as seat belts, child restraint systems, airbags, helmets and other collision warning systems and intelligent cruise control systems) plays a major role. It has been estimated for example, that the introduction of daytime running lights for all motor vehicles would cause 5% less fatalities.

7. Road safety should be incorporated in other policy areas (not just transport, but design and regional planning). The proposed Commission's recommendation in the application of the 1 million Ecu test does not seem enough to guarantee political decisions by the different authorities and institutions that will have to establish or implement road safety measures.

A framework directive for safety assessment based on the existing EU legislation concerning the assessment of the effects of certain public and private projects on the environment, would produce a coherent doctrine on transport safety to be drawn up and implemented at Community level. Such proposed legislation should require all relevant legislation and projects (such as the trans-European networks in the transport infrastructure sector) to conform to basic safety principles.

8. We have also to look at ways of making transport behaviour safer. More than 90% of accidents are caused by human errors. More specific measures in this respect should be considered, such as proposals concerning speed limits, speed limitation devices and measures to improve drivers' training and to introduce an EU penalty points system for driving licences.

Since there is a huge flow of international traffic which is growing day by day it does make sense to have a common speed limit, or at least to harmonise existing speed limits.

9. Despite reductions achieved by different countries over the last ten years, many accidents still result from drinking and driving. While less than 5% of drivers drive with excess alcohol, they are responsible for at least 20% of the serious and fatal traffic injuries in the EU - some 9.000 fatalities per year. A reduction in drinking and driving would make a major contribution to the improvement of road safety. A Commission's proposal of 1988 on BAC level for road users introducing an upper legal limit of 0.50 mg per ml blood alcohol for drivers has been "sleeping" in the table of the Council since 1989. The use of breath testing equipment manufactured to a standard suitable for use as evidence should be promoted. When 0.5 mg per ml BAC can impair driving ability to the extent that it increases the risk of accidents by a factor of 2 and when 0.8 mg per ml can multiply that risk by a factor of 10, I cannot understand why the Council of Ministers has not yet been able to come to a decision on this issue.

Drivers must be given precise information on the risks of taking certain medicines or drugs, the danger of which has become clear. Warnings on medicines based upon an EU categorization of their effects upon driving performance could and should be implemented as quickly as possible.

10. In the EU road traffic accidents are the main cause of death for youngsters aged between one and 25 years. It is better to teach young children and teenagers responsible behaviour than to attempt to change, later in their lives, bad habits they may have acquired. Road safety should be a compulsory subject in primary and secondary education.

I also want to stress the role of educational and information campaigns to improve compliance of road users with safe practices and to increase the public acceptability of police controls. The EU should support such campaigns and ensure advertising that promotes road safety.

11. Enforcement of the laws by police and justice authorities is the logical final step to increase observance of the traffic rules.

Enforcement is a complicated question. It is effective if the public has realistic concerns about

- the risk of being caught
- the risk of being prosecuted
- the risk of being convicted
- the amount of the penalty, and the certainty that it will have to be paid.

All elements should be tuned to each other for optimal effect. If one of them is absent no effect should be expected. Also the process should not take too long in order to have impact.

Traffic regulations and sanctions should be harmonised at EU level and the withdrawal of driving licences should be mutually recognised by the Member States. Cooperation between traffic police forces and enforcement authorities, as well as judicial cooperation for this purpose should be strongly reinforced.

12. During the Conference on "Road Safety: a shared responsibility" last year in the European Parliament, the interventions of road accidents victims and families were very impressive. We have a duty to improve their situation.

The EU should produce guidelines on post accident care. The setting up of special emergency teams for first aid and a follow-up of accidents with special attention to the victims should be promoted. We must strengthen the legal position of the victims. We should not forget that many of them have suffered a dramatic and substantial decline in both quality of life and their social and economic situation.

13. Last but not least I must advocate more research in the area of transport safety, in order to stimulate the early application of technological developments and telematics in cars and infrastructures when genuine safety benefits can be expected, such as seat belt warning devices, "smart restraints", speed control devices and alcohol interlock systems. I want to see more money given to this in the EU-budget.

Transport safety is a shared responsibility. Let us not concentrate on what others should do, but let us also give due consideration to what we - and each of us - can do to promote transport safety. Traffic accidents cause so much human misery. Human life is so precious. If we can save thousands of lives by investing in transport safety, let us do it and let us do it now.

Confidential Incident Reporting Systems

A pro-active approach to managing flight safety

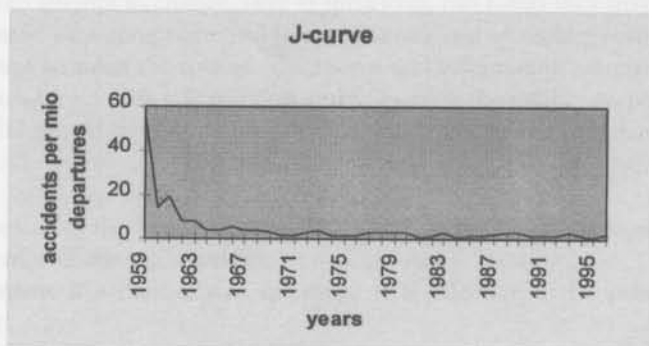
Bart Bakker

Global Aero Consultancies, Past President IFALPA, The Netherlands

1. Aviation safety record

Safety is of major concern to the aviation industry and occasionally to the public, when it is suddenly exposed to often disproportional media-attention after mishaps. Compared to other transportation industries -maritime, rail or road- the aviation industry enjoys a superior safety record. Safety consciousness within the industry, the allocation of resources to safety-related issues, new technologies and improved procedures are among the contributing factors to this record, showing a dramatic improvement over the situation in the late 50's (Table 1).

Table 1.



Nevertheless, there are growing concerns about how to improve, or even how to maintain, this favourable aviation safety record. The ever-increasing seating-capacity of transport aircraft and the continuing growth of global air transport justify these concerns. For example, transport aircraft seating 300 to 500 passengers are now common, and plans for larger aircraft seating over 600 passengers are under way.

Congestion of air traffic at complex hubs is commonplace. The substantial increase in traffic, due to decreasing regulation, is leading to a high demand for aircraft, causing a backlog of new orders, and consequently older types of aircraft have to serve longer. Fierce competition results in financial pressure. Increased demand for aircrews erodes training programs. Maintenance is being outsourced to curb costs or by lack of expertise or qualified

resources. Safety Oversight by understaffed and underpaid authorities can hardly keep up with these changes, and the industry is left to regulate itself.

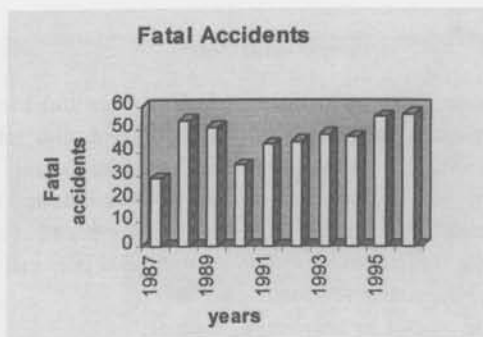
The air traffic control system, under-equipped and under-staffed to cope effectively with the rapidly increasing traffic, has often reached its limits, or is severely like in the African region. What can we do to keep the system working safely?

In the past 30-odd years of regular operation with commercial jets over 20 tons AUW, enough statistical data has been gathered to enable us to gain an insight in air transport safety. According to aviation insurers over 400 western-built jet transport aircraft have been lost in normal operation (excluding sabotage, military action, test and training) either destroyed or damaged beyond economical repair! An average of 13 big jets lost annually!

Productivity in million hours-flown has grown steadily over the last 10 years, increasing the hours flown per total loss from an average of 800.000 hours per hull-loss three decades ago to almost 2 billion hours per hull-loss the last decade, indicating that flying big jets statistically becomes safer each year.

It seems that the average in the last two decades is bottoming out around this level with a substantial total safety increase since the 60's and 70's (table 1). Safety awareness and implementation of lessons learned in the air transport industry, have paid off. A further decrease in hull-losses per hours-flown apparently can only be reached with a disproportional financial investment.

Table 2.



However, with the increasing number of aircraft and departures it means that with maintaining the present safety level, the total number of hull-losses and fatal accidents per year will go up (Table 2).

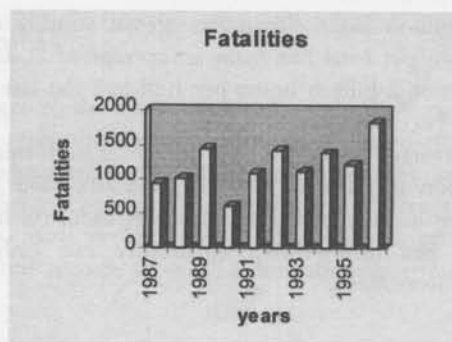
Based upon the predictions of Airbus Industrie air passenger traffic will triple in the next 20 years, growing at an annual world average of over 5%, with an expected aircraft sales world-wide of 16000 new jets with 100 or more seats, of which 1400 550+-seat aircraft. In 2016 just one year's annual traffic growth increment will equal total world traffic in 1967!

Boeing similarly predicts 16.160 new jets between now and 2016 in its "Current Market Outlook". Boeing expects single-aisle aircraft to be the biggest sellers at 11.260 aircraft, with wide-body twins numbering to 3.720, while there will be 1.180 new 747-size aircraft and larger! A simple analysis suggests that in the next 15 years already the annual

number of fatal accidents world-wide will increase by over 25%! An average of one hull-loss nearly every two weeks! Since the number of accidents is roughly double the number of hull-losses: that means an accident every week! And if that involves a fair percentage of megajets, the number of fatalities will soar disproportional (Table 3)!

The bottomline is that the number of hull-losses (and the number of fatalities!) will increase dramatically over the next 15 years, unless the rate of hull-losses can be significantly lowered through a major commitment of the whole industry. If we are to retain the confidence of the travelling public there is a clear need to further reduce the total number of accidents.

Table 3.



1.1 Are accidents expensive?

Safety will not just happen: it must be managed. Accidents and incidents are preventable through effective safety-management. It has been argued that safety management and accident-prevention are difficult to translate into dollars and cents. However, the Icarus-committee of the Flight Safety Foundation has made an attempt to quantify the actual accident-costs. The Committee identifies two basic categories of accident costs:

1. insured costs, including hull-losses, property damage and personal liability, which can be recovered; and
2. uninsured costs which cannot be recovered, such as:
 - insurance deductibles
 - increased operating costs on remaining equipment
 - loss of spares or specialised equipment
 - fines and citation
 - legal fees resulting
 - increased insurance premiums
 - cost of the investigation
 - liability claims in excess of insurance
 - cost of hiring and training replacements
 - loss of business and damaged reputation
 - cost of corrective action
 - loss of use of equipment, and

- cost of rental or lease of replacement equipment.

Some of these costs may be covered by additional insurance or by the government. But the investigation-costs itself can run into millions of dollars, a recent example is the TWA 800-case off Long Island. Accidents are very to extremely expensive.

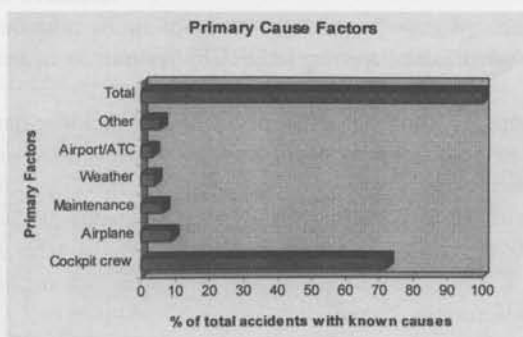
1.2 The Errorfree Flightdeck

When discussing primary causes for accidents in civil aviation, invariably the 70% or so prescribed to human-related causes are called pilot- or crew error, a serious misnomer.

True, there definitely is pilot error, but it should never be forgotten that the cockpit crew is the last defence in a long chain of, inter alia, faulty system-design, wrong procedures, inadequate information and miscommunication (Table 4). So I prefer to speak of human error. To reduce the number of accidents through CFIT (Controlled Flight Into Terrain)- and CRM-programs, and equipment such as TCAS and EGPWS is very important, however if we would be able to eliminate the 70% human errors a giant improvement would be achieved.

In order to provide an error-free environment, first we have to identify what is wrong, and then how to fix it. Incident reporting through feedback from the crew can play a very important role. Similarly, simulator training and line checks can identify possible risks or traps. The fact that many operational crews have successfully used a prototype system doesn't prove that it is safe, or that errors cannot be made.

Table 4.



Since aircraft are used globally its operation should be user-friendly to pilots from many backgrounds and cultures. When a crew consisted of 3 or more crewmembers, there were specialists with different skills, specifically selected and trained for their speciality. A flight engineer would approach and solve a problem in a different manner than a pilot. With a dual pilot operation, the individuals have the same training, the same interest and similar priorities.

A wrongly designed workplace can be changed to be safer and errorfree. In an aircraft, however, a faulty system design or an imperfect flightdeck layout cannot be changed, or at great costs, so the crew has to adapt to it. If we seriously want to strive for the errorfree flightdeck, a concerted effort and input, right from the designphase, between

engineers, manufacturers, regulating authorities, airlines, test pilots and line pilots. Feedback of information through reports and real-time evaluations is very important.

How can we obtain this information? It is obvious that this information should best be available, before an accident happens.

2. Mandatory accident/incident reporting

Even if we consider all the accidents of the last three decades, the number of accidents is, fortunately, too low to give a significant statistical value. It would give us more statistically valid data if we would consider every incident: often the precursor to an accident is a relatively minor event, already occurring many times. The important thing is to collect and interpret all these incidents. Usually incidents are reported to and managed by the airline (delegated by the national authority), while near-accidents (incidents with material damage) have to be reported to the national authority. However, there is no obligation to report and promulgate incidents internationally.

Accidents and near-accidents reported to the national authority usually are recorded in a database. Independently, airline operators and manufacturers also collect accident and incident data. All these databases have their own characteristics and priorities, making them absolutely incompatible.

ICAO, the International Civil Aviation Organisation representing 187 States, should be in the best position to collect and process accident and incident data from its Member States.

2.1 ICAO Accident/Incident Data Reporting (ADREP) System

In 1972 ICAO developed a comprehensive accident and incident data reporting scheme. Designed basically to review and provide trends for the prevention of accidents, ADREP contains data from world-wide accidents and incidents involving aircraft over 2250 kg Take-Off Mass. Presently in total there are over 20.000 reports on file provided by States. After verification data is translated into three of the official ICAO languages: French, English and Spanish, a time-consuming and costly process, taking over 23 months from occurrence until the information is published.

The reporting of accidents and incidents by States to ICAO is inconsistent and sending in these reports is often delayed. Many reports suffer from inadvertent miscoding or fundamental errors and incomplete data. ADREP-data is provided in bi-monthly summaries of accident and incident reports and an annual publication includes statistical data on number of occurrences, injuries and number of persons involved, and a breakdown of events, their phases and the factors involved.

Still, usefulness of ADREP is limited, reflected by the low average of only 200 requests for ADREP-data annually, because

- information is often incomplete;
- ADREP-data do not disclose the State of Registry to avoid sensitivity;
- problems of late and selective reporting by States;

- need for translation in three languages, resulting in significant delays and costs;
- late publication of available data;
- only accident/incident reports from State authorities, not from individuals, and
- lack of interest of States, often promoting their national systems.

The failure of ADREP to provide for an efficient and effective global database of accidents/incidents, might have caused the proliferation of data-management systems by airlines, manufactures and safety authorities. Many of these systems, however, lack the human-factor related data, which is so important to address issues which lead to 70% of accidents and near-accidents.

2.2 Incident management

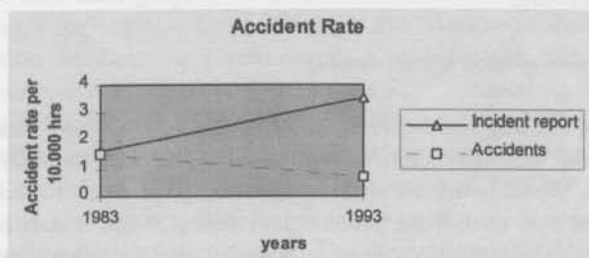
The value of investigating incidents must not be underestimated. Incidents are precursors of accidents: industry-wide estimates suggest that there are approximately 360 minor safety incidents that underlie each accident. It is important therefore, to investigate incidents and analyse trends that may point to potential accidents (Table 5).

It is commendable that many air carriers are developing in-house incident reporting systems. However, this development is not without danger. How does each such a system affect the utility of a national or centralised incident reporting system?

An individual operator may well be able to spot an event of an operational nature, but if it is of an airworthiness type this may not be possible, since the experience of other operators may not be available.

The implementation of an incident reporting system by the Royal Canadian Air Force in 1983 resulted in an impressive decrease in overall accident rate.

Table 5.



source: Royal Canadian Airforce

2.3 Basic elements of confidential incident reporting systems

Before going into the various types of schemes and their effectiveness, I would like to make some general, but important comments to the basic elements of an incident reporting systems.

- An incident reporting system should be confidential: the source of the report should be protected and non-identifiable, in order to stimulate pilots and other users to report as many incidents as possible, without the fear that reporting will lead to

sanctions or repercussions.

- The safety authority should be tasked only to manage the incident reporting system. Litigation, freedom of information acts, liability and judicial prosecutions are elements which have to be carefully studied and regulated if a confidential incident reporting system will have any form of success or effect.
- The safety authority tasked with the collection and interpretation of reports and data should be independent and separate from the regulating authority in order not to confuse responsibilities, and ensure confidentiality. It should answer to a higher, non-judicial authority.
- A supervisory Board, made up of representatives of interested parties, including the regulatory authority, pilots, air traffic controllers, maintenance engineers, airlines, etc., should be regularly following the process, handling of data and confidentiality.
- The operator should have, in addition to a system for reporting to the safety authority, an internal system for receiving and evaluating reports to ensure that everyone will understand the need for safety and the means by which it is to be achieved. It assures the senior airline management that the system is important and working and it acts as a spur to staff to keep the system going.
- Reports and feed-back should be supplied to airline pilots, air traffic controllers, airlines, manufacturers, etc., with safety trends, and a summary of significant de-identified incidents.
- In order to effectively implement safety-trends, there should be a continuous refinement and adaptation of procedures and regulations, identifiable to the safety reports. Temporary regulations should be incorporated into the airworthiness and procedural aviation regulations.

Data should be made available world-wide in order to improve the global safety-level. Formats, definitions, categories and reporting forms should be identical to enable ease of exchange and processing.

2.4 Litigation - freedom of information - liability

Under the present existing regulatory framework the accident and incident investigation process relies on the voluntary participation of pilots, aircraft, manufacturers and by the airlines themselves. We all know too well, information given freely to accident and incident investigators is not and cannot be protected in many States which have implemented Freedom of Information legislation, from later use in civil or criminal proceedings against the very parties that volunteered the information in the first place.

The reason for the voluntary participation of pilots manufacturers and operators is, of course, a collective sincere interest in correcting any correctable deficiency in the overall safety system before it becomes the cause of an accident. The question also arises as to whether or not voluntary participation in the investigative process is worth the possible criminal prosecution - civil liability - administrative action - loss of market advantage that may ensue.

In the US any Federal Government body, such as the FAA, has to release the data of investigations, bringing up the implied threat of lawyers browsing through these data.

The unwitting release of commercially or personally sensitive items would sink any scheme before it had a chance to float.

Unless adequate safeguards are provided for privileged information now voluntarily provided to accident and incident investigators by pilots, manufacturers and operators, the accident investigators will be left alone with a pile of wreckage, a flight data recorder and very little else to go on during the investigation. The travelling public and the industry as a whole would suffer as a result.

3. Incident reporting schemes

Fatal accidents are fortunately few, hull-losses are more frequent, incidents resulting in damage are more frequent, but there are many occurrences which have not resulted in damage or injury, but may indicate a pattern or safety-trend. Collecting and analysing these incidents may be the best way to go for an early identification.

As early as 1983 IFALPA adopted a Policy in which it considers that it is the responsibility of every pilot, besides the mandatory reporting of accidents and near-accidents, to voluntarily submit incident reports, verbal or written, to highlight any deficiency in the aviation system either on the ground or in the air. Member Associations are urged to approach their State authorities to secure the establishment of an incident reporting, included in the national regulation. In order to ensure that such incident reporting system operates with optimum effect and elicits a maximum amount of pertinent information, it is necessary that the full and uninhibited participation of pilots be provided. For this purpose, an incident reporting system should operate on the basis of anonymity and should provide immunity in respect from sanctions arising from the incident. Some of the major programmes are mentioned below.

- **CHIRP.** One such programme in the U.K. is the Confidential Human Factors Incident Reporting Programme - CHIRP, under the auspices of the Royal Air Force's Institute of Aviation Medicine at Farnborough, responsible for the voluntary incident reporting programme, as a subdivision of the Psychology Division on behalf of the CAA. Originally envisaged for aircrew, CHIRP was so successful that in 1986, four years after its start, a parallel reporting systems for Air Traffic Controllers was set up. Soon aircraft maintenance will contribute to the system. The success of CHIRP is continuing and demonstrates the need for such a confidential reporting system. Recently a decision was made to assure funding into the next decade. The strong point of CHIRP is that it is run by a complete independent organisation.

- **BASIS.** In 1990 the British Airways Safety Information System was first created: a system to assess safety risks from incidents throughout the airline by means of a matrix. The assessments are available and communicated to all relevant operational departments, to be validated and prioritised, resulting in improvement to procedures, component change, or investigation. The confidential Human Factors module in BASIS is to provide sufficient evidence by relating Human Factors to risk to ensure improvement. The data stored by BASIS is validated and formatted to allow non-confidential data to be suitable for exchange purposes. Data is exchanged with the U.K. Flight Safety Committee, the European

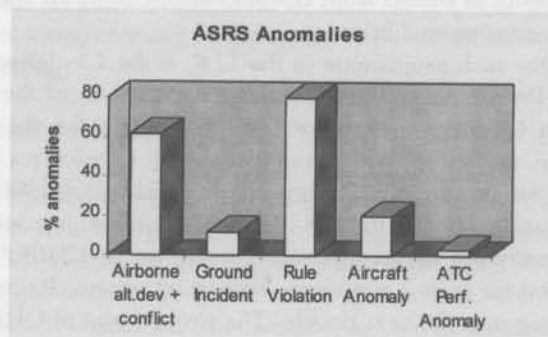
Regional Airlines Association, Air Transport Association of America and Airbus Industrie. More than 100 airlines now have access to BASIS.

- **GAIN.** The FAA is venturing a new reporting system Global Analysis and Information Network (GAIN) along the BA BASIS model. According to the FAA the system GAIN must be privately funded and operated, within a non-punitive framework with improved safety as its only goal. It is interesting to see how GAIN will survive with funding, litigation, the Freedom of Information Act and confidentiality as pitfalls. At least the initiative is laudable, especially when its intended global character can be accomplished.

- **ECC-AIRS.** In 1990 the European Commission established a Task force to harmonise Accident and Incident investigation and management in the European Union, including an EC Incident Reporting System. As IFALPA President I was closely involved in the development of the Mandatory Incident Reporting System, when the IFALPA Study was selected as the winning proposal. The main argument for such a regional system is, apart from the single format and economy of scale, the appeal to country-members with small aviation communities where it is virtually impossible to set up a practical truly confidential system. The drawback of the ECC-AIRS is that there is yet no European Air Regulation Authority, the JAA not being designed for it, and its limitation to EU States. In order to be truly effective it should ideally comprise all 27 European States.

- **ASRS.** In the US the Aviation Safety and Reporting System (ASRS) was established in 1978 to receive, process, analyse, interpret and report data on aviation safety incidents that pilots, air traffic controllers and others voluntarily submit (Table 6). NASA designed and developed ASRS at the request of the FAA, NASA, as honest broker de-identifies the incident reports and operates the system.

Table 6.



Reports to ASRS are treated and processed to guarantee confidentiality to the reporter, an important aspect because many incidents involve inadvertent violations of FAA regulations. Additionally, reporters are granted immunity against FAA punitive action, if reported within 10 days and no violations have occurred within the last 5 years. Criminal offences and accidents, however, are excluded from ASRS.

An Advisory Subcommittee with members of the total aviation industry (including unions) assist the ASRS managers. Airline pilots are the most frequent users. In 1980 several thousand pilot reports were received, in 1993 ASRS received 30,498 reports of which

20,659 pilot-reports were received, and 1356 from air traffic controllers! ASRS data are published regularly in a world-wide publication called *Callback*, as well as on-line on electronic bulletin boards.

Recently the FAA suggested to integrate ASRS into the new GAIN, mainly to secure funding, while NASA would still be tasked to handle the reports to ensure anonymity. It would be interesting to see how immunity would be guaranteed.

ASRS is close to the ideal Confidential Incident Reporting System, although it is limited to the US, and is suffering from cuts in FAA funding. Since 1988 annual funding has remained constant at \$1.9 million. However, ASRS is generally considered a unique source of reliable data.

It is also viewed as the aviation community's early-warning system. An executive of a major US airline noted "ASRS is one of the best safety databases in the system, data may be slightly biased because of the immunity aspect, however, that does not impact the value of the reports as case studies".

4. Small states

In smaller States, or regions with small aviation communities with only a handful of operators and a small number of aircraft movements a day, it is relatively simple to identify crew and operation. In such an environment incident reporting systems are very difficult to sustain, since the most important aspect, "confidentiality", is missing so individuals who wish to file a report will feel exposed and brandished. Still, the need for a confidential incident reporting system in such a small community is even more acute, since there usually is an increased culture of "cover-up and clam-up". If there is a neighbouring State with a well-established confidential incident reporting system, joining or co-operating closely would provide an ideal opportunity.

There should be a protocol to cover the handling of proprietary and commercially sensitive information, the aspect of cross-border litigation to highlight a few of the possible traps and pitfalls. An independent regional safety institute, delegated by the authority to collect, de-identify and manage the incident data-base, could operate as a neutral party amongst all the players in the aviation industry.

Which path will be followed is of minor importance and depends on the local or regional situation. The bottomline is that a sufficiently large and safe operating environment is created to diminish the chance of identification of crew or individuals, that the aspect of confidentiality is assured, and that a protocol is in place between the key-players in the aviation industry, monitored by an independent multi-disciplinary board. Only then will individuals feel encouraged to report incidents and experiences, which, when identified and acted upon, will prevent incidents turning into an accident.

4.1 Measuring safety with incident reporting and flight data

A pro-active approach to follow safety-trends is through incident reporting systems. The collected data has to be analysed, interpreted and divided into selected categories for further

processing and interpretations. But before deductions can be made, first the current level of safety (CLS) in all relevant areas has to be established, the problem areas identified and selected, what is going well and, finally, what improvements are effective.

The sources of information consist of verbal reports, written reports, confidential reports and flight data. All these reports should contain the following information:

- what happened (from participants' perspective);
- why it happened;
- how to prevent it.

With the information from these reports the safety issues of all aspects of the operation and flight regime should be identified and addressed, including maintenance, dispatch, flight support, weather, airport operations and air traffic control.

It goes without saying that the Human Factors aspects of all these factors are of utmost importance and of great interest. If we look at the Human Factors aspects of, e.g. Flight Deck- and ATC operations we should recognise:

- Interaction with Automation
- Information Management;
- Crew Resource Management;
- Workload, and
- Pilot-Vehicle Control Loops.

It is interesting to know that with increased and new technology the role of the pilot and the (ATC) operator also changes: increased automation, new technologies and new operating procedures change established operating patterns and initially increase mental and physical workload. For instance, the use of combined Auto Flight Systems and Flight Management Systems replaces the familiar, well-trained co-ordinated and instinctive manual operation of flight controls and throttles by a series of independent selector inputs along the separate axis of the aircraft. After the introduction of any new technology there has been an increase in accidents and incidents, until the teething-troubles had been weeded out and the new technology mastered and integrated.

In addressing safety issues, therefore, we must identify the problem, identify the cause, identify the solution, make the correction and, finally, evaluate the correction for its effectiveness. What is needed is utilising all available data, also from other sources (manufacturers, airlines, authorities, etc.), to see the whole picture, then determine the full distribution of performance, establish baseline measures and apply powerful statistical methods, like event analysis and distribution analysis, to establish probability, risk and track safety interventions for trends and trend shifts.

4.2 Use of flight data recorders

Flight Data Recorders can provide a wealth of parameters and information, not only after an accident, but to provide information on day-to-day operations. However, litigation, punitive actions and the Big-Brother-is-watching syndrome make pilots and operators weary of the consequences of continuous monitoring. Unless a solid agreement with the Pilots Organisation, the Authorities and the Operator is made, spelling out rules on immunity and anonymity, access to the valuable data under day-to-day operations is very

restricted. In the Former Soviet Union (FSU) and Eastern States, and even now in the CIS, it was (and still is) common practice to evaluate the FDR read-outs after every flight with the crew present. Possible disciplinary action was dealt with on the spot!

Increasingly in the "Western World" agreements are in place and data made available, providing the industry with the best measure of practice versus policy and SOP's. It shows continuously and unobtrusively, events, deviations and the underlying distributions. It can identify malfunctions of ground- and airborne equipment, and even identify improper or wrongly designed procedures. Together with confidential reports it can complete the picture why incidents occur and provides a powerful tool to monitor the standard of operation and increase Flight Safety

4.3 What can we learn from incidents?

The safety information, the deviations from SOP's, the occurrences are a valuable source for training scenarios, where crews can be confronted with safety problems. Proper trend analysis, risk analysis and incidents statistics can provide us with improved guidelines for Flight Deck design and -procedures, as well as with similar guidelines for ATC design and procedures, and Maintenance practices and procedures. It is a continuous task, which has to be executed by a multi-disciplinary team of experts in a Safety Department which should have the proper funds to do their job, in the company structure answering directly to the CEO.

5. Conclusion

A truly global confidential incident reporting system should grant anonymity and immunity, be operated by an honest broker independent from the regulatory or judicial authorities and not operated by an other operator with commercial interests.

Perhaps it will be a pipe-dream to aim for a global confidential incident reporting system, with all its legal, political and financial implications. The aviation industry, in the meantime, should not allow a proliferation of incident reporting systems and schemes, but concentrate on a selected number of viable and proven systems, with all the above quoted ingredients, which will guarantee the greatest number of active participation from all human players in the aviation industry. It is essential that the resulting databases are compatible and data-exchange is freely possible.

The reporting, investigation and analysis of incidents is a highly effective means of accident prevention. If the aviation industry can learn from its incidents there would be fewer accidents, and less headlines in newspapers and less visual aviation drama on the late TV-newsprograms. Accident investigation is sadly done after the accident has occurred and people are long dead and buried. To complement accident investigation we need hazard investigation. Reporting systems must be set up so that hazards can be identified (mandatory and voluntary with immunity and confidentiality).

Mandatory reporting systems tend to gather technical information, whereas voluntarily reporting systems tend to gather human factor information, an area we all know,

needs targeting because the "human" category presents the best opportunity for future improvement in the accident rate.

Safety can be measured with incidents through on-going study of data after application of powerful statistical methods. This will identify safety issues, make us understand causes, and help define intervention strategies to eliminate occurrences and deviations. It can provide the operators with new, improved guidelines and procedures, however, safety interventions have to be tracked to evaluate the corrections. Feedback is essential for trend detection. Data from Flight Data Recorders can be a powerful combination with confidential reports to learn why incidents occur. However, a solid agreement between all players has to be in place covering aspects of litigation, anonymity and immunity, before data can be accessed in a day-to-day operation. Safety incidents can provide pilots, controllers and other operators with training scenarios, where lessons can be learned. It is our duty to protect them from doing that by identifying and correcting the pitfalls in time, before incidents become accidents. That is what safety and accident prevention are all about.

References

- [1] Aircraft Accident & Fleet Activity Data, The Boeing Company, Seattle, U.S.A.
- [2] Dr. John K. Lauber, VP Training & Human Factors, Airbus Service Company, U.S.A.
- [3] Statistical Measures of Safety, Dr. Sheryl L. Chappell, Delta Technology Inc., Atlanta, U.S.A.
- [4] Litigation, Mr. Edmund P. Smart, IFALPA Representative to ICAO, Montreal, Canada.

The Estonia Accident: A Tragic Outcome of not Making a Pro-Active Approach

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Statens Haverikommission, Sweden

I became the director general of the Swedish Board of Accident Investigation in June last year. This means that I do not have very much experience in accident investigation. However, I spent most of my time during my first six months as a director general working with the finalizing of the final report on the capsizing of the ro-ro passenger vessel MV ESTONIA. I was during these months a member of the Joint Accident Investigation Commission of Estonia, Finland and Sweden.

It is not my intention to tell you about all the work the Commission carried out. Neither am I going to go into all the findings, conclusions and recommendations. Those are easily found in the report and I am sure that many of you are well informed on these matters. Instead I like to focus on what - in my opinion - is the most important lesson to learn from this extremely tragic accident, namely that a pro-active approach is essential to avoid accidents and save lives. If international organisations, national authorities, shipowners, classification societies and shipyards had managed to systematize, spread and - with focus on safety - use available information on earlier incidents the ESTONIA accident would probably never have happened.

Let me as a background in a few words go into what caused the ESTONIA to capsize and sink in the Baltic sea on 28 September 1994.

The ESTONIA's bow visor locking devices failed due to wave-induced impact loads creating opening moments about the deck hinges. The visor attachments were not designed according to realistic design assumptions, including the design load level, load distribution to the attachments and the failure mode. The attachments were also constructed with less strength than the simplistic calculations required. It is believed that this discrepancy was due to lack of sufficiently detailed manufacturing and installation instructions for certain parts of the devices. The bow visor locking devices should have been several times stronger to have a reasonable level of safety for the regular traffic between Tallinn and Stockholm.

To prevent misunderstanding I want to make quite clear that to the tragic outcome of the accident contributed also other technical deficiencies and human mistakes. In this context however I want to focus on the construction of the bow visor. The reason for this is that I want to show you what opportunities there were during the years to take action to prevent the accident.

The ESTONIA was delivered in 1980. At that time, despite scattered information, the industry's general experience of hydrodynamic loads on large ship structures was limited, and the design procedures for bow doors were not well-established. Already before the construction of the ESTONIA incidents had happened with bow visors on ro-ro ferries.

Later on, during the 1980's, several serious incidents happened. In many cases involving failure of the visor locking devices the visor started to move - making opening and closing moments. When these moments were visually observed from the bridge, the crew took action and an accident was avoided. The Joint Accident Investigation Commission has without extensive research found information on about 15 incidents with bow visor attachments on ships operating in Scandinavian waters. The Commission has found it fair to assume that a number of incidents have taken place also in other trading areas.

The Commission has specially noted that many of the incidents occurred during the first year of the vessel's operation. This of course indicates that the incidents were not caused by problems concerned with maintenance. The ships involved in all these incidents have all been under the survey of one of four major classification societies.

The Commission has more in detail looked into one of the incidents. This incident happened to the DIANA II, a Swedish-flagged near-sister vessel to the ESTONIA. The visor design of the DIANA II was the same as that of the ESTONIA. The DIANA II operated on a route between southern Sweden and northern Germany. The DIANA II was at sea on the stormy night of the foundering of the JAN HEWELIUSZ in January 1993. According to available information no abnormalities were noticed on the DIANA II. A couple of days later, whilst the vessel was enroute to Sweden, the chief officer to be relieved and the one starting his tour of duty made a joint inspection round throughout the vessel, whereupon they noticed damage to the visor locking arrangements. The classification society was called upon. The survey report shows that the starboard locking device lug was lost, the bottom lock was bent and its welds cracked and the port side locking device lug was bent and its weld cracked. The damage was repaired by normal procedures, to what was estimated to be equivalent to the original standard. The survey report was not by the classification society considered to indicate a serious incident. No initiative was therefore taken to investigate the matter further, nor was any general action taken.

So the fact is that a near-sister vessel to the ESTONIA, under the survey of the same classification society as the ESTONIA, had a serious incident concerning the bow visor attachments in January 1993. This happens to be at the same time as the ESTONIA changed flag from Finland to Estonia and route from more sheltered waters to mainly open sea between Tallinn in Estonia and Stockholm in Sweden. This incident did not lead to reinforcements on any of the two ships.

In most of the other ships, which had had incidents with the bow visor, reinforcements were, however, made during the necessary repair. In several cases reinforcements were also made on sister ships. But in other cases, like in the DIANA II case, the classification society involved was, satisfied with a repair restoring strength of the device to original standard.

The Commission has noted that in several cases the affected Administration communicated with the classification society involved and was satisfied with the information that the strength requirements had been increased. Increased requirements would, however, in accordance with the so called grandfather clause apply to new ships only. Retroactive upgrading of existing ships through rules and regulations with retroactive effect has generally been considered unacceptable within the shipping industry and this attitude has been accepted within the IMO as well as amongst classification societies.

So the fact is that numerous bow visor incidents occurred prior to the ESTONIA accident on vessels built before and after the ESTONIA. These included an incident on the DIANA II, a near-sister vessel to the ESTONIA, but the experience did not lead to systematic inspection and requirements for reinforcement of visor attachments on existing vessels.

Information on bow visor incidents was not systematically collected, analysed and spread within the shipping industry. Thus masters on board had, in general, very little knowledge of the potential danger of the bow visor closure concept.

The classification society design requirements for bow doors became more clearly defined and the design load levels were in general increased after the ESTONIA had been built but, according to established practice, the new rules did not apply to existing vessels. So neither upgrading of design requirements nor the series of visor incidents led to strengthening of locking devices or operative instructions. I think you are correct to say that this shows that the shipping industry has here failed to make a pro-active approach. Feedback or feedforward on the safety issue of bow doors has not been given within a loop of all parties involved - international organisations, national authorities, shipowners, classification societies and shipyards.

The Commission has found the attitude of the shipping industry unacceptable in cases of incidents with serious safety implications. In the opinion of the Commission all amendments to requirements, founded on actual risks having become known, should lead to requirements with retroactive effect, both in IMO regulations and in the rules of the classification societies. The Commission has noted that a move in that direction has taken place since the ESTONIA accident.

In its recommendations the Commission states that procedures for collecting and analysing incident data must be improved and upgrading of existing vessels as regards the safety of human life must become regular. Ways of distributing this information efficiently and internationally must be established. The responsibility for following up the status of existing ships must be taken by the national authorities, supported by the classification societies. I do of course hope that these recommendations will be implemented and that we in the future will see more of feedback and feedforward on safety issues within loops between all parties concerned in shipping.

Flight Safety in the CIS Countries

T.G. Anodina

Chairperson of the Interstate Aviation Committee, Commonwealth of Independent States

Civil aviation as one of the most integral and technologically advanced activity spheres of any developed state cannot stay away from changes in economic infrastructure and socio-political changes in public life. The CIS civil aviation once strictly centralized within the indivisible system of the Soviet "Aeroflot" had to encounter this in full measure.

One can characterize six years of the CIS's civil aviation existence as a transition period accompanied by profound political, economic and social transformations in the whole society, by structural changes in the air transport system of the former USSR when a lot of airlines with different forms of property were formed. The crisis political and economic processes of the transition period led to the recession of solvent demand for air transportation and air operations. It is enough to mention that passenger turnover was reduced 1,5 times and the number of passengers transported was reduced approximately twice. These radical changes in the aircraft transportation and operations structure were taking place in the absence of a sufficient number of specialists qualified for running a self-dependent airbusiness- the managerial staff of a new formation, and we also witnessed the outflow of highly qualified personnel from civil aviation to different commercial structures.

At the same time the development of legal state regulations and branch regulation documents often failed to keep pace with new political and market realities. All this could not but tell upon the level of flight safety. In 1997 we had 42 aircraft incidents in the CIS's civil aviation (in 1996 we had 57), including 14 accidents (in 1996 we had 20), 264 lives were lost (in 1996-293). The analysis of the accident rate in regular passenger air transportations (domestic and international), where scheduled transportations are performed by heavy (more than 10 tonnes) aircraft (75% of the total transportation volume) showed that starting with year 1996 a major improvement of flight safety took place (Table 1).

Table 1.

year	1992	1993	1994	1995	1996	1997
amount of aircraft incidents	19	11	8	11	4	3
accidents included	1	2	3	2	1	0
fatalities	84	198	227	150	5	0
number of written off planes	5	5	4	4	4	2

In 1994 there were 3 accidents in the abovementioned type of transportations, where 227 lives were lost, in 1995 - 2 accidents and 150 lives lost, in 1996 5 lives were lost in one accident. In 1997 there were no aircraft accidents with fatalities in the sphere of scheduled

passenger transportations. Summing up the results of our activities for the past five-year period the World Flight Safety Foundation awarded some of the CIS airlines ("Transaero" of the Russian Federation and "Uzbekiston havoyollari" of Uzbekistan) with its premium for a high level of flight safety.

Charter (unscheduled passenger and freight) transportations by heavy aircraft (more than 10 tonnes) are the main source of accidents. In 1997 we had 9 aircraft incidents, 3 accidents and 207 lives were lost in these transportations. The number of accidents by 100.000 flight hours in unscheduled passenger and freight transportations by this type of aircraft in the period from 1992 to 1997 differs radically from the same index in scheduled passenger transportations. The risk of fatalities in these transportations exceeds considerably the risk of fatalities in scheduled passenger transportations. Figures 1 and 2 give relative flight safety indices for scheduled and unscheduled transportations over the period from 1992 to 1997.

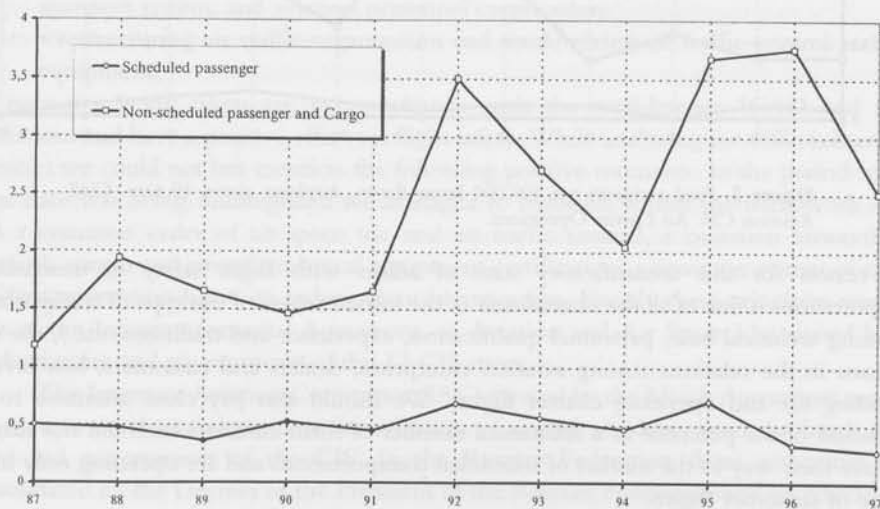


Figure 1. Accidents per 100.000 hours flown. Airplanes above 10 tons. Civil Aviation CIS. Air Carrier Operations.

This is where all our present troubles root in. There were practically no unscheduled transportations in the USSR formerly. These transportations accounted for less than 5% of the total transportation volume. Accordingly we had little experience in organizing such transportations and executing control over them. Unscheduled transportations today make up almost 25% of the total transportation volume and they remain the source of a higher accident rate.

What causes particular alarm is not only a high absolute accident rate level in this type of transportation, but also its negative dynamics, that is leading to a considerable increase of fatalities, when each second or third aircraft accident is accompanied by human losses. In 1997 in 3 such accidents (AI-24, Russian Federation, in the vicinity of Chercsessk, March 18; OO-154, Tadjikistan, Sharjah airport, December 15; BE-42, Ukraine, in the

vicinity of Thessaloniki airport, December 17), 207 people from 208 of those on board were lost!

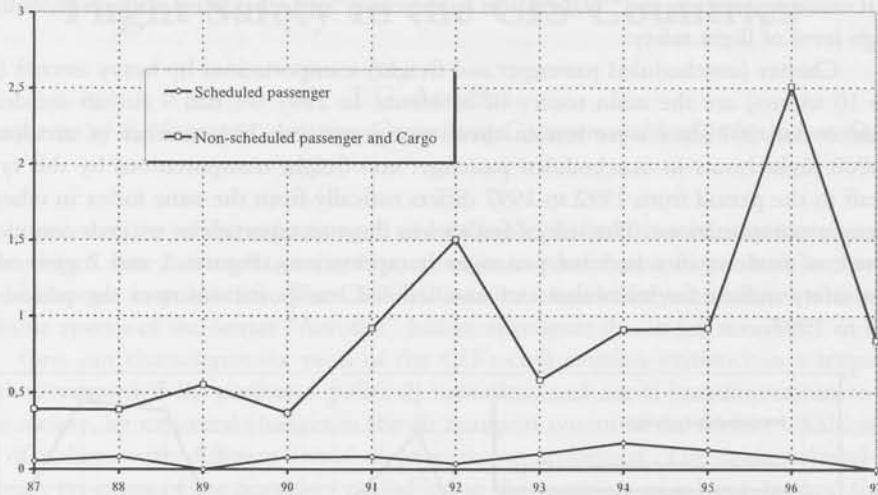


Figure 2. Fatal accidents per 100,000 hours flown. Airplanes above 10 tons. Civil Aviation CIS. Air Carrier Operations.

The reason for this unsatisfactory state of affairs with flight safety in unscheduled transportations is first of all the unreadiness of the infrastructure of this type of transportation (meaning technical base, personnel qualification, experience and traditions, etc.), the state of chaos in the relations among aviation enterprises, dealers and customers, low level of providing for and operating charter flights. We should also pay close attention to the estimation of the potential of a substantial number of small airlines which did not manage to make their way to the market of scheduled transportations and are operating only in the sphere of customer flights.

It should be mentioned that a considerable positive experience and traditions accumulated in the USSR civil aviation which are used today in organizing scheduled air transportation, find practically no application, with the rare exception, in the sphere of unscheduled transportation. Certain new negative factors have arisen.

First of all it concerns violations of aircraft loading and centering, insufficient fueling, deviations from standard flight patterns, ignoring the necessity of making a missed approach or landing on an alternate aerodrome in case of deteriorating weather conditions, etc.

The abovementioned factors have one common characteristic: they result from the fact that new users find it hard and sometimes even impossible to combine their commercial interests with the priorities of providing flight safety.

Finally, transportation flights under regard cannot be effectively controlled by inspectors because of their specific character.

The analysis of aircraft accident causes and factors shows that the composition and correlation of the accident rate factors formed in the recent years remains practically unchanged. The influence of the "human factor" on civil aircraft flight safety stays on the

level of approximately 85%. Approximately 15–20% of aircraft incidents are caused by faults in the aircraft technical equipment.

As a result of aircraft accidents' investigation and special analytical research in flight safety over the period from 1992 to 1997 the Interstate Aviation Committee worked out and presented to all the organizations concerned (aviation administrations, industry, airlines, etc.) more than 1.000 recommendations aimed at improving flight safety. The CIS aviation authorities work out and carry out corresponding measures on the basis of the material available. These measures provide for:

- improving the certification system of the airlines, enterprises and organizations that ensure air transport functioning;
- maintaining airworthiness of aircraft in operation, including the certification of aviation equipment technical maintenance and production centres;
- strengthening the inspection procedures in all the structures that make up the air transport system, and aviation personnel certification;
- restructuring air traffic organization and modernizing air traffic control technical equipment.

All measures being taken are in compliance with the well-known ICAO and IATA resolutions and have a positive effect on flight safety. While analyzing the CIS civil aviation activities we could not but mention the following positive moments. In the period when a huge state was being disintegrated we managed to maintain within the framework of the CIS a common order of air space use and air traffic control, a common airworthiness standards system and aircraft technical equipment certification, a common system of aircraft accident prevention based on independent investigation. Exactly these principles were the basis of the Intergovernmental Agreement on Aviation and Air Space Use signed by the heads of states and governments of the 12 CIS states.

The Interstate Aviation Committee (IAC) formed by the Minsk Agreement received the right to conduct independent investigation of aircraft accidents from the heads of the states and governments of the CIS. In the Russian Federation these authorities were consolidated by the Decrees of the President of the Russian Federation and by government resolutions. We managed to preserve the personnel, scientific and technical potential of the USSR State Aviation Inspection, to develop and maintain the functioning of a unique group of experts and the technical basis of independent investigation.

Long-term experience confirms that the principle of independent and objective investigation is correct. The basic principle of independent investigation is that the body conducting the investigation and working out preventive measures should not have authoritative powers and supervision functions. On the other hand, the aviation administration invested with such authoritative powers should not interfere with the process of investigation and should not formulate the cause of the accident. This principle allows the investigative body that does not participate in transport administration to estimate the transport system functioning quite objectively and to work out recommendations on carrying out corrective measures independently of the political situation and existing norms and demands. When the investigation is being conducted by other organizations that also have regulative functions in their responsibility the conflict of interests is bound to arise. The Interstate Aviation Committee being the successor of the USSR State Aviation

Supervision has been conducting independent investigation since 1991.

The popularization of the independent investigation principle led to the establishment in 1992 of the Association of Independent Bodies of Investigation on Transport set up by NTSB (USA), TSB (Canada), SHK (Sweden) and the Netherlands. After the necessary legal examination in 1994 the investigative bodies of Finland, New Zealand and the CIS (IAC) joined the Association.

Further development and introduction of the independent investigation principle in aviation found its reflection in the European Council Directives dated November 21, 1994 (94\56\EC), according to which each member state of the EC should provide for the conduction of investigation by a permanently functioning body or under its control. This body should be functionally independent, especially from the national aviation administration. The European Council Directives also provide for possible delegating of the right to conduct investigation to some other member country of the Agreement.

The next step in the development of integration processes in the sphere of aviation accident investigation is likely to be the establishment of abovenational bodies, as we cannot rule out the possibility of investigating the role of united administrations.

Furthermore, a relatively small number of accidents means that every separate state investigative body is unable to gain enough experience, while this experience is absolutely necessary for an effective and qualitative investigation. That is why there is a tendency for the regional grouping of investigative bodies. Presently this issue is being discussed in national and international aviation organizations (ITSA, IATA, etc.). We shall in every possible way support and promote any integration processes and maybe our experience in maintaining the investigative infrastructure of the former USSR could turn out to be of use to the world community. In this connection international cooperation in the sphere of aviation accident investigation takes on special significance. The necessity of uniting the efforts of the international aviation community is to a considerable degree conditioned by the fact that accident investigation today is in essence a rather complicated scientific-research work, that not only requires special knowledge in certain activity spheres, but also needs financing. Serious investigation calls for united resources and knowledge, cooperation and mutual use of unique specialists- investigators. The experience of our long-term cooperation with the US in the sphere of aviation accident investigation and prevention proves that such collaboration has its advantages.

For the period from 1989 to 1997 we held more than 10 joint investigations. Close cooperation among specialist on a high professional level in this joint work allowed to make a considerable contribution to a higher flight safety. For example, as a result of a joint investigation of the accidents with Su-29 and Su-31 aircrafts in the U.S.A. in 1995 recommendations aimed at the improvement of production technology of construction elements from composition materials were developed. Our joint investigation of a serious incident with B-757 aircraft in Ekaterinburg in 1996 resulted in working out recommendations aimed at the improvement of the undercarriage construction as well as the improvement of technical maintenance quality of the whole B-557 aircraft fleet.

As known, a repeated investigation of the incident with South-Korean B- 747 aircraft brought down in 1983 over Sakhalin was undertaken in 1993. This repeated investigation held by the international committee under the aegis of ICAO with close

collaboration among Russian, French, Korean, Japanese and American specialists made it possible to objectively complete the analysis of this tragedy and work out recommendations excluding future recurrence of such incidents. A number of serious achievements has also been obtained in the sphere of scientific and technical maintenance of investigations: automated processing of flight parameters and reconstruction of emergency situations within a real time range, equipping acoustic laboratories with modern means of signal identification, introducing new methods of metallographic analysis, etc. Within the framework of international cooperation information data exchange on flight safety is of particular importance. Using modern possibilities of computer engineering techniques and the world electronic set Internet, the whole world aviation community can establish principally new information links. The Interstate Aviation Committee takes active part in this work in cooperation with colleagues from other countries.

And finally one last issue: we are concerned and we know that the whole world is concerned about the fact that aircraft crews are to a large degree getting used to automatic flights. The more we do to ease the work of the crew, automatizing all the procedures, trying to leave less to the pilots, the more it becomes difficult to ensure the adequate work of the crew when switching from the automatic flight regime to the manual if such a necessity arises. It revealed itself several times not only in our country, but also abroad, and this requires adequate reaction.

In 1996 the IATA considered the necessity of carrying out additional research on the highly automatized pilot cabins. We also have some additional requirements for automatized systems concerning the elimination of the monotonous character of flight. We entirely support these IATA initiatives, in particular we discussed them at ITSA and ISASI regular meetings, and we suggest that the international aviation community should combine its efforts to research this new most important problem of modern aviation.

In conclusion I would like to emphasize once again the following points:

1. A considerable increase for the last years of flight safety level in the sphere of domestic and international scheduled transportations in the CIS countries and especially in Russia, as well as positive dynamics beginning to show in the sphere of unscheduled (charter) flights.
2. The experience of regional integration in the sphere of providing independent aircraft accident investigation, realized within the framework of the Interstate Aviation Committee, is being positively estimated not only by the governments of the CIS countries, but also by some authoritative international organizations (ICAO, IATA, ITSA, etc.) and our foreign partners.
3. At present it is impossible to solve the problem of improving flight safety without close international collaboration in the realization of urgent global problems, without coordination on the international level of flight safety oversight principles and procedures, including the use of the positive experience of regional cooperation.

In that respect I want to express my gratitude to the organizers of our Congress and thank them for the given opportunity to make a speech at such a representative Forum.

Attention to Safety in the Decision Making on Transport Infrastructure

A process design

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1. Introduction

This paper presents the findings of a number of case studies on decision making on transport infrastructure and the extent to which attention was paid to safety risks during that process. The cases were analysed as part of a research project commissioned by the Dutch Ministry of the Interior and carried out by the Faculty of Technology, Policy and Management of Delft University of Technology and the Department of Public Administration of the Erasmus University Rotterdam. The purpose of the research was to arrive at a format for a decision making process in which the "input" of safety expertise in the decision making about infrastructural projects is guaranteed. The commission was assigned in the framework of the Dutch government's "integrated safety policy" in which the Cabinet is striving for a more proactive and cohesive approach to safety problems at national and local level.

The first phase of the research has now been completed. The objective of this phase was to formulate criteria for the process to be designed. These criteria are formulated on the basis of an analysis of the decision making about infrastructural projects and the role safety plays therein. The actual development will take place in a later phase of the research. This paper provides a report on the first phase. In section 2 the research lay-out is described: the cases studied, the analysis framework used and the research questions. Subsequently in sections 3 and 4 the most important findings are discussed. In section 5 the contours of the design process are outlined.

2. Case studies, analysis framework and research questions

2.1 Four decision making processes on transport infrastructure

In selecting the case studies an attempt was made to achieve a spread across different administrative procedures, phases and transport modalities in order to gain an insight - albeit a partial one - into the variety of projects which are possible in this field. Furthermore, an additional factor in selecting the case studies was whether the projects had certain specific

characteristics which are interesting from a safety viewpoint. Table 1 below shows the characteristics of the various projects. The decision making about large-scale infrastructural projects has been mapped with the aid of a conceptual framework that is described briefly below.

Table 1. The four decision making processes analysed.

case	location	procedures	stages in the process	modality	specific characteristics
construction Willemsspoor tunnel in Rotterdam (1954-1994)	local	building permit; local land use plan	idea-forming and preliminary discussion; formal decision making; implementation	rail transport of passengers and goods	3 km underground in densely built-up area
construction High Speed Line (HSL)-south (Amsterdam-Belgian border) (1973-present)	national	Key Planning Decision (KPD), infrastructure (Planning Procedures Act, EIS)	agenda setting and initial formation of ideas; formal decision making	rail transport of passengers	HSL system; corridor concept; tunnel under the Green Heart
corridor Amsterdam-Utrecht (doubling rail and motorway) (1988-present)	national	route procedures, EIS	agenda setting and initial formation of ideas; formal decision making;	transport of passengers and goods via motorway, water and rail	corridor concept; development of new Leidsche Rijn residential area based on 'compact building' concept
future of civil aviation (1988-present)	national	structure schematic; KPD, EIS	agenda setting and initial formation of ideas; formal decision making	air traffic	strategic discussion on future of air traffic and transport

2.2 Analytical framework

2.2.1 The analysis of the decision making: stages, actors, crucial decisions

The decision making has been structured by distinguishing three stages: agenda setting and initial formation of ideas, formal decision making, and implementation. The events which take place in the framework of these three stages are described by mapping the actor's involvement and the content and development of ideas. There was particular focus on the moment at which the various directive decisions (points of no return) were taken and the consequences which these had for both the further course of the process and for the role of safety within it. The central idea was that these directive decisions could provide valuable input for the process to be developed and the instruments to be used within it.

2.2.2 Safety: a definition

In the framework of this study "integral" safety is at issue. Such an approach implies focusing attention on:

- different forms of safety ranging from safety of engineering constructions and fire safety to criminality and nuisance.
- both "physical safety" as well as "social safety";
- both "objective" forms of safety as well as perception of safety;
- both qualitative and quantitative approaches to safety;
- both "internal" as well as "external" safety.
- adequate attention to safety in all links of the safety chain (proaction, prevention, preparation, repression and after-care), which implies in particular increasing the attention devoted to safety in the first links of the chain.

2.3 Research questions

The above observations on decision making and safety result in the following research questions. These formed the framework for the analyses in the case studies.

1. Which crucial decisions were taken in the three stages we have distinguished?
2. Which actors were involved? What was their attitude towards the safety issues?
3. Did the decision making occur in accordance with a particular pattern, for example as a consequence of the existing procedures or the design process which was gone through in the course of the project?
4. What was the nature and the scope of the safety issues which were a factor in the project?
5. At what point in the process were decisions taken with important consequences for safety?
6. In what way was attention paid to safety in the process? What forms of safety research were conducted?
7. In what way and to what extent were safety considerations urged and weighed in decisions? What impact did they have on the decision making?

3. Observations on the development of the decision making

The case studies led to the following observations on patterns in the development of decision making processes about transport infrastructure:

3.1 Early decisions

A typical feature of the decision making processes was that at early stage decisions were taken which set their stamp on the subsequent steps in the decision making. The discussion on the implementation of an infrastructural facility begins conversely with a solution: a project proposal. Prior to this a first draft has been developed among a small circle of participants. These participants subsequently endeavour to enter the public decision making

arena with as well-constructed an idea as possible. In the decision making about the doubling of the motorway A2 between Amsterdam and Utrecht, for example, the corridor concept was introduced at an early stage in the process. This concept was prompted primarily by spatial arguments and environmental considerations. In the case of the CAU this means that three main traffic hubs were connected. This corridor concept subsequently determined to an important extent the further working out of the project and the scope for making safety arrangements.

3.2 Erratic decision making: the absence of the central decision

Although decision making processes include important, directive decisions at the earliest stages of the decision making, the development of the decision making is highly erratic. The process develops in fits and starts, takes unexpected turns and displays a repetition of moves.

The decision making on the Willemsspoor tunnel, which was planned to connect the north and south bank of the river the New Maas in Rotterdam, provides a good illustration of the fact that there is no central decision. After the route had been determined, there was subsequently further discussion on the question of whether the connection should be single or double track and whether a tunnel or bridge should be built. Dominant solutions alternated in this: there was zig-zag decision making.

3.3 No watershed between stages and activities

The activities of agenda setting and initial formation of ideas, formal decision making, and implementation do not occur in chronological order. Important decisions are taken in the first phases of the project; in the later phases new ideas come onto the agenda, and in the implementation, too, crucial decisions are taken: there is no watershed.

In the implementation scenario for the Willemsspoor tunnel, for example, a number of pruning measures specified in the decision making phase were reversed. This project was furthermore unique because the working out of the specifications was carried out parallel with the implementation by a joint venture of building contractors so that during that phase, too, decisions had to be taken on numerous other matters. The state of affairs surrounding the CAU illustrates how, during the implementation stage, developments can occur in the environment of the process whereby earlier decision making becomes overtaken by events. The idea of developing a new urban area, Leidsche Rijn, near Utrecht whereby the A2 would have to be partially covered over, ensured that the deliberations which had previously been made in the framework of the CAU were superseded. Such a development may lead to (parts of) the formal decision making having to be started all over again.

3.4 Procedures in different shapes and sizes

Procedures can form anchor points for the process to be designed and the instruments to be used in it. It must be recognized, however, that although they structure the decision making they do not eliminate its erratic fluctuations. The HSL case shows that despite the KPD

procedure, decision making is postponed, steps are repeated (the first HSL policy document from 1991) and new alternatives are added at a late stage (the route over existing track and the Bos variant). Moreover, the procedures do not cover important parts of the decision making: neither the idea-forming and discussion phase nor the implementation phase. Furthermore, in various projects a number of different procedures are relevant: such as those relating to planning permission, environmental permits, regional and local planning, the Environmental Impact Statement (not all projects are subject to EIS procedures), the infrastructure procedure (*tracé-procedure*), the Infrastructure (Planning Procedures) Act (*Tracé-wet*) and the KPD.

3.5 Promoting interests: the importance of participation and positions

Decision making takes place in an arena in which actors promote different interests and are together seeking solutions which are acceptable to everyone. In that process of jockeying for position the interests which are represented by strong parties with a powerful lobby are heard most clearly. Interests which are under- or not represented threaten to become lost in all the manoeuvring. Thus the ample attention paid to safety in the Willemsspoor tunnel can be explained: the municipality of Rotterdam had power of veto: it was responsible for issuing the building permit and assisting in the modification of the local plan. This gave the fire services a foot in the door, since they advised the city council on the building permit.

3.6 The narrow margins of decision making: the importance of vertical integration

Decision making on infrastructural projects does not take place in a vacuum. The scope for policy making within which projects are implemented is restricted by other policy and by strategic decisions which are taken at a higher level. For example, physical planning policy, environmental legislation, but also European rulemaking. The decision laid down in the national structure plan Traffic and Transport 2, that the A2 between Amsterdam and Utrecht is a main traffic artery and that the transport of hazardous materials should be able to take place over this route, meant that the only thing left for the decision making was to decide how, given these basic assumptions, an adequate level of safety was to be realized. The CAU, in more general terms, provides an example of a project that was squeezed into the environment. As a consequence of this, hardly any alternatives to the route were available; the project had to be implemented within the narrowest possible margins.

Elsewhere, this is referred to as the problem of the vertical harmonisation of decision making between the operational and the strategic levels. The CAU case illustrates how the strategic decision making restricts the policy scope for deliberations at project level, including those on safety. At the least the requirement can be set that at strategic level, too, the safety risks of choices must be examined.

4. Observations on the role of safety

The case studies have produced the following observations on the role of safety in the decision making on large-scale infrastructural projects.

4.1 Safety "follows"

The construction of the Willemsspoor tunnel shows that in infrastructural projects a lot of attention is paid to safety. Part of this attention is institutionalised. In constructing a tunnel, for example, construction safety is part of the design practice and is automatically taken into account. The same goes for "railway safety"; the NS (Dutch Railways) has always been concerned about this and safety automatically occupies a central position in the design and implementation of the track planning.

Attention paid to safety at a technical level does not mean that safety also played a prominent role in the decision making on the question of whether the project, partly in view of the relevant safety risks, should be implemented at all. It is equally uncertain whether safety was a selection criterion in weighing up alternatives. Despite all the investment in safety, it remains possible that this is outweighed by the risks involved.

In the decision making processes we examined there was no conscious and explicit weighing up of the acceptability of the safety risks on the basis of information about them. In so far as that occurred it was implicit. Research data with regard to the risks involved and possible safety measures were not always available or adequate. In the case of the Willemsspoor tunnel a quantitative safety analysis was not made until the construction was nearing completion, just before permission was due to be obtained from the Ministry of Transport, Public Works and Water Management for the transport of hazardous materials.

4.2 Safety risks and safety preferences

The safety risks which were involved in the projects differed depending on the specific characteristics of the facility to be realized, the functions which the facility was to perform, the technique which was used in its implementation and the environment within which the facility was created. The attention paid to safety also varied considerably. This depended among other things on the organisations which dominated in the decision making.

In the world of civil aviation the safety level is monitored by the Directorate-General for Civil Aviation (RLD). Attention to internal safety is traditional there and is based on the theory that as long as aircraft comply with the quality requirements and are flown according to safe procedures, the risks for others must therefore also be minimal. Little attention is paid to the environment and the role of the emergency services.

In the Willemsspoor tunnel the combination of passenger transport, goods transport and a transfer option (Blaak station) imposed conflicting requirements on safety facilities. Whereas the transport of hazardous materials demands as closed a system as possible, passenger transport and the presence of a station require an open system.

An instrument aimed at mapping safety impact should on the one hand be sufficiently generic to map the various forms of safety, including those which, given the attention focus of parties concerned, threaten to be excluded. On the other hand, it must also be able to provide a tailored approach: the attention must be aimed at the risks which are relevant to a specific project. Furthermore, these observations also teach that integrated safety is not simply the result of adding together forms of unsafety. These often impose conflicting requirements on the design and the safety measures. So in decision making safety

must not just be weighed up against other interests. The different forms of (un-)safety need to be weighed against each other.

Table 2. Design criteria for a process design.

observations on decision making	observations on the role of safety	problems from an integrated safety approach	design criteria for a process design
	no explicit risk acceptance	implicit risk acceptance; safety issues are passed on to phase of design, use and emergency services	explicit weighing up of safety risks
directive concepts at the start of decision making		attention to safety comes later and is already immediately on the defensive	early attention
during the whole process relevant decisions are taken		early attention is not enough; new developments in safety impact would be overlooked	during the whole process attention to safety is necessary
there is a development from strategic and global decisions to operational and concrete ones		too uniform an approach to safety impact leads to unusable information	attention to safety must fit in with the nature of the decisions which are relevant to a decision making scenario
	the attention to safety is compartmentalized	important forms of safety impact are given no attention	broad attention to safety
	norms are often absent or they are contested	this means no decisions on acceptable safety levels can be taken	those involved must agree on acceptable safety levels in joint consultation
	research is compartmentalized, the quality is questionable and the results and research methods are challenged	hampers the gaining of a broad and reliable picture of safety impact	attention to the quality and steering of the research is required
decision making is promoting and weighing up interests; participation is necessary for promotion of interests	emergency services are restricted and called in too late	opportunities for input from experts, necessary for the harmonisation of measures in various links of the safety chain, are not utilised	promoters of safety interests must gain a place in the design and decision making process
	interested third parties often receive late and inadequate information	contrary to proper administration and adversely affects support for the project	decision making on safety risks and measures must take place in an open process
	the same safety risks are not involved in each process	disproportionate attention to safety risks; adversely affects legitimacy of instrument	attention to safety must be proportional to safety risks
important decisions are taken elsewhere	at strategic level decisions are taken which programme safety impact at project level	prior conditions limit the possibilities for implementing an acceptable safety level	vertical integration must be ensured

4.3 Norms

In the decision making on infrastructure clear norms are available with regard to some forms of safety: construction, railway safety and fire safety are examples. But this clarity is not always present: some norms are the subject of debate. This was the case with the norms for external safety in the transporting of hazardous materials which were only recently laid down. It was also pointed out that these norms are only aimed at a limited number of effects and do not provide any useful information on the design of the emergency services. For a large number of safety effects there are simply no norms.

In the CAU case it appeared that there was no safety equivalent to the corridor concept. Although the studies into external safety were incorporated into one procedure, there were in fact three impact statements carried out parallel with each other, one for the road, one for the railway and one for the water.

4.4 Promoters of safety interests

Bringing the emergency services into the decision making on infrastructure generally occurs on a limited scale and at a late stage. Thus in the framework of the safety plan for the HSL and in collaboration with the emergency services a scenario approach is adopted, but this is primarily aimed at the organisation of the emergency services whereby the HSL is seen as a given parameter. Whether requirements will be added to the design from the perspective of the emergency services remains unclear.

In the initial planning surrounding the Leidsche Rijn it appeared that the designers had an inaccurate image of the capacities of the emergency services. They assumed that the fire, police and ambulance services would always be able to enter the tunnel which would be created by covering over the A2. They had not taken account of the fact that the physical design of a tunnel should incorporate an acceptable risk for the emergency services. Consulting with the fire services at an earlier stage could have prevented this misunderstanding.

4.5 The quality of the safety research

A reaction evoked by the suggestion of something like a Safety impact assessment is that there is already such a great deal of safety research already being carried out. From the case studies it emerges that this is by no means always the case, that the research which is conducted is aimed at a limited number of safety interests and that the quality leaves a lot to be desired.

The decision making on the construction of the Willemspoor tunnel is largely based on a single safety study, namely a qualitative risk analysis. A quantitative analysis only became available towards the end of the construction. In the CAU project, the gap between the outcomes of the safety assessment and the norms was played down. In the discussion on the future of aviation the point was raised that the parameter in which the degree of safety was expressed in research was not neutral. The standard which one chooses for setting safety limits determines the outcome.

As a consequence of the above it is not surprising that research is often unconvincing and becomes the subject of conflict. All this is reinforced even more by the tendency to surround research results with a veil of secrecy, to refuse to make reports public and to provide the outside world with "versions for the public".

4.6 Safety perception by third parties

The implementation of infrastructural facilities has consequences for the safety of "third parties", for example the users and local residents. A difficult point is their perception of unsafety. Sometimes people are not aware of the risks to which they are exposed; in other cases their concern is out of proportion to the actual risks. What is more, the response to the concern expressed by local residents is often inadequate. Moreover, good intentions can be counterproductive such as when the NS handed over its safety plan for the Willemsspoor tunnel to the local residents. The impressive list of safety measures led to the conclusion that the tunnel was extremely unsafe.

Local residents and users have the right to information on the dangers to which they are exposed, or to which they think they are exposed. But for this it is necessary for decision makers themselves to have a clear idea of the safety impact, for example by having the risks mapped and having them weighed up in an explicit deliberation process.

Table 3. Contours of a process design in which comprehensive attention to safety in the decision making on transport infrastructure is safeguarded.

stages in decision making	substantive areas of attention	indication of instruments and organisational provisions
agenda setting and initial formation of ideas	1. which safety risks are relevant? 2. how can a project be designed in which safety is integrated?	quick scan open design processes
formal decision making	3. what is an acceptable safety level? 4. is the project worth pursuing given the safety risks involved? 5. which safety impacts are linked to alternatives?	process design leading to safety covenant rapid assessment of effects in-depth effects research
implementation	6. how should the physical design be shaped so that an acceptable safety level is realized? 7. which demands do safety risks make on the commercial operation? 8. what preparatory activities must be undertaken on behalf of the emergency services?	embedding safety in project organisation integrated safety plan communication strategy implementation and management audit

5. Lessons for the process design

The schematic below shows how far the observations discussed above imply that the attention to safety viewed from an integrated approach falls short. It also indicates which

design criteria this imposes on a process design that aims at safeguarding the attention to safety in these decision making processes. Elaborating on these design criteria, in this section the contours of such a process design will be outlined.

6. The contours of a process design

The design of a decision making process in which the attention to safety is adequately embedded could include the following elements:

1. the design must be based on realistic expectations with regard to safety interests: in addition to safety there are a lot of other interests which also have to be addressed. Attention to safety must contribute to balanced decision making.
2. the design must entail the minimum extra decision making costs, and must tie in with existing working methods and procedures wherever possible.
3. the design must be tailor-made and offer opportunities for mixed scanning: a broad scan of safety risks must precede more in-depth safety research.
4. introduction of bureaucratic procedures and ritual dances must be prevented: rather than legal commitments one possibility would be a handbook for the protagonists of a project to enable agreements to be reached on a voluntary basis on safety research, acceptable risk levels (in so far as not otherwise given) and safety measures. These agreements would need to be laid down in a safety covenant.
5. because decision making on infrastructure is complex and there is no one central decision, the working method must contribute to ensuring that "input" from safety experts is guaranteed at the appropriate times during the whole process. Thus not a one-off comprehensive safety impact assessment but a route planner which indicates at which points which safety questions are relevant and how those questions can be answered. Table 3 shows which questions are involved and which tools might be appropriate for providing answers to them.
6. The design must be aimed at mobilising and consolidating existing safety agencies and safety expertise as much as possible instead of reinventing the wheel. This by no means excludes new methodologies, expertise and participants in processes in which safety is routinely dealt with.
7. The effectiveness of the working method must be monitored and evaluated. An arrangement must be found to build learning capacity about the working method. This could be realized by establishing a Safety Help Unit, a body which advises project organisations, mediates between project organisations and safety experts, arbitrates and evaluates.

Explicating Feedback and Feedforward Loops through the Conduct of Safety Studies

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It has been a pleasure to participate in this important international conference over the past three days, and it is a privilege to join in today's discussion of feedback and feed-forward loops. I would like to share a few of the concerns of some of the actors at the "societal loop" in the systems model that has been the focus of this conference. Specifically I would like to comment on what I perceive to be an important responsibility of actors such as safety boards and transportation research organizations – to rigorously and systematically examine the extent to which the control and communication mechanisms that develop between operators, manufacturers, regulatory and supervisory bodies, and even societal entities; are effective in enhancing the safety of the transportation enterprise. I believe that our organizations bear a special responsibility to account for, and assess, the interactions of all of the multitude of actors in the transportation systems that we are charged with making safer.

Certainly the conduct of careful and meticulous accident investigations is one very important responsibility that we share in this regard. Indeed the reputations that the world's best safety boards have earned is to a great extent due to the careful and meticulous conduct of thorough and comprehensive investigations of individual accidents to determine their causes. While these one-at-a-time considerations of the interactions that have failed, in some way, are important as case studies that often identify important safety issues, they must be supplemented by broader studies of accidents in the aggregate. Just as importantly, there is a need for careful examinations of the nature of the transportation systems themselves. In short, in addition to investigations of individual accidents, we must also invest in the conduct of careful safety studies. At the NTSB we have found it useful to distinguish between three broad classes of safety studies:

1. Statistical reviews and retrospective accident studies that attempt to determine commonalities among collections of accidents (generally from existing accident data bases) and to evaluate accident trends over time;
2. Prospective accident studies that systematically undertake new investigations of accidents of a particular class or type in an attempt to identify common causes and characteristics; and
3. Oversight studies that focus on various aspects of the transportation system(s) that play a role in transportation safety and give rise to accidents or unsafe conditions.

The actuarial compilations of accident trends by many accident investigation and transportation safety authorities provide many examples of the statistical review or retrospective accident study. Indeed, monitoring the health of any transportation system

requires the regular collection and descriptive analysis of accident data. It is a continuing challenge to safety agencies to collect, compile, and analyze accident and incident data that are timely and accurate. In the United States the responsibility for accident data collection and analysis is distributed widely between modes. The NTSB is responsible for maintaining the United States' census of aviation accidents, but other agencies bear that responsibility for capturing data on accidents in the other modes of transportation. The responsibility for recording and monitoring incidents, or those transportation confrontations that fail to meet accident criteria (usually personal injury or a prescribed amount of economic damage) is even more widely distributed, if that responsibility exists at all. There are great needs to improve the care and comprehensiveness with which accident and incident data are collected, and equally important needs to extend the analysis of these data to discover important trends and insights into accident causation. There are similarly important challenges to share and exchange these data and analytic results internationally. In this regard, I would like to acknowledge the significant role that ICAO has played in advocating these kinds of improvements for aviation accident and incident data. It would be helpful if there were similar influences in the other transportation modes.

Turning to the second category of safety study, we at the NTSB have had some success in recent years in addressing important safety issues through the conduct of prospective accident based studies. The problems of fatigue and the use/miss-use of child occupant protection devices represent recent NTSB safety studies that involved the planned collections of accident investigations targeting these issues. In each of these cases accident notification criteria were developed, and planned accident investigations were launched to thoroughly explore the causes and contributing circumstances of an appropriate number of the targeted types of accidents according to an explicit research design, developed to accomplish the desired contrasts and comparisons. While accident based studies can never create the conditions of experimental control that are characteristic of the laboratory study, they do provide for the systematic, quasi-experimental evaluation of causal propositions in a way that the case study (an individual accident investigation) can not hope to do.

It is the final category of safety study, the oversight study, that I would like to focus on today as a research approach that is extremely important in examining and understanding the interaction of the actors in the transportation system. I would like to illustrate this type of transportation safety research by briefly reviewing one study that the NTSB has done, and another that it is currently pursuing.

In November of 1994 the NTSB adopted a safety study entitled Commuter Airline Safety. This study was precipitated not only by the higher accident rate exhibited by commuter airlines, but also by the observation of significant changes in this industry due to rapid growth, and changes in the operating environment of this segment of the airline industry. The methodology employed by this study included:

- Site surveys of a sample of 21 airlines to obtain details of the operational characteristics of these airlines;
- Structured interviews with pilots, flight attendants and maintenance personnel from a sub-sample of these airlines; and
- A public forum held from June 14-16, 1994 in Atlanta, Georgia to obtain testimony from 37 witnesses from government, industry, airlines, trade groups, labor

unions, aircraft manufacturers, and training centers.

This study utilized these data sources to address the adequacy of the commuter airline industry's standards and practices, with respect to a range of flight crew, cabin crew, maintenance, management and oversight issues. The study concluded:

- that the U.S. Code of Federal Regulations, specifically CFR Part 135 had not kept pace with the changes in the environment and operating characteristics of the commuter airline industry;
- that scheduling practices and other flight crew demands contributed to an increased potential for flight crew fatigue;
- that both new and recurrent training were frequently deficient; and
- that effective oversight was often lacking by both the carriers and the Federal Aviation Administration.

Perhaps the most important and sweeping recommendations made in this study asked the FAA to effectively regulate all scheduled commercial passenger service on planes with more than 10 passenger seats under the same regulations (the 14 CFR Part 121 standards). It was gratifying to see the FAA respond to these recommendations with the "One Level of Safety" initiative that became effective early last year. While other actors certainly influenced this desired outcome, we are convinced that the systematic examination of the relevant issues accomplished through the Board's safety study played a significant role.

If we may now turn to another mode of transportation - in the United States a wide variety of regulations govern trucks involved in commercial cargo operations. The Federal Highway Administration, through its Office of Motor Carriers is the Federal agency responsible for overseeing the safety of commercial motor carriers. Its authority, however, extends only to carriers involved in interstate operations, or those trucking operations that cross state boundaries. State laws are highly variable with respect to the regulation of trucks that operate within state boundaries. Limited data are available regarding the extent of intrastate (as compared to interstate) operations, but estimates have been obtained that suggest that 20 percent of tractors operated by private motor carriers are involved in intrastate commerce, and that more than 29 percent of the trucks involved in fatal accidents in 1994 were engaged in intrastate commerce. Because so little is known about the safety of intrastate trucking operations, the Safety Board initiated an intrastate trucking oversight study during 1997, and this investigation is currently in progress.

Data for this study are being obtained from four sources:

1. prospective investigations of selected accidents involving heavy trucks involved in intrastate operations;
2. carrier oversight investigations involving detailed site visits to trucking firms engaged in intrastate commerce;
3. a commercial motor vehicle intrastate operations mail survey utilizing a nationwide sample of intrastate carriers; and
4. a comprehensive review of Federal and state regulations.

A decision as to whether a public hearing or forum will be needed to complete the data collection process will be made when these data collection procedures are complete. While it is certainly too early to anticipate either the findings of this study, or the recommendations that might result, we are convinced that the process that we have

initiated to gather the relevant information is the most effective approach to the study of this transportation issue.

In conclusion, it is our belief that a balanced program of safety studies is an essential complement to the accident investigation responsibility of the NTSB. We would encourage other transportation safety organizations to make use of these tools as well.

The Expert System for the Regional and Local Staff Implementing the Road Safety Improvement Programme in Poland

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1. Introduction

In 1994 the Minister of Transport commissioned the National Committee of Scientific Research to carry out a research project "Road safety improvement in Poland". In 1996 the full text of the National Programme of Road Safety Improvement in Poland, prepared by the Associated Authors' Teams headed by the Technical University of Gdansk, was published in a national monthly magazine for public evaluation and discussion (Krystek, 1996). The GAMBIT Programme contains a set of preventive measures that need to be implemented to stop the growing number of accidents that has been observed over the last few years in Poland and to make the risk on the roads decline continually. The following were adopted as intermediate goals leading to the achievement of the ultimate goal:

- common implementation of low cost measures of road safety improvement,
- acquiring public support for road safety activities,
- creating bases for an effective and long-term policy.

All the goals set forth in the Programme as well as the proposed action are a reflection of the need for a systematic and integrated approach to road safety problems and the need to start the implementation process of the programme from the central level (top-down strategy) and at the same time at the local level (bottom-up). However, bearing in mind how difficult it is to create a political lobby, especially in Poland where the political elite is in the course of continuous change, both in terms of the policy and staff, the authors of the Programme assumed that it will be easier to start the implementation of the Programme following the bottom-up strategy. Therefore, the Programme contains clearly defined tasks for the governor as a representative of central administration (Poland is divided into 49 provinces) and for local authorities in cities and municipalities:

- adapting organisational forms and staff within the structures of local authorities to road safety tasks,
- development of a system of collecting road safety data and programming road safety,
- training for individuals participating in the road safety improvement programme, that is road safety auditors, employees of local administration, design engineers, teachers, etc.
- establishing a local system of promoting road safety and public relations,

- organisation of co-operation between state administration and local authorities and non-governmental organisations.

Indeed it was the right thesis because the action taken at the central level was found completely insufficient to stop the ever increasing road accidents risk (Jamroz, 1997). This gave an extra incentive for speeding up work on the regional and local levels. We started by carrying out two experimental, regional programmes of road safety improvement in the regions of Gdansk and Elblag. The first two governors provided financing for the projects which were given the acronyms "Gdansk GAMBIT" and "Elblag GAMBIT" (Jamroz, 1996, 1,2). At present, work is under way on two new programmes "Suwalki GAMBIT" and "Katowice GAMBIT".

In the course of work on the identification of the elements of the road safety system in order to make a diagnosis, many observations were made both in terms of the road system and organisational structures that are statutorily responsible for its functioning. These are the major observations:

- local institutions and organisations which are responsible for road safety often act on the so called "word of mouth" opinion disseminated by public persons or on subjective "impressions of road users" which usually do not match the facts as they are the result of own experience in road traffic which is not the statistical representation of the situation as a whole,
- most frequently there is a lack of basic data, necessary to select the right road safety improvement measures; that is why the functioning and development of urban road systems follows an incoherent method of correcting the critical elements without any regard of the obvious fact that each of these elements is but a fragment of the whole structure,
- a lot of evidence has been gathered to prove that it is necessary to appoint a regional road safety auditor; his role would be to act as the governor's expert and to approve or have other experts approve proposed solutions and make sure that they comply with the engineering and logical part of the project.

The experience of OECD countries has shown that one of the first obstacles encountered in the process of implementation is the training of adequate staff. The above experience and the results of our own diagnosis led us to start work aimed at establishing some tool that would facilitate the implementation process of regional and local programmes following a uniform philosophy of the national Programme. The tool is meant for three groups of regional recipients; policy makers, safety practitioners and safety researches. This task is made especially difficult because policy makers need the knowledge of development strategies of a safe transport system, the practitioners need to learn about methods of management - following these strategies and for the two groups the knowledge the researchers have is too complex.

What the diagnosis showed is that in all four regions under analysis we are dealing with the same problem as the one faced nation-wide: a lack of the fundamental staff, and even if it is there, it needs substantial additional training in the area of the principles of safe road traffic. We are basically dealing with three professional groups:

- policy makers; people usually without a background in some general road safety knowledge and what is more unaware of the connection between road traffic and

the risk of losing one's health or life,

- practitioners; are divided into groups that are isolated from one another; highway workers, police officers, teachers, driving instructors, etc. and they do not have the knowledge on the mutual relations of these specialities,
- researchers; a small group gathered at universities and institutes, remote from many regions and hence having no background for a continuous co-operation with practitioners.

Road safety links these three groups in the following way: researchers are expected to deliver professionally elaborated national, regional and local programmes which would provide a basis for discussion and then for decisions to be made by policy makers which will be implemented by practitioners. However, the problem is that researchers are expected to come up with accurate diagnoses and draft decisions which most of the time are developed on the basis of highly insecure data on accidents. Hence the conclusion about having to focus in the first stage of work on a data base on road accidents.

One of the first tasks of regional programmes is to develop auxiliary and educational materials first of all for the primary road safety personnel and also for the road safety audit process participants (investors, designers, auditors of road safety). Developing such tools in the form of simple expert systems adjusted to the character of the user seems to be the right solution, especially considering the following ramifications:

- Poland has 49 regions and 860 towns and a small group of specialists who can prepare the local staff to develop and effectively implement these programmes; in the majority of towns the problems of road safety have been assigned to the job description of people who have various levels of general and vocational education,
- Institutions and organisations which can participate in the implementation of the Programme do have computer hardware, however they have no software that would facilitate the decision making; at the same time there is a lot of interest in these tools,
- Road safety actions are multidisciplinary and multi-sectoral, road safety evaluations also use qualitative criteria.

2. Expert systems in road safety

In their analyses researchers concentrate on accident prone factors and the effectiveness of preventive measures. While doing so they frequently fail to attach sufficient weight to the issue of how the public is supposed to implement the results of their studies. In all communities a certain crucial problem appears, one of acceptance for road safety research and the proposed improvement measures. An element that largely facilitates the pursuit of the support and the application of scientific recommendations is the use of models which describe the acceptance process pointing out to the fundamental factors that make or break the process. Without a doubt the process of acquiring acceptance is made easier by adjusting it to the national, regional or municipal context. It all points to a need for developing a systematic approach in the process of implementation to road safety improvement measures using tools which give highest hopes for their contribution to disseminating the objective knowledge and the best practices in the area of road safety in all those places with no expert

teams representing various fields related to road safety.

In the recent years, a fast development of expert systems technology has been observed. This technology is a means of an effective knowledge management while expert systems are a relatively new generation of computer programmes used for problem solving in a manner similar to that employed by a specialist. According to the definition an expert system is a computer programme that exhibits, within a specific domain, a degree of expertise in problem solving that is comparable to that of a human expert (Ignizio, 1991). A knowledge based expert system includes three basic modules:

- the knowledge base (long term-memory with facts and rules),
- inference mechanism,
- the short term memory.

The basic advantages of the systems are (Wilson, Dunn, 1994):

- accessibility - facilitates continual usage of available knowledge,
- consistency - establishes objective and repeatable decision making paths,
- productivity - improves decision making without having to resort to many different specialists.

This technology is widely accepted also in the area of traffic engineering and transportation and is showing a high development potential (OECD, 1992). The traffic safety expert systems used and developed so far are related to issues such as: highway design (Paniati, 1997), intersection design (Wilson, 1994), speed management (Donald, 1994), safety audit (Middleton, 1992), accident investigation (Gitelman, 1997).

Today's expert systems are the most effective tool that uses road safety principles and models in implementation processes and considering the above mentioned advantages it can be a useful tool in relatively small municipalities which do not have experts in all disciplines (OECD 1997).

The aim of the initial work undertaken within regional road safety improvement programmes in Poland is to establish some assumptions for an expert system, first of all in terms of the structure and the contents of the knowledge base tailored to the needs of the tasks related to the Programme.

3. Assumptions to an expert system in the area of implementing a road safety improvement programme at a local level

A general structure of safety management developed for regional staff has been presented in Figure 1.

Development and implementation of a road safety programme at a local level has the following ramifications (Proctor, 1997):

- adequate quality of data on accidents,
- option to do computer sorting in order to identify high risk groups, dangerous areas (spots, sections, areas),
- establishing the priorities for measures that are most effective in a particular situation
- introduction of mandatory reviews of plans and road designs (safety audit),

- the option to monitor the activities in progress
- developing an operating plan of road safety improvement.

Without a doubt each region or municipality has its own characteristic and specific conditions of the road safety system, considering the organisational structures of local administration, the staff, available funds, road safety problems resulting from various causes and circumstances of road accidents. In Polish conditions there can be huge insufficiencies in the data bases that are necessary for a proper road safety analysis. Depending on the size of the towns and municipalities, the responsibilities for roads and road traffic management are covered by various bodies. Therefore it is assumed that the expert system being developed will take into account the type of user and type of activities that the user wants to employ to solve the problem.

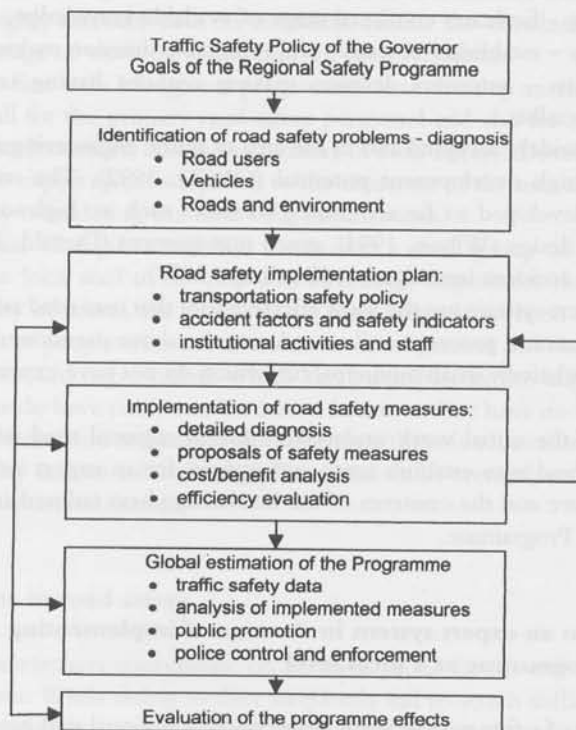


Figure 1.

The basic features of the system are:

- assistance for various groups of users of the system in solving road safety problems at various decision making levels that are present in the regions and municipalities,
- raising the awareness of road safety through work with an attractive, interactive computer programme.

Among the potential users are:

- local government administration and local authorities employees dealing with road

safety problems,

- road administration employees,
- designers and planners of the transportation infrastructure,
- road safety auditors.

Each of these groups of users can handle problems:

- of a strategic nature; road safety diagnoses and programming of improvement measures for the municipality,
- of a detailed character; implementation of concrete, engineering and educational measures of road safety improvement.

With the type of user and character of the analysis stated it will indicate the selection of procedures. This is due mainly to the varying levels of professional background and knowledge of the terminology and the complexity of the analyses. All procedures will be based, however, on many different common principles adopted as indispensable for the process of road safety measures implementation.

It is assumed that the base of the knowledge will be an element of the system that will be developed successively, adjusted to the current priorities resulting from the implementation of the national programme and regional ones. The targeted solution is to contain a scope of knowledge large enough to enable the basic procedures such as:

A. Identification of road safety problems - diagnosis

- dangerous behaviour of users
- high risk groups
- accident concentration spots (areas, sections, road network points)
- main causes and circumstances of accidents

B. Formulating the strategic programme of road safety improvement

- prediction of the road safety state
- goals of the programme – road safety ratios
- directions of priority corrective action

C. Analysis of possible road safety improvement measures

- intersections
- speed limits
- traffic calming measures

D. Programme implementation

- marketing measures
- public relations

E. Evaluation and monitoring

- road safety audit
- before-after study
- cost-benefit analysis
- cost-effects analysis

The procedures will be facilitated by the following elements contained in the knowledge base:

A. Computational methods

- calculating accidents rates
- general predictions of changes in the numbers and accident rates

- prediction using a comparison group
- accident cost calculation
- statistical identification of accident concentration spots

B. Road safety models

- descriptive models
- predictive models for aggregated data
- risk models for non aggregated data
- accident consequence models

C. Built-in data bases (permanently in the system) and external ones

D. Additional information

- thesaurus
- improvement programmes: national, regional
- examples of problem visualisation: e.g. accidents maps
- a review (catalogue) of improvement measures
- ranking lists of the effectiveness of measures
- legal regulations
- references and Internet links

It goes without saying that development of these systems will involve a huge effort and extensive studies and cooperation in the area of using international experience.

4. Conclusion

The goal of the project is to develop an expert system including a set of base knowledge on the traffic and road situation so that the expert system would simulate for the user a real expert responding to a question asked of him. The first task for an expert system will be to play the role of a didactic tool for the fundamental road safety staff at the local level. It is obvious that similarly to the case of road safety improvement programmes, if the expert system is not accepted by the user, it will not be used at all. We hope that the expert system will turn out to be a useful tool of achieving better effects in road safety activities and consequently will make possible a better cost/effectiveness rate.

We also expect to see some additional benefit: the area which uses state-of-the-art tools and there is no doubt that the expert system is one, makes the politicians think that it is difficult and the specialists receive appreciation of their knowledge and efforts. Based on Polish experience we can definitely say that expert systems are an important element of promoting the issue of road safety and of acquiring the support of the public and politicians.

References

- Donald D. (1994): Using Expert System technology to Set Appropriate Consistent Speed Limits - The Australian Experience. The Third International Conference on Safety and the Environment in the 21st Century. Tel-Aviv, November 1994.
- Gitelman V., Hakkert A.S. (1997): Towards computerised supporting tools for road accident investigation. The Fourth International Conference on Safety and the Environment in the 21st Century. Tel-Aviv, November 1997.

- Ignizio J.P. (1991): Introduction to Expert Systems: The Development and Implementation of Rule Based Expert Systems. McGraw-Hill. Inc. U.S.A., 1991.
- Jamroz K, Michalski L. (1996): Gdansk GAMBIT - Programme of Road Safety Improvement in Gdansk Region, Gdansk, 1996 (in Polish).
- Jamroz K, Michalski L. (1996): Elblag GAMBIT - Programme of Road Safety Improvement in Elblag Region, Gdansk, 1996 (in Polish).
- Jamroz K., Krystek R., Michalski L. (1997): The First step in the Process of Implementation of the National Programme of Road Safety Improvement in Poland. The Fourth International Conference on Safety and the Environment in the 21st Century. Tel-Aviv, November 1997
- Krystek R. at al. (1996): GAMBIT - "Integrated Programme of Road Safety Improvement in Poland". Final Report 1994-1996. Associated Authors' Team. Gdansk 1996.
- Middleton G., Lee G. (1992): Road Safety Audits: The Development of an Expert System. OECD Workshop on Knowledge-based Expert Systems in Transportation, Montreal, June 1992.
- OECD (1992): Operational Experience and Perspectives, OECD Workshop on Knowledge-based Expert Systems in Transportation, Montreal, June 1992.
- OECD (1997): Road safety principles and models. Paris 1997.
- Paniati J., True J. (1997).: Interactive Highway Safety Design Model (IHSDM): Designing Highways with Safety in Mind. FHWA, TTHRC Technical Report, 1997.
- Proctor S. (1997): Planning a Road Safety Strategy at Local Level. The Fourth International Conference on Safety and the Environment in the 21st Century. Tel-Aviv, November 1997.
- Wilson D.J., Dunn R.C.M. (1994): Safer intersection design using an expert system. The Third International Conference on Safety and the Environment in the 21st Century. Tel-Aviv, November 1994.



Making the Safety Scales Work

Balancing safety in the growing railway industry

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1. Introduction

The railway industry in The Netherlands has a growing amount of participating companies. The industry is in a transition from an integrated railway system, controlled and operated by one company into a coordinated multi stakeholder, multi target railway community.

The NS (Nederlandse Spoorwegen) is a Government owned "private" company. The NS used to be the sole integrated operator of the Dutch railways. Operating, planning, designing, maintaining every part of the system and balancing cost and performance in one hand.

Recently the European council and our national government decided on opening the tracks for other operators. In 1994 the integrated NS was split into several rather independent companies. Lately new train operators, new contractors for track maintenance and other participants operate in the Dutch railway industry. Most of the participants operate commercially and focus on the individual company baseline (profit).

Railned, NS Railinfrabeheer and NS Verkeersleiding - non-profit organisations working for the Department of Transportation (Ministerie van Verkeer en Waterstaat) - focus on total systems performance. Balancing safety and securing a minimal level of safety at all times within the changing industry.

This paper elaborates on safety effects in the organisational change, various stakeholders' targets, and our efforts to balance the safety systems wide.

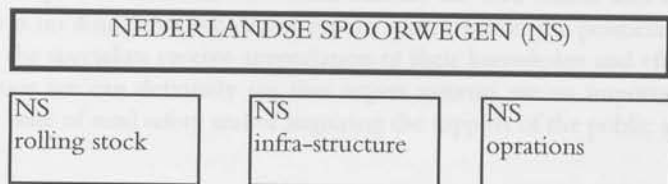


Figure 1.

2. Organisational change

Until 1994 the NS was the sole operator of the Dutch railways. For the best part of this century NS operated, designed and maintained the trains, engines, coaches, tracks, stations

and signalling equipment. In fact one company managed the whole Dutch railway industry. Either by owning it or being the buyer. In this organisation setting NS owns both sides of all the systems interfaces. Once a decision to improve safety has been reached, the top-down implementation of the best value for money solution is easily effectuated.

The organisation was changed to comply with the directive of the European Council. The cost of ownership and operating the infrastructure (i.e. tracks and signalling) had to be separated from the other operations. New operators started passenger and cargo-train-services in addition to the existing NS operated services, and NS Verkeersleiding provide the independent network scheduling. On behalf of the National Government NS Railinfrabeheer provides the infrastructure: tracks, platforms, and transit areas for passengers.

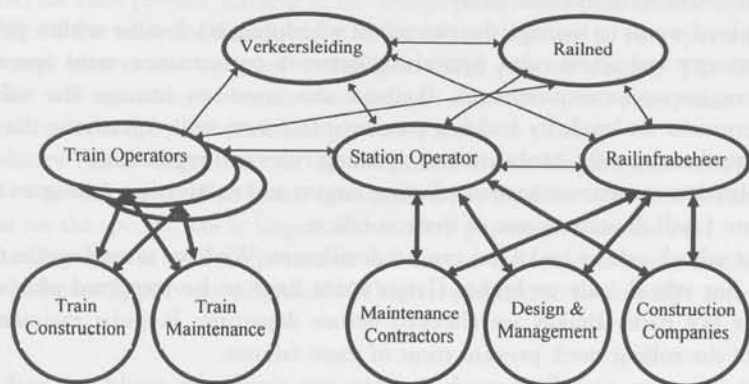


Figure 2.

The Dutch railway industry consists of a growing number of companies. In this fragmenting industry partnerships and agreements become a necessity.

3. International railway industry

High speed trains must travel through several countries without changing engines. International standards for interoperability specify the necessary technical interfaces between systems. This will provide uniform interactions at the interfaces of the infrastructure, trains and command and control systems.

National freedom of choice of safety measures across interfaces will increasingly be limited by international standards.

4. Stakeholders' targets

Railway safety is a result of efforts in the commercial companies and the government funded task organisations. The commercial companies are train operators, station operators

and their suppliers. Railned, NS Verkeersleiding and NS Railinfrabeheer are government funded task organisations. From a safety point of view we have to consider the stakeholders targets and motivation.

- Train operators want to operate a train service for profit and have satisfied passengers/customers, at low cost, high service and minimal delays.
- Station operators want to operate a station for profit and have satisfied shop owners while serving train operators
- NS Railinfrabeheer wants to build and maintain high quality, safe, reliable, value for money infrastructure, within government set budget and priority.
- NS Verkeersleiding wants to manage track-time (slots) for train operators and maintenance according to schedule, safely and within priority rules set by government with minimal delays.
- Railned wants to manage the process of scheduling track-time within government set priority and access rules, optimising network performance, train operators goals and maintenance requirements. Railned also wants to manage the safety up to government set levels by auditing participants, functionally specifying the interfaces and performance for hardware and updating rules and regulations.

These stakeholders sometimes have conflicting targets and motivation. Using an imaginary Hot-Box case I will illustrate some of these conflicts.

A hot wheel, axle or brake can cause a derailment. We have several means to prevent or detect a hot wheel, axle or brake. Cargo trains have to be inspected after every trip checking for hot parts. Brakes are checked before departure. Regular maintenance and inspection of the rolling stock prevent most of these failures.

Train operators or rolling stock maintenance companies could cut back on these costs by skipping inspections, using cheaper under qualified staff and old rolling stock. Some companies own a lot of ageing rolling stock. The cost of changing this installed base of rolling stock will prevent the company from installing an on board detection system.

NS Railinfrabeheer could install track side Hot Box detection systems. The most effective placement is before a junction or a station, stopping the damaged train before the first switch. The use of this system results in stopping most of the defective trains in time. Consequences are the train blocking the tracks and causing delays and putting the driver at risk walking between tracks to inspect the train.

The ideal situation for our new High Speed Line (HSL) would be a win-win solution. All trains using the HSL are equipped with on board temperature detection. The additional investment for bearings with detection is minimal. The temperature information is mainly used for maintenance analyses, resulting in minimal maintenance and inspection cost and high reliability for the train operator. The industry obtains the state of the art continuous hot box detection for safety providing the opportunity of assessing the risk before stopping the train. Of course there are some problems to be solved among others the small installed base of rolling stock and limitations by international interoperability.

In this case we have a rather straight forward win-win solution. In other cases like cargo rolling stock the installed base is enormous and internationally used in the same way as containers. A solution can only be reached by long term international effort.

5. Balancing safety

Safety and the cost of safety must be balanced across two types of interfaces: Functional interfaces and Organisational interfaces. The functional interfaces change slowly, driven by technical innovation. The growth of the industry changed organisational interfaces and started a process of commercially driven organisational innovation.

In the process of balancing safety, cost and performance we need the stakeholder analyses to manage and facilitate the implementation of safety solutions. Starting at the HSL-Zuid project (Dutch part of the Amsterdam - Paris High Speed Line) the relevant stakeholders join in regular safety meetings to advice on balanced safety in the project.

All safety solutions will be documented in an "Integraal Veiligheidsplan" (Dutch Safety Case) for each project, starting in the design phase. This plan will be updated during the total life of the railway infrastructure. A lot of revisions are to be expected due to the life cycle and innovation cycle of components and process design. The difference in expected life will cause almost continuous change: Track 30 - 100 years, train 7 - 25 years, control and command 5 - 20 years and process 2 days - 3 years.

Industry Safety targets are set by Railned and the Department of Transportation (Ministerie van Verkeer en Waterstaat) in the railway safety plan 1998-2002. The HSL-Zuid project has set the specific safety targets and a safety philosophy for the HSL.

The Department of Transportation will set the safety goals in the first safety policy called "Beleidsplan Spoorwegveiligheid". Which is planned to be formally approved in this year (1998)

6. Findings and conclusions

Balancing safety and sharing the investment efforts amongst participants needs constant monitoring and will need occasional guidance. The changed railway industry needs adapted incentives to manage safety. Stakeholder analysis is one of the tools to select the effective incentives.

The framework for safety management has been established. Now we have to prove our safety scales still work by actually balancing the safety across the interfaces.

Building Partnerships, Creating Support for Recommendations

Barry M. Sweedler

*Director, Office of Safety Recommendations & Accomplishments,
National Transportation Safety Board, U.S.A.*

I am very pleased to be in Delft before this distinguished group of both old and new friends in transportation safety.

As you heard from National Transportation Safety Board Chairman Jim Hall, we strongly believe that our investigations have improved and standardized the investigation process and improved transportation safety. You may remember that the Safety Board is an independent agency, not located in a larger department, but with authority over other federal agencies in transportation accident investigation.

Congress requires the Board to determine the probable cause of transportation accidents and to formulate recommendations to prevent their recurrence. Congress did not provide the Safety Board with any regulatory authority or grant funds to stimulate transportation improvements. In retrospect, this was a very wise decision because it ensures both the independence and the objectivity of the Board. We are not subject to the changes of department secretaries (ministers) and are not inappropriately influenced by either industry or other agencies.

This process promotes both objective and in-depth investigations; development of detailed findings, and issuance of recommendations to prevent the accident. Recommendations must be based on investigation of the facts and thorough analysis to develop logical and supportable recommendations. One may think that is the end of the process. As Winston Churchill said, it is not the beginning of the end, but the "end of the beginning." Much more must be done. For what have we gained if the recommendations aren't implemented?

The investigation is the first step in the process, but adoption of the Safety Board's recommendation is not even the end point. The real bottom line is to prevent transportation crashes. If the Safety Board has no regulatory authority, how does it improve transportation safety?

With the federal transportation agencies, Congress provided the Board with an important tool. The Department of Transportation (DOT) and its modal agencies must respond to Safety Board recommendations within 90 days of receipt and indicate, in detail, what action will be taken to implement the recommendation or explain why it will not be implemented. They must also continue to keep the Board informed while work continues on the recommendation. The Board must also be informed when the recommended action has been completed. However, the Board may not agree with the action and may, eventually, have to close the recommendation in an unacceptable status. Congress also

monitors both the closed and open recommendations to determine whether the agencies are complying with the Safety Board's recommendations. Where necessary, Congress may provide direction and other incentives for agency action.

In its 30-year history, the Safety Board has issued nearly 11,000 recommendations (10,743). Of that number, 6,518 were issued to the U.S. Department of Transportation or its agencies. Approximately, 81 percent of the recommendations have been closed in an acceptable status. Just over 700 recommendations to the DOT and its agencies remain open.



Figure 1. Recommendations issued by mode.

The Safety Board issues two classes of recommendations: urgent, and other. Most of the urgent recommendations have been issued in the aviation mode followed by maritime, railroad, highway and pipeline.

Over 4,200 recommendations have been issued to other federal agencies, state, county, and municipal agencies, and to transportation companies, manufacturers, associations, labor unions and others in a position to make safety improvements in the transportation system. In most cases, Congress did not provide these groups with incentives to pay attention to the Board's recommendations. However, Congress took action in certain areas. For example, subsequent to Safety Board recommendations, Congress enacted legislation requiring States to enact minimum drinking age laws and zero alcohol tolerance for drivers under the age of 21 years. Congress also mandated transportation employer alcohol testing programs.

With the other recommendation recipients, the Safety Board's ability to cause change for greater safety in transportation is dependent on a variety of techniques. First, and most important, the Safety Board carefully monitors actions on its recommendations. The recommendations are issued to the recipients and follow-up is made orally, in writing, and in person as necessary. The Safety Board recently reorganized to achieve the aggressive follow-up necessary to change. I will discuss the reorganization later. While both the leadership and staff of the Board are involved in follow-up at different levels, the staff provides the necessary monitoring, evaluation, and coordination to support the follow-up. Personal contact and persistence help explain the Board's recommendations to companies or political leaders who may have seen few or none of these recommendations previously.

Table 1. DOT acceptance rate.

Jan 1998																	
MODE	CEX	CAA	CAAA	CUA	CUAS	CR	CS	CNLA	Total Closed	OAA	OAAR	OUR	ORR	OAR	Total Open	Total Issued	Acceptance Rate
SEC DOT	0	114	19	18	0	13	5	21	190	27	0	4	0	8	37	227	87.91%
FAA	4	2064	435	492	22	118	44	36	3213	215	12	40	49	46	362	3575	83.13%
FHWA	0	255	52	37	3	20	14	9	390	35	1	7	0	3	46	436	87.95%
NHTSA	0	118	39	29	0	22	7	13	228	18	2	2	20	2	44	272	85.10%
FRA	1	199	41	83	7	26	13	25	395	26	0	5	9	19	59	454	73.76%
RSPA	1	155	23	65	1	11	13	23	292	34	1	16	0	15	66	358	72.30%
FTA	0	36	7	11	0	1	0	3	58	3	0	0	0	4	7	65	80.70%
USCG	1	537	134	247	14	51	14	31	1029	62	6	5	2	10	85	1114	73.56%
MARAD	0	11	1	0	0	0	0	5	17	0	0	0	0	0	0	17	100.00%
TOTALS	7	3489	751	982	47	260	110	166	5812	420	22	79	80	105	708	6518	80.89%

Definition of Status Assignments:

CEX:	Closed--Exceeds Recommended Action	OAA:	Open--Acceptable Response
CAA:	Closed--Acceptable Action	OAAR:	Open--Acceptable Alternate Response
CAAA:	Closed--Acceptable Alternate Action	OUR:	Open--Unacceptable Response
CUA:	Closed--Unacceptable Action	ORR:	Open--Response Received
CUAS:	Closed--Unacceptable Action/Superseded	OAR:	Open--Await Response
CR:	Closed--Reconsidered		
CS:	Closed--Superseded		
CNLA:	Closed--No Longer Applicable		

Table 2. Recommendation acceptance rate by mode.

JAN 1998																	
MODE	CEX	CAA	CAAA	CUA	CUAS	CR	CS	CNLA	Total Closed	OAA	OAAR	OUR	ORR	OAR	Total Open	Total Issued	Acceptance Rate
Aviation	5	2264	460	500	22	122	45	44	3462	244	14	46	68	85	457	3919	84.02%
Highway	3	874	130	127	4	55	31	82	1306	164	7	19	105	95	390	1696	88.70%
Intermodal	1	99	12	30	1	3	0	21	167	19	0	7	0	11	37	204	77.51%
Marine	3	1045	191	428	14	91	14	76	1862	79	6	5	27	53	170	2032	74.76%
Pipeline	1	697	54	107	1	22	14	35	931	78	0	15	17	69	179	1110	87.09%
Railroad	3	987	123	260	11	53	17	102	1556	101	0	12	48	65	226	1782	81.10%
TOTALS	16	5966	970	1452	53	346	121	360	9284	685	27	104	265	378	1459	10743	82.65%

Definition of Status Assignments:

CEX:	Closed--Exceeds Recommended Action	OAA:	Open--Acceptable Response
CAA:	Closed--Acceptable Action	OAAR:	Open--Acceptable Alternate Response
CAAA:	Closed--Acceptable Alternate Action	OUR:	Open--Unacceptable Response
CUA:	Closed--Unacceptable Action	ORR:	Open--Response Received
CUAS:	Closed--Unacceptable Action/Superseded	OAR:	Open--Await Response
CR:	Closed--Reconsidered		
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CNLA:	Closed--No Longer Applicable		

Next, the Safety Board participates in professional organizations and meetings with the recommendation recipients. As you know, the United States is pluralistic society and has

been called a nation of "joiners." There are hundreds of transportation organizations and thousands of transportation-related groups, both domestic and international. Such organizations may include: ICAO, IMO, the Transportation Research Board, American Public Transit Association, the Association of American Railroads, the Motor Carrier Safety Advisory Committee, the National Conference of State Legislatures, and many others. At these meetings, the Safety Board presents papers and speeches and takes every opportunity to promote recommendations to that group or association. The meetings also provide opportunities for fruitful exchange of information; updates on progress; and discussion of potentially acceptable alternatives to the recommendations. The personal relationships developed at these meetings provide a greater understanding of the goals of each and may benefit both the Board and the recipients in the future.

Recently, the Safety Board has initiated or participated in a variety of coalitions, primarily in the highway and railroad area. This has become an important way to create support for recommendations by building partnerships that bridge organizational differences to save lives. An example of one of these is a highway safety-related coalition. The Safety Board and the National Highway Traffic Safety Administration invited a variety of national organizations to join the Administrative License Revocation Coalition (ALR Coalition). The purpose of the coalition was to promote enactment of State laws whereby the police officer, as an agent of the motor vehicle agency, could confiscate the driver's license of a driver who exceeded the legal alcohol concentration of who refused a chemical test for alcohol. When the coalition was formed in 1991, 29 States had such laws and, by 1997, 39 States and the District of Columbia had ALR laws.

In 1994, the ALR Coalition expanded its range of interests to the following State laws: zero alcohol tolerance for young drivers; graduated drivers licensing for young drivers; lower BAC (0.08) laws for all drivers; and monitoring of State minimum drinking age laws to prevent repeal. In 1997, the Coalition agreed to participate with another coalition that is promoting standard (primary) safety belt and child safety seat laws.

Over 50 groups and government agencies now participate in the coalition. Members include safety organizations, insurance companies and associations, auto manufacturers and associations, medical groups, advocacy groups such as MADD and RID, and women's clubs.

In many areas, the progress made by this coalition has been dramatic. For example, when the Safety Board issued its recommendations on zero alcohol tolerance laws for young drivers, only 6 States had a law consistent with the recommendations. By the end of 1997, 46 States and the District of Columbia had such laws. The remaining States are expected to enact such laws in 1998.

The Safety Board participated with other groups and the National Committee on Uniform Traffic Laws and Ordinances to develop model laws for graduated licensing of young drivers, standard seat belt laws, and model child safety seat laws. Development of a model law is a necessity so that States can adapt that model law to their own constitution and code. Six States now have graduated license laws consistent with the national model and 12 other States have components of such laws. Also, in 1993, only 8 States had a nighttime driving restriction for young novice drivers. This law provides for safer driving and better understanding of night driving by requiring that a licensed adult driver

accompany the young (15 & 16 year-old) driver. By the end of 1997, 18 States had such provisions.

Progress in lowering the legal alcohol concentration for all drivers has been more difficult, especially in the face of well organized and well funded alcohol and hospitality industry opposition. Nevertheless, 16 States now set 0.08 as the illegal alcohol concentration and 15 of these States have made that level a "per se" offense. The Coalition members have also been successful in defeating measures to repeal minimum drinking age laws at state and federal levels.

The Safety Board also participates in the Air Bag Safety Campaign, an automotive industry-funded coalition promoting safety belt and child safety seat laws and educational programs related to airbags, safety belts, and child safety seats. When the Board issued its recommendation on standard (primary enforcement) seat belt laws, only 9 States had such laws. As of the end of 1997, 13 States had enacted standard laws and others had improved child safety seat laws. This is commendable considering the perceived personal privacy rights and "rugged individualism" in the American psyche.

The Safety Board, with the U.S. Coast Guard, state boating law administrators, insurance companies, and others, formed the National Recreational Boating Safety Coalition several years ago. As a result, all but 2 States now have a law prohibiting boating while impaired although 9 of the States with such laws did not enact implied consent to chemical testing for alcohol concentration. This limits enforcement of the law. One State has enacted boat operator licensing. As of 1997, 31 States have laws requiring young persons to wear a personal flotation device while in the boat. Twenty of those States have laws that are consistent with the Safety Board's recommendations.

The Safety Board helped with the national development of Operation Lifesaver in 1977. This is an industry funded, public-private partnership to reduce rail grade crossing fatalities, first formed in 1972. Forty-nine States now have their own Operation Lifesaver programs. The vast majority of rail-highway grade crossings in the United States are unprotected crossings. Therefore, education and communications among the various railroads, state, county and city highway departments, the federal government and the motoring public is necessary to reduce these crashes. This partnership has resulted in a reduction of crashes and fatalities at rail grade crossings. For example, in 1972, over 1,200 people were killed in rail-grade crossing crashes. By 1996, that number had been reduced to 488 and collisions had been reduced from 12,000 to about 2,000.

The Safety Board also participates in the Roadway Safety Foundation, a coalition of organizations concerned with traffic engineering and traffic safety. This group considers Safety Board recommendations and promotes redesign and reconstruction as necessary. Also, the foundation is an important group in the reissuance of the Manual of Uniform Traffic Control Devices.

Approximately 42,000 persons die each year on roads and highways in the United States. Between 700 and 900 persons die each year in recreational boating mishaps. Safety Board initiation and participation in coalitions are necessary in our federal system of government and critical to enactment of relatively uniform State laws and practices. This, in turn, achieves the goal of the safety recommendation - preventing crashes from recurring.

While we have a long way to go, we have made progress. The U.S. used to

experience over 55,000 highway fatalities, over 1,000 recreational boating fatalities, and 1,200 grade crossing fatalities each year.

We, and our partners, are committed to reducing traffic and boating fatalities even more. For example, we are partners with the National Highway Traffic Safety Administration in the "Partners in Progress" program. The goal of that program is to reduce alcohol-related fatalities from over 17,000 in 1996 to 11,000 by 2005. This is a commendable and difficult, but achievable goal.

We believe that this kind of aggressive advocacy of Safety Board recommendations is necessary to achieving our safety goal. To that end, Chairman Jim Hall has reorganized and renamed my office. It is now the Office of Safety Recommendations and Accomplishments. We now have a dedicated staff of safety recommendation specialists for each mode of transportation in our Safety Recommendations Division. They provide the development, monitoring, evaluation, and follow-up necessary to achieve the change recommended by the Safety Board. The Safety Accomplishments Division develops programs to publicize successful adoption of our recommendations and to recognize those companies that take action on their own to improve safety and who place safety as the highest priority. We will recognize the safety leaders and, by their example, stimulate those who do not have the same priority.

We believe that partnerships and our reorganized recommendation follow-up are even more effective than the approach we had been using. We expect higher levels of safety as a result.

Self Surveillance and Other Tools for Safe Driving

Jan L. de Kroes

Netherlands Association of Road Traffic Victims, The Netherlands

European Commissioner Neil Kinnock told us at the opening of this congress that the toll of the European road traffic is 45.000 people killed and more than two million people injured every year. His message can be condensed in one sentence:

THIS CAR-NAGE HAS TO BE STOPPED

A road vehicle can brake from top speed to standstill in a much superior way than ship, train or airplane. A road vehicle is more manoeuvrable and driving a car is simpler to teach and easier to learn than steering a ship or flying a plane. Yet, in spite of this Inherent Safety, road transportation has become the most unsafe mode of transportation.

Analysis of road traffic accidents teaches us that in the great majority of these cases human error is the causal factor. My own experience as chairman of the Association of Road Traffic Victims in the Netherlands indicates that nearly all accidents are wholly or partly caused by severe transgressions of the traffic rules. Predominantly, higher speed than is permitted on the road concerned, too high alcohol consumption and reckless driving, very often in combination.

In three aspects there is a big difference between road transportation and the other transport modes: Accident & Incident Investigation, Surveillance and Recording & Reporting.

1. Accident & Incident Investigation.

In the other transportmodes every accident and many incidents are subjected to a thorough investigation which results in recommendations to the parties concerned. The road traffic accidents are only partly investigated and then predominantly for legal reasons only. And incidents in road transport are very rarely investigated indeed.

2. Surveillance.

Surveillance in the other modes of transportation is done from a distance by means of instruments, mostly radar, so that the position of all ships, trains and planes in the area of surveillance are known. Close encounters and near misses will reveal themselves to the human operator, who is more and more supported in this task by special programmed computers. Surveillance on the roads is mostly done sparsely by policemen on the road side or in vehicles moving with the traffic stream. Only speed transgressions are systematical recorded by instruments placed at the side of the road. It is fair to state that the lack of surveillance in road traffic is a major contributing factor to the accident rate. This is even more true when the notion of surveillance is extended to probing the alcohol percentage

in the blood of the drivers.

Proposals for surveillance from a distance of highways by TV camera's require many operators because of the many vehicles and check points involved. This would lead to a large and costly organization. These proposals are mostly considered as too expensive. They might only be economically justified on busy main roads. This would mean that the difference in safety between primary and secondary roads would become even more unbearable.

3. Recording & Reporting.

There is a need for data recording for many different reasons. Modern ships and planes have technical status monitoring and reporting by means of an on-board computer. In this way the staff is warned for oncoming malfunctioning and curative measures can be taken in time. The stored data allows also the maintenance staff to study the development of a hardware failure from the start.

The on-board computer also collects, processes and stores all kind of trip information for supporting the navigation. Also fleets of trucks and busses employ on-board computers for monitoring and storing trip information. "Just in time" delivery of goods or arrival of bus passengers becomes more and more customary. Besides that, there is a lot of self-surveillance by means of the data in the on-board computer and the reporting of these.

Governments today are making big investments in building safer road infrastructure. One of the new devices of this program are variable optical indicators for safe speed in the traffic lane that change according to the traffic situation ahead. These indicators have also signs to be used in clearing and blocking the traffic lane for road maintenance.

Manufacturers of road traffic vehicles and their owners make big investments by producing and buying safer vehicles. All under the directives of national and international authorities. However, these investments in roads and cars will not show to full advantage if there will not be made appropriate investments in improving the human factor. Effective surveillance is considered too costly. So Self Surveillance by the drivers themselves as part of their normal driving task, might be the better answer to the problem of the lack of surveillance.

A safer vehicle means to-day primarily safer for the people inside the car. In the next century the emphasis must shift to new devices that will support the driver in safe driving, making road traffic also more safe for the people outside the car, in this case primarily pedestrians and cyclist. Pedestrians and cyclist constitute from 30 to 50 % of all road traffic victims in the Netherlands. They tend to be a forgotten group.

The new devices in the vehicle, that will assist the driver in safer conduct, will be, among others:

- Speed Adaptors, in which the speed limit is normally set at 30 km/hour. This limit can be increased and decreased by the driver during the trip in steps of 10 km/hour. Upon entering an area with a lower speed limit than the limit set, the driver is obliged to set the adaptor at that new limit.
- Intelligent Speed Adaptors, in which the speed limit is set by beacon transmitters placed at the side of the road. These beacon transmitters could make use of the loop antenna's of the existing traffic lights.
- Proximity Detectors warning for close encounters in the blind spots at the sides

and rear of the vehicle.

- In-Car Closed Circuit TV allowing for observations in the blind spots.

The data of these new devices can be recorded in an on-board computer or black box, together with customary data as time and date, distance travelled, use of lights and direction indicators, actual speed, acceleration and shocks. Today the black boxes can be divided in "Accident Reconstruction Recorders" and "Trip Recorders". It is predictable that these properties will be combined in the future black box. In general, the recorded data can be read but not changed.

After an accident, the data in the black box can be used to reconstruct the accident. This is important for the cases of criminal and civil law. These data are also important for insurance companies to determine the premium, for training programs and for simulation of drivers' task.

Fleet owners, who have installed black boxes in their vehicles, observed a big reduction of the number of accidents. The black box proves to be a very valuable tool for safety. The reason being that people aware of being observed might tend to modify their behavior in the right direction. This favorable result is the incentive for self surveillance.

This change of behavior and improvement of traffic safety could also be gained by private drivers, the owner-drivers. With a black box the driver can, in case of an accident, prove that his or her driving was not a causal factor. Without having accidents he or she can prove to be a non-aggressive driver who obeys loyally the traffic rules and because of that deserves a low insurance premium.

The effect could be improved if an "association for safe driving" would check the content of the black box regularly and give advice to the driver in acquiring a safer style of driving. Moreover, this association could give certificates to drivers with a long record with no transgressions, with a visual token to be fixed to the exterior of the car.

Such an association for safe driving could be supported by insurance companies. The task of the association could even be absorbed by the insurance company itself. For insurance companies have much to gain when the cars insured by them have a lower accident rate than those of the competition. Moreover, part of the gain could be given back as an bonus to the owner-driver. This might result in a bigger market share of the insurance company in the attractive market segment of safe drivers.

Insurance premiums are apt to rise because the insurance companies are hold more and more responsible for damages previously borne by social security funds and by partners and family members. This could be an extra incentive for insurance companies to stimulate road traffic safety.

So the reward for the preferred private driver should be a higher status and a lower insurance premium. In the beginning the black box will be an extra feature to the car for those who care but in the end a driver-owner without a black box will be suspect.

The idea of self surveillance could be extended when the black box can record, besides data, the images of the in-car closed circuit TV. When a driver feels that his safety is impaired by another vehicle he or she can, by pushing a button, transfer the images taken during the last seconds from a temporary memory to the permanent one of the black box. The images and the other data of these crucial seconds can then be used for discussions inside his or her association for safe driving.

This could result in a letter written in a polite factual style that will then be send by the association to the owner of the car that, also to the opinion of the association, impaired the safety. As only the registration number of the car involved can be read from the TV images this letter has to be send via an intermediary, being either the National Registration Bureau or the insurance company of the other party. This intermediary checks if the content of the letter is polite and factual. Of course, the other party has the right to reply. However, the other party will be aware that the letter is known by the intermediary.

When a driver is witness to an incident in which a second vehicle impairs the safety of a third party, being either a vehicle or a pedestrian, and records this incident the same procedure can be followed. When a driver is witness to an accident the images and other data of the black box should be placed at the disposal of the legal authorities.

In the above way it seems possible that also private drivers will participate in self surveillance, a development that has already successfully started for the professional drivers. It gives a picture of a road traffic system in which there is less freedom to commit transgressions without getting comments. In which the driver will behave more professional. It will not be the new era of "Big Brother is watching you" but one of greater social consciousness.

This era of greater social consciousness has already begun for the truck drivers in the U.S.A. Fleet owners put the office telephone numbers on the back of the trailer with an invitation to call the office in case of a transgression of the driver. To-day with so many mobile telephones on the road, the office is often informed before the driver returns home.

Some car drivers will feel pain with the prospect of losing part of their freedom on the road. They ought to consider that their pain is much less than the pain suffered by the road traffic victims and their families.

In the above described way it seems possible that the great majority of owner-drivers will voluntarily accept self surveillance and greater social consciousness, motivated by the potent combination of Solidarity, Pride, Fear and Greed.

The most important result of the above described development will be the reduction of the number of road traffic victims and then we could answer Commissioner Kinnock:

THIS CAR-NAGE WILL BE STOPPED BY US IN THE NEXT CENTURY

US meaning not only the participants of this congress, but all professionals concerned with road transportation and its safety. These professionals will hopefully be inspired by the congresses under the banner of "Safety of Transportation".

Single Accident Investigation in Road Traffic

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1. Introduction

In 1998, the Dutch parliament passed legislation establishing a Transportation Safety Board with the mission to investigate accidents and to make recommendations for preventing similar accidents in the future. The Board activities cover all modes of transportation; aviation, shipping, railroads, roads, pipelines and underground transport infrastructures. A major consideration for the Boards functioning is the role of investigation of road traffic accidents. Such investigation has hardly any tradition in road traffic due to the nature of road traffic, which is quite different from the other modes and due to the fragmented nature of the knowledge infrastructure regarding road safety.

To fit in with the existing knowledge infrastructure, the role and position of the Board requires definition. The current environment might be characterized as diffuse. Vehicle manufacturers, road infrastructure designers, legislators and accident investigators all working more or less parallel rather than interactively. Moreover, road safety research is more focussed on "defects" at the component level rather than systematic system deficiencies. While there is a great deal of operational knowledge and experience, a coordinating mechanism is lacking. An early start to such a mechanism was given by the former Road Safety Council, a non-investigative body predecesing the present Transportation Safety Board. The Dutch Transportation Safety Board will has to continue and elaborate on the developments of the earlier board.

Road traffic accident investigation has a very limited tradition in a scientific as well as a operational respect. The structuring of the Boards activities in road safety focus primarily on the first three steps of the board processes: initiation, factfinding and safety deficiency identification. The Board has to establish linkages between its findings and policy and other organizations who are in a position to eliminate or mitigate these deficiencies.

Like in the U.S.A. and Scandinavia, transportation accident victims start to organize themselves and claim access to the safety debate to contribute to the improvement of transportation safety. Unlike the U.S.A. and Scandinavia, where these groups focus on aviation and passenger ferries in the maritime sector, in Europe road traffic victim organisations have emerged and joined in a European Federation of Road Victim Organisations. The Dutch Association of Road Victims has taken the initiative to investigate road accidents and established an independent Accident Investigation Committee. This committee of experts voluntarily investigates accidents on request of

victims and their relatives. A first case study results indicate methodological pitfalls and opportunities. Like in the U.S.A. where the NTSB has extended its legislative responsibilities to family support of aviation accident victims, a cooperation between the Dutch TSB and victim organisations may emerge with respect to accident investigation in road traffic.

2. The specific nature of road traffic

2.1 *The road traffic system*

Although there are no fundamental differences between the road traffic system and the other modes of transportation, a number of specific characteristics exist. As a consequence, the road safety knowledge infrastructure has a limited and scattered nature. This nature justifies a dedicated elaboration of road traffic accident investigation methodology.

The specific nature of the road traffic system can be expressed by its characteristics:

- In road traffic a very heterogeneous population exists with respect to vehicles, traffic participants, design, construction and categorization of infrastructure. A wide variance in skills exists between traffic participants and drivers of various vehicles. Major differences exist in vulnerability. Drivers are autonomous in the selection of their mode of transportation, the performance of their drivers tasks and their behaviour towards other traffic participants. Very heterogeneous transport flows exist due to the intense mixture of passenger and cargo transport.
- the presence of a deviant risk awareness. Ordinary traffic participants differ in their risk perception from professional operators in other modes. If a major accident occurs in another mode, the public requests immediately an open and full investigation into the causes of such accidents. In road traffic with 1300 casualties and 50.000 injuries a year in The Netherlands alone, such an outcry does not exist.
- the limited extend of road traffic accidents. Compared to other modes, road traffic accidents have a vast majority of high probability-low consequences type of accidents. Major accidents hardly occur, probably with the exception of fog-related accidents on highways. Other modes have a more balanced ratio between high and low probability types of accidents.
- the embedment of safety management systems in road traffic is very limited. Safety management in road traffic is submitted to a wide variety of objectives, formulated by a wide range of independent stakeholders with often conflicting interests. Parochial interests and incoherent policy making exist with respect to Sustainable Safe Road Infrastructure, Integral Safety concepts of local community administrators, transportation of hazardous materials, working conditions legislation for professional drivers, local and regional urban and spatial developments, related to mobility, accessibility and economical development. Road traffic is unfamiliar with a company safety culture as does exist in other hightech industries. In the process industry, aviation, shipping, power supply and offshore safety culture in private enterprises already exists for decades in an institutionalized manner.

- the limited feedback learning capacity. Often vehicles, operators, roads and environment are analysed separately and not considered as components of an integrated system. Consequently, learning experiences limit themselves to this component level. Policy oriented feedback in road traffic is hardly institutionalized. In transportation of people institutionalization is lacking and in transportation of goods the feedback is limited to within private transport companies. Learning focusses on "proven defects" of components and does not take into account the systematic safety deficiencies in the system. In the car manufacturing industry "passive" as well as "active" safety is implemented, but safety of road infrastructure has been introduced only recently. Safety enhancing strategies concentrate on operational practice and are characterized by a separate interest in engineering, education or enforcement. Only very recently the liability of road infrastructure management has been legally settled.

2.2 *The road safety knowledge infrastructure*

By the deviant nature of the road traffic system, a wide variety of actors, issues, methods and techniques exist. The policy for developing road safety knowledge differs from the development in other modes (VeWa 1996).

The existing road safety research focusses on the components of the system in operational practice. Attention is paid to the visible factors of operator, vehicle and infrastructure in their operating practice, which are considered the most prominent contributing factors in accident causation. Theoretical concepts take accidents as the starting point for analysis such as the phase model of the accident process or the precrash-crash-postcrash model of Haddon (Haddon 1964, CVVO 1982). Road traffic safety research has not yet made the step in the evolutional development of transport safety research from the deviation concept - the accident causation approach - to the deficiency concept - the systematic safety deficiency approach - (Kahan et al). Inclusion of higher systems levels and non-operational systems life cycle phases in the analysis enable the disclosure of more structural deficiencies.

Existing traffic safety research is dominated by empirical expertise. Other types of knowledge development are possible and can be applied in road safety research. In addition, modern scientific notions and methodologies can be applied such as pattern recognition techniques, advanced statistical techniques like multivariate regression analysis, systems engineering, simulation techniques, crash and biomechanics, vehicle dynamics, fatigue and crack propagation theory or cognitive psychology.

Existing traffic safety research is submitted to pricing mechanisms. Apart from the lack of a market with purchasing power, such mechanisms hampers the willingness to cooperate between the various knowledge providers. Accident analysis is interdisciplinary by nature due to the complexity of the subject and the necessity to draw up recommendations which can count on the support of all stakeholders. Existing traffic safety research is heavily oriented towards implementation. The eventual result is the yardstick instead of the knowledge of causes, backgrounds, relations and dynamics of the processes which may lead to accidents and incidents.

In existing road traffic research each component and aspect has its own dedicated research institute or organisation. There is a lack of coordination between the institutes, each of which seem to have developed a specialism of their own in contrast to shipping and aviation where major research institutes exist covering all aspects and issues. A continuous reorganisation of administrative departments has destabilized the knowledge infrastructure. Job rotation, flexibility, decentralisation and the lack of coordination between ministries has disrupted the community of highly qualified and experienced safety advocates in governmental services as still do exist in aviation, shipping and railroads.

Finally, the existing road safety research has a policy oriented nature. A wide diversity of policy areas each have their influence on the research agenda and its priorities. A wide range of autonomous topics is covered such as Sustainable Safe Infrastructure, specific projects on transportation of hazardous materials, working conditions legislation as allowable driving times for professional drivers or risk standardisation with respect to external safety as an integral part of environmental legislation.

A need for a new approach in road safety is emerging. There is no reservoir left of new measures available in the present research strategy. Optimazation of principles and a fine tuning of methods will not supply the drastic reduction which is required to achieve the goal of 25% reduction of road accidents in 2010. Policy complications in the implementation of the present safety enhancement tactics are not likely to generate a drastic reduction of accidents on the short term. There seems to be a market niche for a new approach; the in-depth investigation of single road accidents, similar to other modes of transportation (RvTV 1998, MvT 1998).

3. Position and role of a Safety Board

In general the objectives of the Dutch road safety research can be categorized along two lines. One line distinguishes a policy support objective versus a knowledge development objective. The other line distinguishes a generic orientation versus a specific knowledge orientation.

orientation	policy	knowledge
generic	patterns trends	fundamentals aspects
specific	target groups standards	in-depth investigation

This categorization facilitates a positioning of the safety research and its applicability for Safety Board use.

A *generic policy support orientation* focusses on the collection of primary data, characterized by its probabilistic nature and statistical-epidemiological techniques. The use

of such larger, aggregated data bases with limited information items serve their goal for trend and pattern analysis and policy monitoring purposes.

A *generic knowledge development orientation* applies a deterministic approach, focussing on fundamental and anticipating research within one of the existing scientific disciplines. Mathematic modelling, laboratory experiments and simulation techniques are applied. This research is the domain of dedicated research institutes in the area of fundamental and applied aspects such as human factors, vehicle behaviour or infrastructure design.

A *specific policy support orientation* is developed to serve the development and implementation of specific policies. By the richness in detail and the dedicated nature of the research, safety enhancement strategies and tactics can be developed for specific problem definitions, such as Sustainable Safe Infrastructure. By this orientation the transportation of hazardous materials has been harmonized and standardized by the application of quantitative risk analysis with respect to the external risk consequences for this target group.

A *specific knowledge development orientation* focusses on in-depth analysis of accidents and casuistics. Historically this area has been the domain of police investigations and insurance companies. It is characterized by its technical-analytical approach. This research aims at the identification of accident causation factors. In other modes TSBs have established a long and lasting reputation in this area.

Both statistical-epidemiological as casuistic approaches prove to have their limitations in road accident investigations. A fine tuning of each of these approaches may be valuable, but will not supercede the inherent limitations of the approaches themselves. A synthesis between the two approaches seems to be beneficial and may compensate rather than eliminate the limitations in both approaches.

A synthesizing approach provides a basis for research by the definition of working hypotheses. Defining hypotheses enables the integration of scientific notions in the research issues of the Safety Board problem definition. A synthesizing approach defines accident patterns and priorities within the context of the Boards research programme. These patterns should be open to the involvement in the analysis of higher systems levels such as organisation and legislation, as well as contextual factors and should include other life cycle phases as well such as the design and construction phase. Data collection and composition of the research teams should be tuned to the Board objectives. This fits in with the Boards authority to provide researchers with specific instructions during the investigation (RvTV 1998).

Research techniques can vary widely from field observations, via experimental settings, simulation, laboratory tests to mathematical modelling. Their fit with reality, complexity, flexibility, repetiveness and involvement of multi-disciplines may vary considerable (Stoop et al 1998). They can be complementary as well and should be applied simultaneously to compensation their methodological limitations.

Accident investigation as perceived by Safety Boards actually is a specific scientific activity which cannot be reduced to a single discipline, research orientation or research technique. The added value of road safety accident investigation by a Safety Board is not to add a different research technique to the available scala of techniques of existing institutes, but to combine their techniques for its own mission: to obtain a better insight into the nature of road traffic accidents and to formulate realistic recommendations to prevent

similar accidents in the future. The Transportation Safety Board has a unique role and position in the road safety research community:

- it is independent in its problem definition. The Board is not dependent on preferences or requirements by funding organisations with respect to research issues and subjects. The Board defines its own research agenda.
- it maintains objectivity and is neutral with respect to the question of blame and liability. It distinguishes itself in this respect from police and insurance in in-depth accident investigation
- it defines its own research objectives. By its mission the Board perform its investigation in full publicity and has the authority to point at systematic safety deficiencies and to draw up recommendations.

The Dutch Transportation Safety Board has some restrictions towards policy related research. The Board has no authority to criticize and to make recommendations on future policy plans. The recommendations should be based on actual accident investigations and safety research findings. The scope of the Board research agenda in road traffic safety should be directed by the relevance of this research for policy making and the identification of safety deficiencies in the road traffic system. The Boards decisions to start an investigation consequently depend on selection criteria. The Board investigates major accidents, which raise the public attention and request for a full and open investigation. The Board also investigates types of accidents, derived from a systematic analysis of large aggregated data bases, trend analyses, or pattern recognition of a series of limited, but "typical" events. These safety studies may retrospectively concentrate on a small series of similar incidents, or may focus on a single accident, including a "go-team" for on-site investigation. Such a single accident selection may be adopted from other sources, such as the public, stakeholder groups or victim organisations.

4. Organisation and procedures

During the process of accident investigation a Safety Board distinguishes 5 primary processes: initiation, fact-finding, safety deficiency identification, recommendations and monitoring (Kahan et al 1997). In particular the first three processes are relevant with respect to road safety (Stoop et al 1998). Each of these processes can be characterized by a motto. For the first process of initiation the motto is "pick and choose": the Board must apply techniques of pattern recognition to identify accidents and sets of accidents for investigation. For fact-finding analysis, the motto is "make or buy". The Board will have to decide what internal and external resources and methods are best applied to investigations, and must allocate the tasks and roles to itself, regional and local authorities or outside experts. For safety deficiency identification, the motto is "understand to recommend". Here, the Board has to establish linkages between its findings and policy and other organizations who are in a position to eliminate or mitigate the deficiencies. Making recommendations and monitoring the Boards results are similar processes for each mode.

The Transportation Safety Board legislation contains some restrictions for road accident investigation compared to the other modes of transportation (MvT 1998, RvTV

1998). On one hand these restrictions originate from the nature of the road traffic system itself. By its legal mission the Boards learning in road traffic has been restricted to accidents which identify systematic deficiencies in the system. On the other hand the vast number of accidents necessitate a practical selection procedure to single out "typical" accidents which are open to investigation. In road traffic safety no international constraints exist such as in aviation where by ICAO regulations a mandatory investigation of every serious aviation accident is performed.

Consequently, some of the procedures for the benefit of investigation in aviation do not exist in road traffic. Legal exceptions are made for incident investigations, mandatory reporting of all accidents, preservation of accident sites for investigation purposes and impoundment of wreckages and other materials. Data collection on site therefore has some limitations which do not exist in the investigations in other modes.

Despite these limitations, accident investigation can be performed on a high quality level if some requirements are taken into account (Grayson and Hakkert 1987). General requirements are defined such as the application of a scientifically based methodology and careful planning of the investigation, interdisciplinary composition of investigation teams, predefined working hypotheses to be investigated and a multiple data acquisition strategy applying various techniques. Specific requirements deal with standardizing procedures by the application of checklists and technical equipment to record data on site and the training of investigators. At present data is readily available from police sources, insurance companies, hospitals and governmental inspectorates. Additional sources are available from the files of transportation companies, medical registration systems and emergency services.

In the future standard data sources will be possible by the introduction of traffic management service recording equipment, in-car data collection and the input from societal groups with their own specific notions and perceptions (Stoop et al 1998).

In addition to these readily available data, the investigation teams will have to collect data on site by visits, road image analysis, traffic and conflict behaviour techniques. Desk research will be required to supplete and verify these on-site data, such as by analyzing police protocols, research findings, judicial document analysis, local accident pattern analysis over a certain time period, damage and injury analysis, technical surveys and in-depth interviews with the traffic participants, eyewitnesses, relatives and experts.

5. Victim organisations and accident investigation

Single accident investigation as performed by a Safety Board, may be triggered by other organisations, such as a road victim organisation. In The Netherlands the Dutch Association of Road Victims have organized an Accident Investigation Committee. The Committee consists of road safety specialists of various disciplines which place their expertise to the disposal of in-depth and independent accident of road accidents. This committee has investigated an accident on request of the relatives of a bicyclist which has been killed due to a collision with a car (VVS 1998). The report aimed to serve as an example of the potential of in-depth accident investigation in road traffic, similar to procedures which already exist in aviation, shipping and railroads. The report aims to fit in with developments

within the international Safety Board community. Therefore, it closely follows the arrangements for accident investigation as stated in the Dutch legislation on safety board research topics and procedures.

Besides recommendations on the accident itself, methodological insight was gained in the investigation process. During the investigation it became clear that the three steps information gathering, fact finding and establishing the most probable causes of the accident, should be clearly discriminated among each other. Each step has its specific techniques, and requires its own expertise. Moreover, each step should be concluded carefully to prevent a reconsideration to fit in information which has become available later on during the process, to formulate new hypotheses or to change the description of the chain of events. Especially where witnesses, relatives and experts have different opinions, the process may be disrupted frequently. Since the identification of systematic deficiencies is the objective, the role of indirect stakeholders such as road infrastructure management, vehicle maintenance and justicial authorities may be underexposed in the available accident data. The definition of multiple working hypotheses proved to be important because establishing the cause of the accident eventually proved to be ambiguous. In a unique experiment, a full scale accident reconstruction was decisive as a verification on the two working hypotheses on speed, angle of approach and inflicted damage to the vehicles. By the publication of this report the process of investigation is not closed. The report could function as a start for a public hearing by the Safety Board. Investigation restrictions, as stated in the law, did have no effect. It proves to be possible in practice to come to results under the legal restrictions, even for an accident that happened some years ago. Last but not least, the report may be instrumental in overcoming the mourning and grief for road victims, their families and relatives by contributing to the answer why and how the accident could have happened.

6. Conclusions

Single accident investigation in road traffic can have future benefits. It may stop fatalism as the main argument for accepting the present level of casualties and injuries. In-depth investigation may disclose underlying multicausal patterns and relations. It may provide hinsight notion in accident causation for accidents, and especially types of accidents, which were incomprehensible. This hinsight notion eliminates time and resource consuming effect estimates, which are inherent to epidemiological and statistical approaches. More specific recommendations become available through the enhanced transparancy of the chains of events in the types of accidents under investigation. In-depth investigations may disclose systematical deficiencies, not only in safety, but also in the way accidents and their aftermath are dealt with by the authorities. Victim organisations confront authorities and safety Boards as well by their own experiences with police investigations, emergency and medical care, justicial procedures and family care aspects. Victim organisations introduce a new element in the safety chain.

References

- CVVO 1982, Voorstellen voor een kader waarin wetenschappelijk onderzoek tbv verkeersveiligheidsbeleid geplaatst kan worden. Commissie verkeers- en vervoersonderzoek. Ministerie Verkeer en Waterstaat 1980.
- Grayson and Hakkert 1987, Accident analysis and conflict behaviour. In: J. Rothengatter and A. de bruijn, Eds. Road users & traffic safety. Assen, Van Gorcum.
- Haddon, Suchman and Klein 1964, Accident research. Methods and approaches. Harper & Row publishers. New York, Evanston and London.
- Kahan, Van Dorp, Frinking, Stoop and Van der Horst, 1997, The evolution of safety boards. In: H.M. Soekha (Ed), Aviation Safety, Utrecht VSP, pp 639-648.
- MvT 1998, Memorie van Toelichting, behorend bij de Wet Raad voor de Transportveiligheid. Eerste Kamer der Staten Generaal, Vergaderjaar 1997-1998 Nr 304.
- RvTV 1998, Wet Raad voor de Transportveiligheid, 24 maart 1998. Eerste Kamer der Staten Generaal, Vergaderjaar 1997-1998. Nr 304.
- Stoop, Kahan, Van Dorp en De Kroes 1998, Wegverkeer binnen de Raad voor de Transportveiligheid. RAND Europe Leiden, oktober 1998.
- VeWa 1996, Meerjarenprogramma Verkeersveiligheid 1996-2000. De daad bij het woord. Ministerie van Verkeer en Waterstaat, Den Haag 1996.
- VVS 1998, Rapport 1 van de Commissie Ongevallen Analyse van de Vereniging Verkeersslachtoffers, Ongeval met dodelijke afloop op een hoofdweg binen de bebouwde kom ter hoogte van een T-kruising met een wijkontsluitingsweg. Arnhem, oktober 1998.

The Applicability of the Aircraft's "Black Box" to other Modes of Transport

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Just prior to World War II, the commercial aviation industry recognized the need for some form of flight recorder. However, technology could not deliver and the War delayed further development. As aviation developed after World War II, it was much less reliable than it is today. One of the major impediments to rapid development of the industry was the low level of confidence in aviation safety among members of the general public. Aviation accidents tended to be spectacular and they attracted wide media coverage. The risks of flying were regularly reinforced by news stories. There was a strong desire among the carriers, the manufacturers and governments to make the industry safe enough to gain public confidence and to exploit the commercial opportunity that seemed to be there.

Many measures were introduced to make flying safer. Engines were made more reliable. Improvements were made in airframe design and construction. Crew training was improved. Navigational aids were improved and many other things were happening, if not in accordance with an overall plan, at least in a co-ordinated way. One of the great benefits to aviation was the International Civil Aviation Organization (ICAO), a United Nations agency that established world wide standards and recommended practices for many safety related items.

One of the most vexing problems was how to analyse the failures. When an aircraft crashed it was common for the crews to be killed, the wreckage was often at the bottom of the sea, on the side of an inaccessible mountain, or a tangle of broken and melted metal at the bottom of a crater that was made at impact. Accident investigators often, but not often enough, would solve the mystery of the accidents. However, the work was time consuming and public speculation was often rampant during the investigation. This was often complicated by the civil claims associated with the losses of life and property. Many nations were at work at ICAO developing standards and practices to separate accident investigation for safety purposes from the civil claims and to standardize operating and investigative practices around the world. Something was needed to improve the accuracy and timeliness of the analysis of accidents as well as improve the objectivity.

Flight data recorders and cockpit voice recorders (FDRs & CVRs) were still seen as the best way of getting reliable and objective information to accident investigators. They were finally introduced in the early 1960's, primarily in response to unsolved aviation accidents. Their use was primarily intended for safety purposes. These recorders were nothing new in principle. Recorders had long been used to gather such things as weather data, seismological information, and data on industrial processes. In fact, the earliest flight recorder was on the first manned flight by the Wright Brothers; a crude altimeter and

timing device to document the flight. In transportation, there had been journey recorders on highway transport trucks for many years. What was slightly different was the operating environment of the recorders. They would have to withstand many cycles of pressure and temperature change and they would have to have a very high degree of reliability. These requirements were not particularly challenging. What was perhaps the most formidable challenge is that the recorded information would have to withstand the deceleration associated with a 500 or 600 kph impact with terrain, fires fed by thousands of gallons of aviation fuel, and the possibility of deep water immersion.

Pilots, through their professional associations did not have major problems with data recorders, but only cautiously agreed to voice recorders. They were concerned that voice recordings might be used for disciplinary and litigation purposes. Some only accepted the recording of all sounds in their work-place on the understanding that if they perished in an accident, their voices might provide information to make flying safer. The implied contract with the pilots has been generally respected and voice recorders are rarely listened to by anyone except in a post occurrence situation. Although there is no regulatory requirement for a CVR bulk erase feature and it is also rare for pilots to use the bulk erase feature, it is still designed into systems developed today so that pilots have the option to erase the recording after a routine flight.

Most recorders in use today run on a 30 minute continuous loop, with all information over 30 minutes old being automatically over-written. Two hour voice recordings are now being introduced without apparent problems, which suggests that pilots concerns about potential misuse have not substantially materialized. In many incidents, the 30 minute recorder does get overwritten and the move internationally to two hour recorders was primarily to minimize the chances of the recorder being overwritten in non-catastrophic incidents where power often remained on the aircraft for some time.

The understanding (at least in Canada) was that the voice recording was for circumstances when the pilots were not alive to speak. Some hold that this should be the only time they are used. Another view is that the use of the voice recorder to analyse incidents where there is little or no damage to the aircraft can be extremely valuable because of the natural limitations of human memory. While the voice recorder may not have originally been intended to be a supplement to or a means of verifying what surviving pilots say, experience has shown that human beings (pilots) rarely accurately recollect complex sequences during an often rapid and high stress event. This issue has not been fully resolved, but there is general consensus that voice recorder information should not be sensationalised, taken out of context, used in isolation, and are viewed by some as an intrusion on privacy in the workplace and therefore must be treated with caution.

There is a likelihood that video recordings will be added to the array of recorders now in use on transportation vehicles although many recorder specialists feel that there is better value in improving existing data recorders prior to introducing video recorders.

In Canada, Rail Event Recorders (no voice) were introduced in the 1980's by regulatory order of the Canadian Transportation Commission. No other regulations or significant changes have been made since then, however the TSB believes that voice recorders should be introduced. In the US, there is current activity to develop crash survivable voice and data recorder standards for trains.

Marine Voyage Data Recorders (VDRs) which will record both voice and data were introduced in the last five years. The introduction was largely driven by insurers and operators to aid in the resolution of insurance and liability disputes. Recent activity within the International Maritime Organization (IMO) has gained momentum to set standards for the devices internationally for safety purposes.

FDRs and CVRs have developed significantly in the last decade commensurate with technology in general. Today's most modern aircraft system records close to 1000 parameters at an average frequency of once per second. It should be noted that of the hundreds of FDR parameters on a modern aircraft, almost none are instrumented solely for the flight recorder. They are available on the aircraft's data buses and recording them is therefore fairly easy. The aircraft manufacturers for the latest generation of large aircraft are well ahead of the regulatory requirements because the manufacturers want to be able to verify that their aircraft performed as designed in case of an accident. They also rely on the information to help them design improved aircraft for the future.

Rail recorders yield basic information such as speed, brake pressure and throttle setting. Although human factors are involved in most rail occurrences, there has been little driving force to have voice recorders installed. Recent US NTSB recommendations included adding voice recording functions to trains (not necessarily requiring a second recorder).

Marine recorders which have been installed on a very small portion of the SOLAS (Safety of Life at Sea) class fleet, at the expense and initiative of a few operators, concentrate heavily on the voice recording aspect and the operating data seems to be of lesser interest. The most important data parameters recorded tend to be related to navigation.

Some aircraft operators, mostly in Europe, use the flight data on a regular basis to monitor fleet wide trends. In the US, this process has recently been dubbed FOQA which stands for Flight Operational Quality Assurance. The US FAA has not guaranteed ALPA (Airline Pilots Association) that US run FOQA programs will be kept separate from enforcement and the fixing of liability. This causes significant concern within ALPA.

None-the-less, the development of FOQA seems almost inevitable. There are significant operational efficiencies and accident prevention benefits to industry to study the data on a routine basis. There are numerous companies that develop software that will store and analyse recorded flight data. On-board monitoring is also available and some systems transmit reports automatically to the ground (ACARS).

A FDR/CVR on a modern aircraft is often essential to the analysis of an accident. In modern aircraft with glass cockpits and numerous computer controlled systems, the lack of a properly functioning flight data recorder can seriously compromise the ability to understand the sequence of events. The survivability requirements for new recorder designs has been significantly improved over the years to very high levels. The concept of dual redundancy has also been recently introduced (two dual function or combined FDR/CVRs on one aircraft) in an attempt to improve survivability beyond 99%. In several investigations where most of the wreckage has been inaccessible (such as ocean or mountains and high fragmentation accidents) the accidents have been analysed almost entirely on the basis of FDR/CVR information. On the other hand, accidents like TWA 800 demonstrate that even sophisticated recording systems cannot always yield the answers. Recorders are most

useful in identifying operational problems and human factors, which are still the most common elements in the majority of accidents. The recorders increase the efficiency and objectivity of investigations and provide reliable information about what happened. In order to understand the "why" of an accident, it is necessary to first thoroughly understand the "what". Recorders can often effectively allow investigators to develop the "what" in great detail.

Experience in aviation investigations has shown that witness information is often unreliable, yet there is a strong tendency to accept such information. This could possibly be because in most countries the legal system places a great deal of emphasis on "eye-witness" testimony. In aviation investigations, there have been few instances identified where misleading information or falsehoods were purposely provided. It is rather that humans simply don't remember dramatic, upsetting and rapid events very well. The recorded data can often be used to convince witnesses (and pilots) of what actually happened as opposed to their memory of what transpired.

United States FAA rules concerning flight recorders changed recently at the instigation of the NTSB after several unsolved accidents. The parameter list was increased significantly. For new large aircraft, there is no problem owing to the large number recorded already. However, many existing aircraft require expensive retrofits. Transport Canada's position is to "harmonize" with the FAA's, but Canadian rules are several years behind the US. The marine industry is developing international rules. The rail industry is somewhat static in the recorder area with few changes.

TSB (Canada) developed a multi-modal Statement of Requirements (SOR), placing emphasis on the importance of recorded information for investigative purposes in aviation, marine, rail and pipeline transportation. The intent of the SOR is to provide investigators with enough information that the reliability, comprehensiveness and timeliness of the analysis can be roughly equivalent regardless of the mode of transport. The SOR is a draft and requires further consultation prior to forming the basis of a formal recommendation to regulatory authorities. The SOR is expected to evolve as the TSB gains experience from its investigations and technologies change and improve. The main recorder issues briefly by mode are: Air - parameter lists and the recording of data link messages, Marine - Float Free vs Fixed and recording resolution of radar, Rail - introduction of voice.

There is a void in the TSB SOR in that it does not address highway transportation issues. There is also a concern that those with interests other than safety will use selected recorded information to support whatever theories suit their ends. It seems very important to apply state's accident investigation data to analysis based on scientific methods. If others use some of the data for different purposes it is important to insist that they do not present it as the accident investigator's information.

Today's solid state recorders are much easier to play back than older tape-based models, but there is still substantial room for error in producing and interpreting the data. There can be difficulties in the conversions to engineering units. There can also be factors that affect the reproduction of the data, sample rates, resolutions, source of sensors, etc. The main areas of responsibility for analysis facilities typically are:

- Validation of vehicle behaviour and operation - Are the vehicle systems interacting as intended, or is all/some of the data wrong?;

- Vehicle Performance - Is the vehicle performing as the data says it is or is all/some of the data wrong?;
- Developing a detailed sequence of events using analytical tools such as flight animation.

In the Air environment, the State of Occurrence is responsible for conducting the investigation. The State of Occurrence decides to have the recorders analysed wherever it sees fit. In the Marine environment however, the situation is not nearly as clear. The traditions of the Marine industry could become a source of difficulty in accessing recorders in a post occurrence situation. International regulations and agreement in advance would be worth the effort. IMO seems like a logical place to resolve such issues. The work being done on recorders at the IMO is very important to the development of international standards.

The Marine and Rail modes are less developed in the use of recorders than aviation. Much can be learned from the Air experience and there is little need to "re-invent the wheel". This has been seen to some extent in the working group developing the Marine VDR performance standards. Some "air recorder experts" have participated both from investigative authorities and industry and contributed to shortening the development period. Although the modes are different, there is a surprising amount of commonality when it comes to defining recorder requirements. The differences are not usually because of the mode of transport, but because of the different philosophical approaches to safety and investigation among the modes. There have been recorders on highway transports but generally for reasons other than accident investigation.

The operational environment in all of the modes is becoming increasingly complicated. Two way data link, Automatic Dependant Surveillance, Free Flight, Enhanced TCAS where aircraft systems are communicating intentions with each other are all rapidly developing technologies. New ships are being designed with integrated bridge systems. New trains have sophisticated systems on board. The network of systems that controls numerous vehicles simultaneously is also becoming very complex. Road transport where by far the majority of transportation accidents and deaths occur have the least amount of recorded data to assist in safety analysis.

There is an increasing need to have reliable recording systems to produce information to analyse failures in all modes of the transportation system. The "black box" and the devices that feed it with information are all within the range of commercially available technology. For the most part, the technology has received more widespread application in aviation than in other modes. There are enough similarities among modes that a case can be made for increased use of "black boxes" in all modes of transport. The basis of justification would simply be that the data would lead to quick, objective analysis of safety failures in the system. Once the occurrences are analysed steps can be proposed to eliminate the risks to lives and to property.

Central Advice System for Fleet Management and Operations

Improving the safety and reliability of rolling stock

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1. Introduction

Due to the changed role in current society, the requirements for mass transit products have changed dramatically over the last few years. The impact of social-economical changes lead to the necessity for polyvalent service and technical staff. Technological evolution has made systems more complex, "intelligent" and interactive. On-board systems are therefore required to support higher comfort, increased availability, better maintainability, reduced life-cycle cost and increased efficiency.

Safety, availability, reliability, maintainability and life cycle costs of transport systems are directly determined by the efficiency in fault diagnosis throughout the life cycle. Improved efficiency in operational diagnosis comprises;

- Significant increase in the level of diagnosis automation.
- Significant increase in the coverage of problems.
- Significant increase in the accuracy of diagnosis by tuning symptoms, additional tests and actions.
- Ensuring guaranteed response times for critical on-line diagnosis situations.

To cope with the mentioned evolution, a Central Advice System (CAS) for rolling stock (trains, trams, underground, light-rail transport systems, etc.) is under development as a decision support system for drivers, maintenance personnel and fleet managers. This development takes place within the framework of the European research and development project BRIDGE (ESPRIT Project 22154). BRIDGE specifically aims at real-time diagnosis of very large technical applications. The overall goal is to significantly improve diagnosis efficiency in operations and reduce the efforts required in supporting actions.

In this paper, the theoretical background of the BRIDGE tools will be discussed, the functionality of the Central Advice System will be presented, followed by the application of BRIDGE in CAS.

2. The BRIDGE-project

The BRIDGE project aims specifically at real-time diagnosis for large technical applications. Two main problems are encountered due to the size and complexity of such applications. First of all, the definition of the domain knowledge requires attention. The relations between faults, failures, symptoms and repair actions can be fairly complex and sometimes unknown. The efforts for the related acquisition, representation and maintenance of this domain knowledge should be minimised. Secondly, to be able to work in real-time within the framework of embedded on-board systems, the search process for the diagnostic reasoning should be predictable and have a guaranteed response time.

The BRIDGE tools comprise two separate tools; the Support Function Tool (SFT) and the Operational Diagnosis Tool (ODT). The SFT is an off-line tool to support the acquisition and maintenance of the knowledge base. The knowledge representation is based on case-based reasoning (CBR); a reasoning technique that allows for a definition in the form of each fault independently in terms of symptoms, etc. CBR then allows searching through these so-called cases to find the cause and to suggest corrective actions. Development support within the SFT includes the evaluations of integrity, coverage, accuracy and the real-time behaviour. After definition and analysis of the knowledge, and to generate from the definition a dedicated real-time diagnosis system, the ODT [5]. The ODT performs the on-line diagnosis of the alarms, and presents the diagnosis and additional tests that can be performed or questions to narrow down the search process. The ODT does not directly access the knowledge base of the SFT. A problem is diagnosed in the real-time kernel of the ODT, which is based on a novel approach in real-time expert systems [3].

2.1 Representation of domain knowledge

Facts and their relations represent domain knowledge. The facts of diagnosis applications comprise the physical configuration of the technical application that is diagnosed, possible health states, operational modes, operator levels, and the alarms, symptoms, tests, interventions and faults. The total number of facts in large technical applications, as emphasised in the BRIDGE project, can be in the order of tens of thousands.

Problems, or failures, are represented as relations between these facts. Different types of models can be developed from such relations; i.e. probabilistic models, causal models or fault-trees. Due to the complexity and number of on-board systems, it is almost impossible for human experts to explicitly define and maintain all facts and their relations consistently. Acquisition of a consistent application model would be too costly. In practice, it becomes impossible to develop such a model [6].

Diagnostic knowledge of the kind encountered in transport systems is implicitly available in the description of failure cases. A case describes a specific failure only by the occurring facts. The relations between these facts are not defined explicitly. A new problem is diagnosed by remembering similar fault cases. The action of the most similar case is reused as a diagnosis for the new problem. Additional tests can also be retrieved from these similar cases. The relevance of additional tests can be identified from case similarities and their information gain. This technique has already been successfully applied in a modified form

in the BRIDGE prototype [5].

Because case-based diagnosis avoids the explicit compilation and definition of relations, the efforts required for development and maintenance of diagnosis systems can be much smaller than for other techniques. Possible disadvantages of case-based diagnosis are a reduced accuracy and increased response time. Several BRIDGE features solve these disadvantages:

- In the knowledge representation, the general application knowledge is separated from the failure behaviour. General application knowledge is represented in the Configuration and Systems Description (CSD). Failure behaviour is represented as cases in the fault-base. The CSD only contains well-defined application knowledge that is independent of the behaviour of the application. Even for large industrial applications this knowledge is well defined and can be acquired relatively easy. An example is presented for CAS (see further).
- A diagnosis task defines the operational conditions for diagnosis, such as the technical subsystem of a new problem, alarm level, operator level, and the maximum available effort and time for executing tests and actions. These conditions thus bound the diagnostic reasoning.
- A failure case represents only one occurrence of a set of inputs, its causing fault and its intervention. In practice, however, a fault may cause other symptoms or results as well, and an intervention may be appropriate for several failures and faults. Several failure cases could be abstracted into a single case for a fault or intervention. This abstract or fault-case, is defined by the complete set of inputs and interventions. Each of these inputs can be associated with a certainty factor.
- The accuracy of diagnosis can be improved when general background knowledge about the application is included in case-based reasoning. Furthermore, the CSD enable essential evaluations of the knowledge base.
- Searching a fault-base directly would seriously degrade the response time for on-line diagnosis. Instead, use is made of a novel approach to real-time expert system techniques, representing the domain knowledge, and is used during on-line diagnosis in the ODT.

2.2 The search network

To address the problems of searching large amounts of cases, a fault network was developed [5,6], resembling the Rete network [1]. The network relates diagnoses inputs to faults and interventions. The initial developments used the network on-line as search medium, and initial evaluation has shown to give a satisfactory behaviour [6] and confirms several major advantages over other diagnostic approaches:

- The size of the network is minimised and contains no redundant nodes or relations. Computer memory can be reduced for large applications.
- Search is highly efficient for interactive systems. The network is only searched forward in a predictable manner.
- All possible faults and actions are searched in one pass through the network, allowing for the simultaneous treatment of multiple symptoms.

- The diagnostic strategy for a particular diagnosis task determines the categorisation of inputs. The strategy is thus inhibited in the network structure.
- Any input is immediately propagated through the output layer and avoids any backtracking or look-ahead search.
- The search procedure and size of the network strongly reduce the response time for diagnosis.

2.3 Analysing coverage and accuracy

The network of the BRIDGE prototype has been redeveloped and extended with sub-networks for the CSD and the SFT evaluations. The network facilitates the evaluation of integrity. Any integrity conflicts are detected as ambiguous links during generation of the network. The intermediate nodes, as categories of common inputs, facilitate the evaluation of, coverage and accuracy. The coverage of the knowledge base is the set of faults that can be diagnosed and the set of interventions that can be identified in the ODT. An indication of the coverage can be provided from the set of resolved and unresolved operational problems. Such a problem can be simulated in the network. Matching intermediate nodes identifies the coverage of faults and interventions for such a problem. The accuracy of a diagnosis depends on the accuracy with which a fault or intervention can be identified and depends on the additional information that can be obtained in operational conditions. The accuracy of the ODT should therefore be evaluated for different diagnosis tasks and operational conditions. The results of such an evaluation reveal the need for refinement or addition of tests and questions.

2.4 Real-time expert system techniques

Still, the network does not allow for real-time response time during search. For on-line use, an alternative approach is employed based on novel real-time expert system techniques. A state-based architecture is adopted, where only one process is active at any time, having exclusive access to any global data and no process will be pre-empted. In addition, a case-set compiler is used to address the problems of guaranteeing hard real-time response times [3], generating deterministic C-functions for the search paths.

The response time of the ODT depends on the amount of knowledge to be searched and the search process itself. The response time thus depends on the diagnosis task and operational condition. The BRIDGE project specifically emphasises the hard real-time requirements of operational diagnosis. The real-time characteristics of the envisaged system have to be assessed in the SFT. The response time of the on-line diagnostic system must match the requirements specified for the transport system. There is a need for formal analysis of the resulting on-line expert system that will be derived from the network structure, potentially in combination with the systems in which it will be embedded. A highly novel methodology for specification, analysis and synthesis of real-time systems is the Q-methodology (see ref. 4), developed from an original approach by Quirk which allows specification and verification of all required timing characteristics during the design of real-time systems. This methodology was further developed and combined with the Object

Modelling Technique [7] within the framework of the LIMITS project, supported by the European Union.

3. Efficiency in operational diagnosis

The rapidly evolving developments in rolling stock equipment strongly increase the complexity of problems occurring during service. Managing these problems during service and maintenance becomes very difficult. For each problem that appears, several possible causes exist, often linked with multiple systems and with a high impact on further service. The solutions to be taken depend on the impact on safety and service, and on the available resources. The decision process involves expertise from different persons, such as drivers, engineers and fleet managers. Efficiency for managing problems depends on the efficient processing of information about the current status of the application, a vast amount of domain knowledge, and experiences from other experts.

A Central Advice System (CAS) (see Figure 1) can be employed to support this complex decision making process. Two distinctively different tools are part of the CAS approach (as in BRIDGE):

- Support Function Tool (SFT), to support the off-line development of the on-line diagnostic system. Coverage and accuracy of the on-line diagnostic system are verified and improved with new operational experience. Verification of the real-time characteristics takes place here as well.
- Operational Diagnosis Tool (ODT), which provides a real-time on-line diagnostic system to support drivers, maintenance teams and fleet managers.

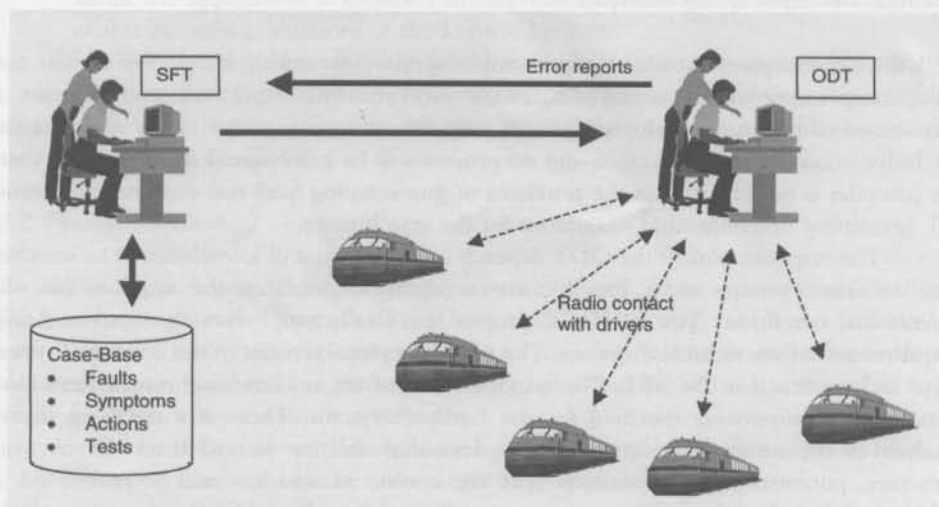


Figure 1. A schematic overview of the Central Advice System.

As is shown in Figure 1, several types of users work with the two subsystems. The engineering departments work with the SFT on the definition and maintenance of the

domain knowledge and generate the ODT. The ODT is used by the operators, which can be fleet managers that supervise the dispatching of trains, or for example maintenance teams that use the tool for in-depth searches.

3.1 Support Function Tool

The Support Function Tool assists in the development and maintenance of the Operational Diagnosis Tool. This comprises the definition of the knowledge, verification of the consistency and the coverage, verification of the real-time characteristics, analysis feedback reports from crew, etc.

3.1.1 Knowledge definition

The knowledge of system engineer(s) and system developer(s) is defined in two parts:

Configuration and System description: The configuration of a fleet is defined as a hierarchy of trains, vehicles, systems, components and spare parts. Furthermore, lists of possible health states, operational modes, operator levels, tools, etc. can be defined for each application.

Fault-Base: This is the case-base [5] with all anticipated faults and failures of the fleet and its on-board systems. The complexity of inter- and intra-system behaviour of large industrial applications poses a tremendous problem for the development of diagnostic tools (see later).

The procedure for defining the knowledge is as follows. Engineers start by defining the configuration and system description, describing in an object-oriented manner the physical and logical composition of the trains. Then, the fault base has to be defined, describing the faults, symptoms, tests and test results in relation to the configuration and system description.

3.1.2 Network generation, analysis and knowledge compilation

The SFT automatically generates the search network upon request, for example after an update of the knowledge base. Because the experience of all users is recorded and updated in the knowledge base, it is automatically shared among all others users after a next update. After this, the earlier mentioned analysis and verifications take place:

- The integrity of the knowledge base is automatically maintained in the SFT. Any integrity conflicts are prompted back to the user for modification.
- The coverage of the knowledge base is estimated from the resolved and unresolved cases in the history. Newly encountered cases can be added to the knowledge base.
- The accuracy of diagnoses can be evaluated for different diagnosis tasks. Accuracy can be improved by (re) defining tests and questions.
- Real-time requirements of the ODT for a diagnosis task can be estimated from the generated network.

Finally, the knowledge compiler compiles the network into C-functions that will operate in a state-based environment so to ensure guaranteed response times for the operational diagnosis tool.

3.1.3 Knowledge updating and extension

Initially, the fault base only contains anticipated faults and failures, i.e. those faults and failures that the engineers have thought of during the development of the system. During operation, however, additional faults and failures may become apparent, and also these failures and their interventions can be incorporated in the fault base. The engineers are presented with recorded failure descriptions and use the SFT to semi-automatically update the fault base. The information is automatically retrieved from the recordings and possible updates of the knowledge base are prompted to the user. Those updates can consist of modification of existing knowledge or of addition of new items. The user has the option to accept, modify, or reject suggestions. In this way, the fault base grows incrementally and reflects the corporate knowledge on diagnosis of trains within a company.

3.2 Operational Diagnosis Tool

The Operational Diagnosis Tool of CAS provides accurate and valuable information in real-time about any problem in a fleet, including their impact on the health state of the vehicle. It also suggests recovery actions to resolve or reduce the problem. The provided information and suggested actions are task specific:

- Drivers only receive information about interventions that can be executed within operational restrictions and within a certain time limit.
- Maintenance teams receive more detailed information about repairs, tools, spare parts, required efforts, etc.
- Managers receive information about train health states, impact on service, required efforts for interventions and spare parts requirements.

The inputs from all tasks are recorded in a history logging for later use and analysis (see 3.1.3).

3.2.1 Advice during service

During operation, events can happen which are critical for service or degrade operation. Such events trigger alarms to notify the driver. In most situations quick intervention is needed to be able to continue the journey or to keep the vehicle in service until the next maintenance activity.

The ODT of CAS supports a driver to interpret the available on-board information in an efficient way. An alarm is used as the starting point for the decision path. The ODT returns a prioritised list of possible interventions to the driver. Upon request, the ODT also presents details on the interventions and their consequences on service and safety.

When the input information is insufficient to accurately diagnose the alarm, the ODT requests additional information. A list of relevant additional tests and questions is presented for which the driver could return answers. The ODT only requests additional information that is relevant for the current problem and that can be obtained in the current operational situation.

3.2.2 Advice for maintenance

Diagnostic information from the on-board systems is used as primary input for more detailed diagnosis during maintenance. As with the service advice, the ODT proposes the most appropriate tests and questions that can improve the accuracy of diagnosis.

The diagnosis tasks for maintenance and service are somewhat different. Interventions for maintenance are for example to replace a "Line Replaceable Unit". The tests and questions that can be answered are also different.

3.2.3 Advice for management

On short term, the information retrieved from the ODT can be used for planning of the actual corrective maintenance as well as for the preventive maintenance. Furthermore, the fleet manager and maintenance manager can accurately allocate the trains or vehicles for service or maintenance respectively.

On long term, the information retrieved from the ODT can be used to forecast and optimise resources, such as stock, parts, staff, workshop, and etc.

4. The Bombardier transportation-division BN trial application

CAS will be applied as a trial application on the new tramways of one of BN's customers. These tramways contain advanced electronic technology:

- Microprocessor-based systems (brakes, converter, doors, passenger information system, ...) which have their own control strategy and auto-diagnosis.
- An integrated network system with communication channels based on the TCN standard of the TC9/WG22 committee (train network: WTB, vehicle network: MVB).
- An integrated alarm and diagnostic concept [1], including a driver touch screen for alarms, a vehicle computer for non-volatile storage of diagnostic symptoms information, and the possibility to launch start-up, shut-down and maintenance test sequences.

4.1 Alarm and diagnostic symptom information

Symptoms are generated for alarms and diagnostic symptoms. Symptoms are presented with following information:

- Location is specified by the unique vehicle number, car-body type (A or B), and system name.
- Unique symptom code and an associated plain text description. The code identifies a problem as accurately as possible.
- A first advice and a severity-level as an indication of the impact on service. The five severity-levels are health states:

Critical alarm	The driver has to intervene immediately. Most of these alarms can cause a service interruption, for example "service brakes on" during traction increase.
Disturbed service alarm	Problem degrades normal performance of the train, for example "Door out of service".
Warning	This serves only as general information to the driver.
Maintenance corrective	Problem has no direct impact on the service, but it is advised to resolve it after service. State is only available at the driver's screen at the end of the commercial service.
Maintenance preventive	Problem has no direct impact on the service and only has to be repaired during the two-monthly preventive maintenance period. State is only available by downloading the logged database.

4.2 Objectives

The main objectives of the trial application are to prove by experiment that the BRIDGE tool can:

- Improve train availability and safety. The severity level can be decreased occasionally for different problems from "critical alarm" to "disturbed service" or even "warning" by advising the correct driver intervention during service.
- Decrease maintenance cost. Time and efforts can decrease by advising the correct repair action during maintenance.

The systems related to train safety and train availability are monitored. For the trial application these include the traction, converter, electrical doors, brakes (including electro-dynamic, mechanical and pneumatic), compressor and automatic train protection.

Models are available for the doors, pneumatic brakes and compressor system. Initially, the knowledge base for is created from models. The knowledge base is updated with experience feedback from the experiments. Experience feedback is thus the only knowledge source for the other critical systems.

The trial period will be performed in two main parts:

- February '98 until June '98. The BRIDGE alpha release will be used during vehicle testing at Bombardier Transport-Division BN-site.
- From September '98 onwards, the BRIDGE beta release will be used at the customer's site.

4.3 Practical application information

CAS will run under "WindowsNT. For service, CAS will be installed on a desktop platform in the control centre room and will be operated by the fleet manager. Information is passed

to the driver by phone. For maintenance, CAS will be installed on a portable PC and used in the field.

The development of the application and of BRIDGE is done using OMT/UML (Object Modelling Technique/Unified Modelling Language) methodology and the software is written in "Microsoft Visual C++". The graphical user interface is "Windows look and feel". The knowledge base is implemented in "Microsoft Access". The link to the BRIDGE tool is implemented using ODBC in such a way that other relational databases can easily be used.

5. Conclusions

A Central Advice System has unique real-time/on line retrieval and off line update capabilities. The treatment of fault conditions encountered on modern trains is expected to improve significantly with the installation of CAS. Following advantages are emphasised:

- All knowledge is available for all personnel. Modifications of vehicle systems, complex or sporadic problems are distributed without difficulty.
- Information on problems treated in a temporary way during service is available for maintenance people.
- CAS provides a systematic approach to solving problems, which will decrease the efforts and number of spare parts wasted or damaged. The trial and error method, as often used, is only successful a first time in about 60% of the problems.
- Direct (hypertext-) links present the electronic Maintenance and Repair Manual information for tests, questions, interventions and spare parts.
- Reporting on problems is simple, uniform, complete, and generated automatically. The fleet/train manager can make a short- and long term planning for people and spare parts for the maintenance of the vehicles.
- Knowledge of a fleet's health state allows for better allocation of priorities for maintenance and for vehicles for service.
- Training of personnel can be improved. Real-life situations can be simulated from the history of recorded problems. Training system and vehicle knowledge can be reduced, in favour of learning how to retrieve the information via CAS.

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References

- [1] Coen L. De, 1991, Amélioration de la disponibilité au moyen d'un système d'aide au diagnostique embarqué, CEP SYSTEMES - Maitrise des risques dans le transports ferroviaires, 3.
- [2] Forgy, C.L. (1982). Rete: A fast Algorithm for the Many pattern / Many Object Pattern Match Problem. *Artificial Intelligence*, 19, pp. 17-37.
- [3] Jones, A. V., and M. G. Rodd (1994). An approach to the design of expert systems for hard real-time control. IFAC Workshop on safety, reliability and applications of emerging intelligent control technologies, Hong Kong, 12-14 December, pp. 30-35.
- [4] Motus L., Rodd M.G., "Timing Analysis of Real-Time Software", Pergamon, 1994.
- [5] Netten B.D., and R.A. Vingerhoeds (1994). Automatic Fault Tree Generation. IFAC Workshop of Safety, reliability and applications of emerging intelligent control techniques, Hong Kong, 12-14 December 1994.
- [6] Netten B.D., and R.A. Vingerhoeds (1995). Large-Scale Fault Diagnosis for On-Board Train Systems, in: *Case-Based Reasoning, Research and Development*, (Eds.) Veloso M., Aamodt A., Lecture Notes in Artificial Intelligence 1010, Springer Verlag, Berlin, pp 67-76.
- [7] Rumbaugh J., M. Blaha, W. Premerlani, F. Eddy, and W. Lorenzen (1991). *Object-Oriented Modelling and Design*, Prentice-Hall, 1991.

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Accident Frequencies and Causes within Transportation Corridors: Balance or Imbalance?

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1. Introduction

In many Western European countries a lot of attention has recently been paid to the concepts of transportation corridors and clustered line infrastructures. These concepts are supposed to reduce the total extent of negative environmental effects such as space consumption, landscape fragmentation, noise and smell. Furthermore, implementation of these concepts is an important condition in order to develop multimodal transport.

However, contrary to the reduction of most negative environmental effects, clustering transportation infrastructure may increase risks or lack of safety. According to Kaplan and Garrick [1980], risk primarily consists of three components, known as scenarios $\langle s_i \rangle$, probability of scenarios $\langle p_i \rangle$ and consequence of scenarios $\langle x_i \rangle$. Accident probabilities are the core contents of this paper.

Using Dutch empirical data, we will point out whether or not clustering infrastructure increases accident probabilities or frequencies in the Netherlands. However, these numbers still tell less about accident causes, so subsequently we will compare accident causes for clustered and singular parts of line infrastructures.

In chapter 2, a theoretical concept is presented which describes relations between clustered line infrastructures in respect to safety. In this paper we will focus on one specific relationship of the presented theoretical concept, namely interferences. Interferences occur as a result of clustering line infrastructures and might increase accident probabilities. Our goal is to empirically find out whether or not clustering results in increased accident frequencies on clustered infrastructures.

Therefore we developed a two-step research methodology. Firstly, in chapter 3, an overview will be given of the actual clustered line infrastructure in the Netherlands. We confined ourselves to highways, waterways en railways¹. Secondly, in chapter 4, we will analyze the

¹ Besides highways, waterways and railways, a large amount of hazardous materials is, in the Netherlands, transported by pipelines. In this paper, however, we left this modality out of consideration, because the pipeline research part is not finished yet. High-tension lines are not being taken into account, because their impact on public safety is supposed to be minimal. In respect of airways, we cannot speak of spatial clustering, so we have not considered them either.

theoretical interferences as presented in chapter 2. These interferences will be analyzed empirically in a quantitative way by comparing empirical accident frequencies on clustered and singular line infrastructure. Accident causes will be analyzed in a more qualitative way. Finally, conclusions will be drawn from both the quantitative and the qualitative analyses.

2. Clustered infrastructure and safety: theoretical framework

In this paper we will analyze the influence of clustering infrastructure on accident frequencies. Willems [1995] defines clustered line infrastructure as "two or more infrastructure lines joined in a relatively small zone or corridor with a limited distance between them". Therefore bundling traffic flows is not clustering infrastructure. Clustering infrastructure focusses primarily on reducing land-use and on concentrating negative external effects.

In respect of safety and risks however, several authors showed their serious concerns about clustering infrastructure [Thissen, 1993, Stoop and Van der Heijden, 1994, De Graaf and Rosmuller, 1996].

As usual in safety and risk analyses, safety or risk primarily consists of three components, known as scenarios $\langle s_i \rangle$, probability of scenarios $\langle p_i \rangle$ and consequence of scenarios $\langle xv \rangle$. Risk is a set of triplets of these three components [Kaplan and Garrick, 1981]. In this paper we want to find out if there is any evidence for these concerns in respect accident probabilities (as just one aspect of the risk triplet).

Therefore, we need to have a theoretical framework. Mac Donald, and later on Kjellèn, have developed a concept for analyzing accidents with respect to occupational safety, i.e. the safety within plants. Following Mac Donald and Kjellèn, Hale and Glendon [1987] defined an accident as a gradual process of deviation from the ideal situation resulting in an accident. The accident is followed by emergency response and in the end by recovery, leading to a new stable and, hopefully, more ideal situation. This view on accidents is widely known as the deviation concept.

Rosmuller [1997a] used this concept for analyzing clustering related transportation accidents. He concluded that the deviation concept is not well suited for analyzing transportation accidents in general, because various phases in transportation accidents cannot strictly be defined. Phases in transportation accidents cannot be identified straightforward, because they develop smoothly. However, the ratio behind the deviation concept is still very useful in respect of transportation accidents. With regard to transportation accidents, the deviation concept should be simplified to the following phases:

- pre-accident phase: in which normal functioning develops into possible causes for accidents due to deviations;
- the accident: accidents occur when deviations cannot sufficiently be corrected;
- post-accident phase: in which the accident consequences occur and recovery will lead to a new normal situation.

Applying these three phases to clustered line infrastructures, one has to look for mechanisms according to the accident phases described before. Therefore, Rosmuller [1997b] typified three possible mechanisms:

1. interferences: these are clustering related accident causes. In the pre-accident phase normal functioning on line infrastructure A may influence normal functioning on line infrastructure B. Interferences may increase the probability of accident causes.
2. domino effects; these are clustering related accident consequences. In the post-accident phase this accident may lead to additional accidents on the parallel transportation system. Domino effects may increase the extent of accident consequences.
3. synergism; because of the simultaneous occurrence of two or more accidents, the effects of these accidents may increase the total consequences in a way which is bigger than the sum of the consequences of the individual accidents.

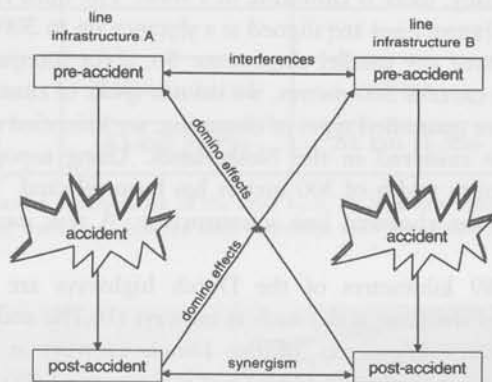


Figure 1. Theoretical framework.

In this paper we will focus on interferences. By empirical research we try to find out whether or not clustering line infrastructures results in higher accident frequencies for highways, waterways and railways.

Interferences may come about in several ways:

- increasing speed: this can arise from the aim to keep up, with for example, a passing train or car, especially when motorists or train drivers are annoyed and therefore try to increase their driving fun.
- panic reactions: in consequence of this a small deviation from the driving or shipping direction may happen, subsequently resulting in panic reactions. These reactions are dangerous, because they are in fact reflexes which cannot be suppressed. During a short moment all the attention of the motorist or shipper is fixed on these reflexes.
- distraction: the potential danger is that passing vehicles, trains or ships always distract, just because they are moving. This can be disadvantageous when drivers and shippers need all their attention to their driving and shipping tasks, especially in complex or busy traffic situations.
- visual inconvenience: at night motorists, train drivers and shippers could be blinded as a result of vehicles, trains and ships coming from the opposite direction. As a result of clustering with waterways, fog may seriously decrease motorists' and train drivers' view.

3. Clustered line infrastructure in the Netherlands

In general there are three types of clustering, based on mutual distances [Kerkstra, et al., 1981]. The first one is tight clustering. In this case, line infrastructures are aligned as close as possible to each other. Here we quantify tight clustering as a less than a 100 metres distance between line infrastructures. The second one clustering in a distance. Clustering in a distance is characterized by a parallel alignment and with a distance less than 300 metres between line infrastructures, but larger than strictly necessary. Clustering in a distance is quantified as an interjacent distance varying from 100 to 300 metres between two or more line infrastructures. Finally, there is clustering in a zone. The third type of clustering is the case where the line infrastructures are aligned at a distance up to 300 metres, but these line infrastructures barely have any parallel alignments. So, if the interjacent distance between the line infrastructures exceeds 300 metres, we do not speak of clustering anymore.

Using these three quantified types of clustering, we identified the extent and the way line infrastructures are clustered in the Netherlands. Using topographical maps, every corridor with a maximum width of 300 metres has been selected. Then an overview has been generated of all the clustered line infrastructure. A few interesting results of this research activity are:

- 13.1% or 289 kilometres of the Dutch highways are clustered with other infrastructure (of the same scale) such as railways (10.7%) and canals/ rivers (2.4%).
- 11.1% or 303,5 kilometres of the Dutch railways is clustered with other infrastructure such as highways (8.6%) and waterways (2.4%).
- 6.6 % or 304 kilometres of the Dutch waterways is clustered with highways (5.1%) and railways (1.5%).

The majority of these identified clusterings could be typified as tight clusterings. In Table 1 we have presented the amount of tight clustered kilometres subdivided in highways, railways and waterways.

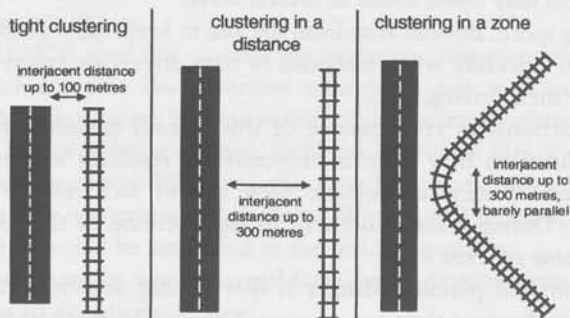


Figure 2. Types of clusterings visualized.

4. Accident frequencies and causes on clustered line infrastructure

In chapter 3, we identified clustered line infrastructures in the Netherlands. In this chapter we will analyze whether or not these clusterings differ from singular line infrastructure in

respect of accident frequencies and causes.

Firstly, we restricted the total amount of clustered line infrastructure to those lines which are only tightly clustered, i.e. an interjacent distance varying from 0 to 100 metres (see Table 1). Secondly, we restricted the remaining clusterings to those clusterings with a parallel length larger than 7 kilometres. These restrictions limit the amount of cases. Figure 1 shows the remaining tight clusterings in the Netherlands. The thick lines represent the clustered highways, railways and waterways.

Table 1. Tightly clustered infrastructure in the Netherlands.

	highway	railway	waterway
highway (2210 km)	XXX *	167 km (7.6 %)	43 km (2.0%)
railway (2747 km)	167 km (6.1%)	XXX	61 km (2.2%)
waterway (4617 km)	43 km (0.9%)	61 km (1.3%)	XXX

* We did not analyze clustered infrastructure of the same kind. So highways clustered with highways, railways clustered with railways, and waterways clustered with waterways were not involved in the research.



Figure 3. Map of tightly clustered line infrastructure in the Netherlands.

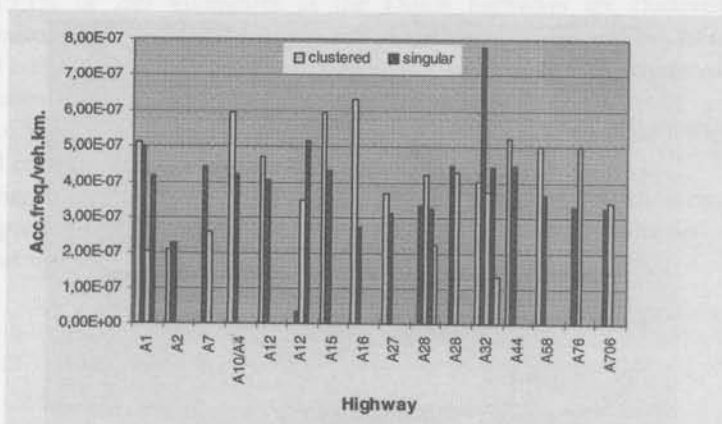
Subsequently we will describe and analyze the accident frequencies and causes of these identified tight clusterings.

4.1 Highway accident frequencies and causes

We examined 18 tightly clustered highway parts. As to highways we gathered data concerning the amount of accidents for 1995, both for clustered and singular parts of the above selected highways. Subsequently, we eliminated accidents on crossings, access and exit roads because we assumed these accidents will not have anything to do with clustering aspects.

In order to express the amount of accidents in a quantitative equivalent, we gathered data about the amount of vehicle kilometres for 1995 as to these highway selections. Dividing the amount of accident by the amount of vehicle kilometres for 1995 for both clustered and singular line infrastructure, we are able to compare accident frequency equivalents distinguished into clustered and singular highway parts. This comparison resulted in the following graph.

Table 2. 1995 Highway accident frequencies distinguished into clustered and singular highway parts.

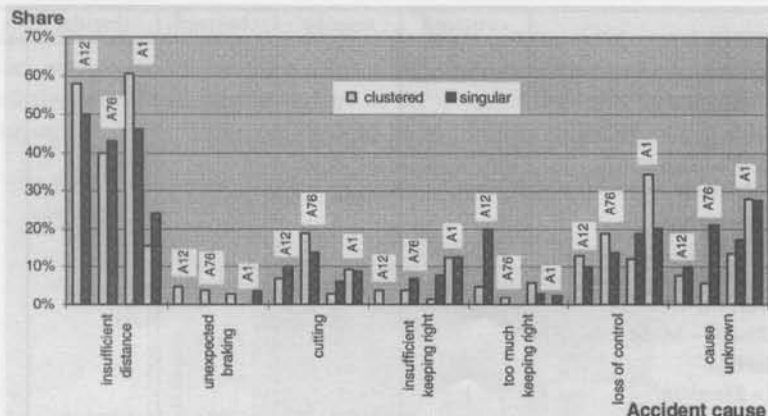


On the one hand, in 13 cases the accident frequency for clustered highway parts is higher than the accident frequency of the adjoining singular highway parts; on the other hand, the opposite is true for 11 cases. From this graph we could conclude that there is barely any evidence for assuming clustering highways results in an increase of accident frequencies.

However, this is only a comparison on absolute numbers (frequencies), which does not give a deep insight into the accident causes. So next, we analyzed accident causes. We specifically analyzed those causes which may be the result of clustering. These specific causes are strongly related to the four interferences as described above. We selected the following accident causes: insufficient distance, unexpected braking, cutting, insufficient and too much keeping right of lane and loss of control. Besides, we added the category unknown causes. This additional accident cause analysis we executed for highways in three counties,

i.e. Highway 12 (Zuid-Holland), Highway 76 (Limburg) and Highway 1 (Gelderland). The results are as follows:

Table 3. 1995 Highway human error accidents distinguished into clustered and singular highway parts.



From Table 3, we conclude that there is hardly any empirical evidence for an increase in human errors on clustered highways. Therefore we conclude that clustering highways does not result in an increase in human error accident causes as a result of the interferences described above.

4.2 Railway incident frequencies and causes

Following the same procedure as described above for highway accident frequencies, we examined 20 tightly clustered railway tracks. For railways, however, we did not look for accidents (for example derailed trains) but for incidents (for example red signal misses). The reason is that railway accidents only rarely occur.

As to incidents, we looked for stopping signals which were missed by train drivers, so called "red signal misses". Red signal misses from 1993 until now (November 30, 1997) were involved in the analyses, because from this moment the Railway Safety Board (SOR) has been keeping up a railway accident and incident database. After excluding the most obvious red signal misses at stations and marshalling yards, this database search resulted in 116 red signal misses. We reported these misses to the Dutch Railways and we first asked them to eliminate technical cause red signal misses (we are interested in human, train drivers, errors). Secondly, we asked the Dutch Railways to locate the remaining misses on their railway tracks in order to know whether or not clustering was the case. After these two selections, only 11 red signal misses remained because the Dutch railways located many misses still at stations and marshaling yards and they typified many misses as technical failures.

In order to get an objective equivalent for the red signal misses, we chose to express those misses in the number of signal passages. We computed the signal passages by multiplying the weekly number of trains on a certain railway track by the amount of signals

on a certain railway track (one sign every 1200 metre) and the number of weeks (203 weeks from 1/1/1993 till 30/11/1997). The following table summarizes the results:

Table 4. Red signal miss frequencies (1/1/1993 till 30/11/1997) distinguished into clustered and singular railway tracks.

	clustered	singular	clustered	singular	clustered
Leeuwarden - Meppel	1,23E-06	0*	0	8,72E-07	0
Amersfoort - Apeldoorn	0	0	0	0	
Utrecht - Arnhem		4,88E-07	0	0	
Amsterdam - Hoofddorp	0	0			
Hilversum - Utrecht	0				
Abennes - Sassenheim	0				
Gouda - Den Haag	3,45E-07				
Rotterdam - Hoek van Holland		0	0		
Breda - Dordrecht	3,49E-07				
Bergen op Zoom - Middelburg	0	0			
Geleen - Heerlen	0				
Amsterdam - Haarlem	0				
Amersfoort - Zwolle		3,02E-07	0	1,97E-06	0
Harlingen - Leeuwarden		2,09E-06	0		
Vlaardingen - Hoek van Holland		2,57E-06	0		
Middelburg - Vlissingen		6,57E-07	0		
Zutphen - Hengelo	0	0			
Amsterdam Amstel - Utrecht		3,94E-07	0		

* No red signal misses during 1/1/1993 till 30/11/1997.

Because the amount of red signal misses is that small, quantitative analyses are less useful. In order to get additional information, we could either expand the period (before 1993), or we could generate deeper insights by interviewing experts.

During our search, we had already contacted some railway safety experts. We chose to interview these experts. Both Mr. Stuijmeel and Mr. Roos have an over 20 years' experience as train driver and are now active at the department of Railway Safety, Dutch Railways. Mr. Stuijmeel and Mr. Roos stated that the absolute number of red signal misses is very small on right-of-way-railway tracks. Thereby they stated that not all red signals misses at right-of-way-railway tracks are reported, because train drivers have to report these misses themselves. This could imply some degree of underregistration. Both Mr. Stuijmeel and Mr. Roos have during their employment at the department of Railway Safety, not heard of any relationship between red signal misses and distraction caused by the other clustered line infrastructure. If there should have been any relationship, they stated, they would have known.

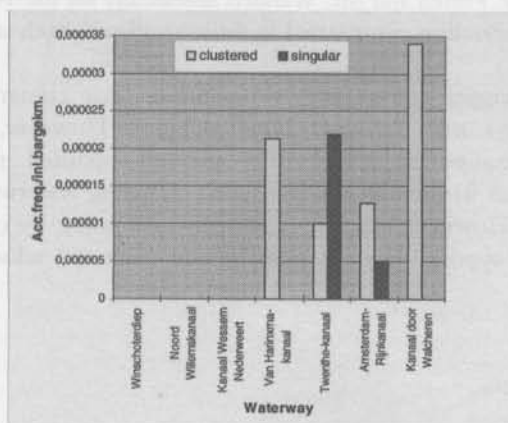
Mr. Hinsbeeck, active at the Railway Safety Board, also stated that clustering hardly causes red signal misses. Besides, in case of some form of distraction, this will never be the only aspect causing an incident. Other aspects, like for example expectations or executing multiple tasks, play a role as well, Mr. Loos stated. From expert consultancy, we conclude that clustering railways with highways or waterways might in some cases distract train

drivers, but based upon both red signal miss frequency analysis and expert consultancy we conclude that clustering will hardly ever cause an accident or incident.

4.3 Waterway accident frequencies and causes

For waterways we followed the same procedure again. First we gathered accident frequencies of the year 1996 for the selected tightly clustered waterways². Subsequently we computed the inland barging kilometres in the year 1996 by multiplying the amount of inland barges, counted at locks and bridges, by the waterway length.

Table 5. 1996 Waterway accident frequencies distinguished into clustered and singular waterways.



Knowing that the above graph is founded upon little accidents (varying from 0 to 9 accidents for specific parts of waterways in 1996), the more important it is to analyze the accident causes. For two waterways, the Twenthekanaal and the Amsterdam-Rijnkanaal, accident causes were analyzed in respect of human errors. Looking at human errors the following table resulted:

Table 6. 1996 Human error accidents distinguished into clustered and singular waterways.

	human errors	
	clustered	singular
Twenthe-kanaal	80% (4/5)	100% (2/2)
Amsterdam-Rijnkanaal	44% (4/9)	50% (1/2)

From this table, we conclude there is hardly any difference between the number of human errors on clustered versus singular waterways. Because the absolute number of shipping accidents is very small, we interviewed some skippers. We interviewed Mr. v. Putten,

² Note that the absolute number of accidents is very small, varying from 0 to 10 for the analyzed parts of the Dutch waterways.

skipper of the Willemina J., who was involved in one of the Twenthekanaal accidents and Mr. Wanders, skipper of the Aqqua Twin, who was involved in one of the Amsterdam-Rijnkanaal accidents. Besides we interviewed Mr. Oomens, skipper of the Krammer. In general at dawn and darkness, all three skippers stated that skippers are blinded especially by vehicles and less by trains coming from the opposite direction. However, for vehicles a nuance should be made in respect of highways and regional ways. The blinding from highway vehicles is not as inconvenient as from vehicles on regional ways. The latter namely drive frequently with full headlights in contrast to vehicles on highways which drive mostly with dipped headlights. Thereby, highways often have guard-rails which block opposite beams of light. Another aspect which is of importance is the presence of radar which make that skippers most of their time navigate on radar instead of eyesight.

We asked Mr. v. Putten and Mr. Wanders specifically for the 1996 accident whether or not blinding and distraction contributed to those accidents. Both stated this was not the case.

Based upon skipper consultancy, we conclude that clustering waterways with highways and railways may seriously blind skippers. However, guard-rails, design adaptations and radar equipment limit blinding effects of opposite highway vehicles. Based upon empirical accident frequencies we concluded clustering waterways does not increase accident probabilities. However, based upon skipper consultancy, we conclude that skippers may be blinded from opposite highway vehicles and trains and subsequently could cause waterway accidents.

5. Conclusions

The title of this paper was "Accident Frequencies and Causes within Transportation Corridors: balance or imbalance?". In respect of accident frequencies we conclude that the answer to this question is that clustering line infrastructure does not cause accident frequencies to increase on highways, railways or waterways. Looking at accident causes, again clustering does not result in the increase of human errors. So, the answer to the subtitle's question is that accident frequencies and accident causes on clustered line infrastructure are in balance with singular aligned line infrastructures.

However, according to Kaplan and Garrick [1980] risk is more than accident frequencies and accident probabilities (chance, π). Accident consequences (effects, ξ) and even more basic, other scenarios (σ) may be of more importance when risks and safety are analyzed in respect of clustering line infrastructure.

References

- Graaf, F.T.G. de, en N. Rosmuller, 1996, Transportcorridors en ruimtelijke planning; Externe veiligheid voorbij?, pp. 487-497, in: Planologische Diskussiebijdragen; Voorbij Beleid?, Delft, Nederland.
- Hale, A.R., en A.I. Glendon, 1987, Individual Behaviour in the Control of Danger, Elsevier, Amsterdam.
- Kaplan, S., en B.J. Garrick, 1981, On The Quantitative Definition of Risk, Risk Analysis, Vol. 1, No. 1, pp. 11-27.
- Kerkstra, K., e.a., 1981, Landschapsstudie en tracéontwerp Goor-Hengelo, STILO Wageningen, Wageningen.

Rosmuller, N., 1997a, Safety aspects of transportation corridors: towards a system-based research framework, pp. 1-21, 3rd TRAIL Year Congress 1997, New times and innovative solutions offered, Vol. 1, The Netherlands TRAIL Research School, Delft/Rotterdam.

Rosmuller, N., 1997b, Clustering Related Transportation Accident Analysis: Interferences and domino-effects, pp. 137-147, 14th International System Safety Conference, Washington, System Safety Society, Virginia.

Rosmuller, N., en J. Willems, 1996, Veiligheid van gebundelde infrastructuur; aandachtspunten vanuit ontwerpperspectief, pp. 1-16, in: Colloquium Vervoersplanologisch Speurwerk, Delft, Nederland.

Stoop, J.A., en R.E.C.M. van der Heijden, 1994, Transportsystemen, ruimtelijke ordening en veiligheid; Hoe V.E.R.der?, pp. 329-339, in: Planologische Diskussiebijdragen, Delft, Nederland.

Thissen, W.A.H., 1993, Veiligheid van grootschalige infrastructuur, pp. 160-165, in: Betuweroute; "Zegen of bedreiging?", NIROV/VLOB, Tiel, Nederland.

Willems, J., 1995, Bundeling van infrastructuur; conceptvorming en ontwerpstructuur, pp. 1-15, in: 1st TRAIL PhD Congress, Delft, Nederland.

Willems, J., 1996, Bundling infrastructure; Theory and design structure, pp. 1-14, in: 2nd TRAIL PhD Congress, "Defence or Attack", Delft, Nederland.



Figure 1

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Safety and Availability within Combi-Road

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Abstract. The Combi-Road project, sponsored by the Dutch government (ICES), took care of the development of a concept for unattended container transport in which the number of vertical movements and changes of carrier is limited as much as possible. In short, Combi-Road aims at the transport of freight containers via unattended guided vehicles, which use their own inexpensive infrastructure. The Combi-Road vehicles are powered by electricity and drive on air-filled tires. This in order to maximise the traction force, while at the same time minimising the local air pollution (exhaust) as well as the noise level. Within the first phase of the Combi-Road project, which was completed recently, theoretical investigations were carried out with respect to the economic feasibility to accommodate the often mutually conflicting design considerations of both components of the concept of reliability, being safety and availability. Next to a theoretical evaluation of the conceptual design, the possibly critical elements were experimentally verified on a test track. During these experiments it turned out that the envisaged functionality and reliability could be realised without the need to use any of the previously built-in alternative fall back scenarios. As a result an intrinsically safe system design is currently available, which next to an effective obstacle detection within so-called "floating blocks" offers track-bound vehicles a possibility to "look" forward over large distances and continuously estimate their own braking distances. This even on branched tracks, with curves, slopes, tunnels, etc. Furthermore, it offers a reliable communication channel between the moving vehicles and fixed systems. As such, the infrared (950 nm) based system has a broader application potential than just within Combi-Road. Here, (underground) tunnel transport systems (metro) or normal rail transport can be thought of.

1. Introduction and problem definition

In short, Combi-Road aims at the transport of freight containers via unattended guided vehicles, which use their own inexpensive infrastructure. These vehicles, to be thought of as "electrical trucks", drive on air-filled tyres and carry one standard trailer with one freight container at a time. In the original concept, Combi-Road was planned to be capable of pulling standard goods wagons as well. The maximum mass of a unit, in case a goods wagon is pulled, can be up to 90.000 Kg, whereas this would be some 50.000 Kg, in case a trailer is used. The vehicle's cruising speed is set at 50 Km/hour.

The fixed infrastructure consists of the the following four elements: The straight branche less single-lane track, Transfer stations, where containers are being transshipped, Junctions, where two individual tracks merge and Forks, where one track splits into two.

Although forks and junctions might, at first sight, be considered as being the same elements, it should be stressed that they differ both in functional and safety views. Further characteristics of the infrastructure are a maximum slope of 4%, a minimum curve radius of 300 m, as well as the possibility to have tunnels. As a direct consequence of the considered total mass, the track slope, the cruising speed and the materials of tyres and tracks, the braking distance may well exceed the maximum distance that can be perceived directly (line-of-sight) from a vehicle. Furthermore, concurrent vehicles approaching a junction, should be taken into account as well.

2. System hierarchy (3-layer model)

Within the industry, different hard- and software architectures are used to fulfil different automation functions. The harsh environment and short response time at the level of the "shop-floor" require equipment different from the type used at the planning and logistics level where huge quantities of data are stored and processed. The different architectures are often positioned within a 3-layer hierarchy (see Figure 1).

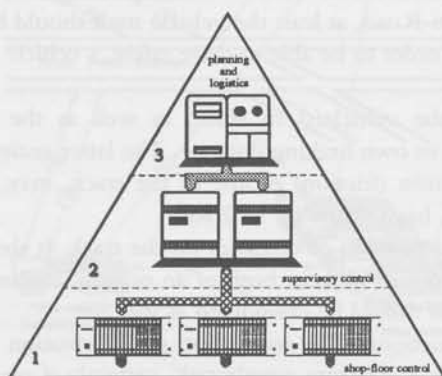


Figure 1.

3. Reliability

It is clear that, in order to get public acceptance and to become an economically feasible modality, a system like Combi-Road, should be highly reliable. Generally, reliability has both availability and failure mode aspects, which each turn out to be applicable to Combi-Road. The single-lane nature of the track will cause a total blocking thereof in case only one vehicle on it fails, even in case this would be a safe failure. Therefore, total failures should be avoided as much as possible and measures should be taken that any component capable of preventing a vehicle from blocking a track, should be kept in operation as long as this is safely possible (key words: fault tolerance or FT, graceful degradation).

The failure mode aspect focuses on the way in which the system may fail. This can either be in a safe or in an unsafe manner. It is possible to design systems in such a way that the chance on an unsafe failure is only a negligible fraction of the chance on a safe failure. Several strategies can be used in the design of these so-called fail-safe (FS) systems, but generally a fail-safe system shows a larger chance on failure than a similar system with is allowed to fail unsafely. Thus, safety requirements often compete with availability requirements and vice-versa. As an extreme example, a system that absolutely never functions, may often be considered quite safe... It will be obvious that in the industrial 3-layer model, for a fault-tolerant and fail-safe (FTFS) system these demanding requirements will at least be applicable to layer 1. Depending on the distribution of functions over the system, the FTFS requirements may migrate to other layers as well.

4. Actual requirements

The fundamental conflict between safety and availability requirements generally leads to very demanding specifications for all (sub)systems that have to meet these requirements. Therefore it is recommendable to have as little of the system subject to these highest demands. Within Combi-Road, at least the vehicle itself should be considered to be fault-tolerant and fail-safe. In order to be able to drive safely, a vehicle should have access to the following information:

1. Its distance to the vehicle(s) in front, as well as the speed and maybe even acceleration thereof and its own braking distance. The latter entity, which in turn, depends on the slope and condition (friction) profile of the track, may, with the infrastructure's characteristics presented, have values up to 2 Km.
2. The presence and position of obstacles on the track. It should be noted that in this respect next to many kinds of objects, both of an organic and inorganic nature, defective vehicles and parts thereof should be considered as well.
3. The status of junctions. The acquisition of information on a concurrent vehicle approaching a junction is a far from simple task, certainly if mechanical adaptations of the track are to be avoided at all.
4. Track related restrictions to the maximum speed, such as curves, slopes, etc.

It should be stressed again that the detection and sensor mechanisms should fail safely. For instance a sensor that does not perceive an obstacle would be a rather poor starting point for the assumption that there is in fact no obstacle. This because the sensor might be defective itself.

5. System overview and analysis

An overview of possible physical entities within the Combi-Road system as well as their potential interconnections is presented on Figure 2. Within this figure a "solid" line with arrows represents a position independent path, whereas a dotted one should be considered position dependent. The figure shows all interconnections to be considered, which does not

imply that these interconnections really will exist in actual practice. Furthermore, no assumptions are made in advance with respect to the nature of information which is exchanged over the given paths. They only represent an aid for the analysis of the different related failure modes.

Starting point for this analysis is an investigation in which ways the vehicles may, via the communication paths indicated, acquire the necessary information summarised (points 1 to 4) earlier, without the a-priori assumption of any vehicle-bound sensors. In order to obtain the information mentioned in points 1 and 2, an exchange of information between mutual vehicles might be thought of (paths 4a and 4b in Figure 2). However, since vehicles may be (entirely) defective and the track may be blocked by other objects than Combi-Road vehicles as well, this option should be discarded from a safety point of view. Thus the possibility to have the vehicles as the only component in layer one is ruled out.

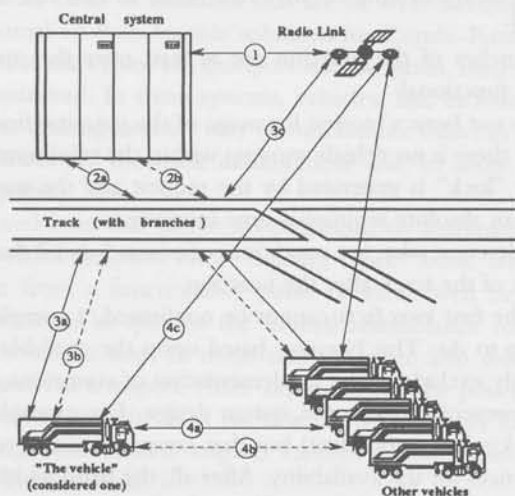


Figure 2.

Communication path 4c might, at least in principle, be used for acquisition of the named information, but only in case this information can be acquired through a fail-safe mechanism, via either path 3c or the combination of path 1 and 2a/b. The data involved are originated by the track and may either be distributed without or with the assistance of the central system. In case of the latter option, all sub-systems will be subject to the very demanding FTFS requirements. This, in turn, is not only highly undesirable from points of view of costs and reliability, but it will also severely increase the real time processing demands for the central system.

The only remaining paths that may provide the information necessary from points 1 and 2, are 3a and 3b, both suitable for the exchange of data between the vehicle(s) and the track. Using one of these paths, of course takes the track, next to the vehicles, into the area of FTFS demands. If only for the acquisition of the data related to points 1 and 2, the location independent (continuous) path 3a might be favoured over path 3b. However, this

might overlook the requirements stemming from points 3 and 4. In case each vehicle would internally have access to a correct map of the infrastructure, it should be considered feasible that, with the input from (wheel) sensors it continuously computes its own position (like in Carin and TravelPilot), but some absolute calibration might be desirable. Such a calibration can be implemented via path 3b, but it should be stressed that this does not automatically exclude path 3a. This because of the possible discontinuous nature of path 3b which may relate the vehicle's safety depending on deduction and the processing of historic data. Of course such an approach would be less solid than one using path 3a. The mere existence of path 3a/b does not imply that the conditions mentioned in point 3 are automatically met. Although the condition mentioned in point 4 will probably be satisfied, surely in case the conditions of points 1 and 2 are met, the condition of point 3 requires some further analysis. This condition boils down to an answer to the question "is the junction (in due time) vacant?". This question can only be answered safely in case the following facts have been actively confirmed:

- Both branches of the junction are at least over the minimum vehicle distance completely functional.
- There has not been a request for usage of the junction from a vehicle on the other branch and there is no vehicle moving within the minimum vehicle distance. In this approach a "lock" is generated by the request and the track communication takes place with an absolute sequential time integrity.
- For completeness sake, the conditions of points 1 and 2 should of course be satisfied for the part of the track after the junction.

In case either of the first two facts cannot be confirmed, a complete stop seems to be the only sensible thing to do. This because, based upon the available information, a collision cannot be absolutely excluded. The implementation of communication paths 3a and/or 3b does have major consequences to the system design. For example, if path 3a were to be implemented as a kind of (redundant) bus that covers an entire route, this might have far reaching consequences for the availability. After all, the band width should be large enough in order to serve all vehicles simultaneously, and special measures should be taken in order to prevent disruption and/or single points of failure.

6. Positioning of solutions

In principle, the choice for a control concept for Combi-Road might be based on three approaches:

- The usage of analogous aspects from road traffic.
- The application of techniques from rail transport (train, metro).
- Using completely new technologies.

Of course combinations of these approaches might be considered as well. This because Combi-Road, next to entirely new properties, seems to resemble some aspects of both road and rail traffic. However, solutions based upon available or currently promoted technologies from the road traffic seem to overlook some important operational differences with Combi-Road:

Combi-Road

- Proprietary "single lane" track
- Unattended
- Highly variable (low) maximum acceleration and deceleration
- High demands with respect to safe failure

Road traffic

- Multi-lane
- Attended
- Relatively well defined (high) maximum acceleration and deceleration
- Unsafe failure can be corrected

These differences cause the Combi-Road problem definition to be partly less and partly more demanding than in case of road traffic, thus anyway different. Therefore it cannot be assumed in advance that all kinds of solutions that are or were developed for road traffic applications, will be optimal or even feasible solutions for Combi-Road as well. As far as analogies are applicable, the ones from rail transport systems (train, metro) probably are also or even more to be considered. In these systems, vehicles, like in road traffic are indeed attended as well, but their braking distance may be much more than can be surveyed by the driver. Further resemblances are the track confinement and, to some respect, the safety demands (Dutch ATB system).

It should be stressed here that recent investigations on automatic train influencing (Dutch: ATB) systems which function on a "floating block" basis, are carried out. This principle might, at least from a functionality point of view, well be applicable within Combi-Road! Nevertheless in spite of the mutual resemblance related to the single degree of freedom, it should be kept in mind that there are also substantial differences between Combi-Road and rail transport. After all, issues like the possible (range of) mass ratios between pulling entity and the load on tow, as well as ones like propulsion and braking systems show large and (trailer, wagon) variable dissimilarities. Furthermore the traffic density differs for both systems.

7. Starting points

In the final choice of a control concept for Combi-Road, the following starting points played a decisive role:

- The intrinsic safety of the system.
- A very high operational availability, with as derivatives:
 - As much autonomy as possible at the vehicle level.
 - A clear preference for a distributed (scalable) system.
 - The avoidance "single points of failure".
- No negative operational consequences (throughput etc.)

Based upon these starting point, a group of control concepts was arrived at in a more or less analytical way.

8. Analysis

As long as a longer section of the track is vacant than the vehicle's current braking distance, the vehicle may drive on safely. Therefore, at the level of a vehicle both the vacant track length and the current maximum braking distance (friction, load and slopes considered) should be known. Of course the surveyed track length never has to exceed the absolute maximum braking distance, whereas the current braking distance may either result from a simple (worst-case) estimation, or from a more refined computation which takes the current conditions into account. The latter option leads to a higher maximum throughput. It should be stressed again here that the perception of a vacant track is not equivalent to not sensing any obstacles. After all, the apparent absence of obstacles may be caused by limitations or defects of the sensors, whereas a vacant track perception requires an active confirmation thereof. On a simple straight track, this principle may be conceived as an imaginary rod with a length equal to its braking distance, being pushed forward by the vehicle. On Figure 3 a more general presentation of the "vacant track" principle is given. Here it is clarified that curves, junctions, as well as slopes, tunnels and forks should be considered.

8.1 Completely autonomous vehicle on a passive track

Starting from a maximum autonomy at the level of the vehicles, the application of a sensor system on each vehicle, capable of unambiguous determining a minimum vacant track length, without any active external assistance, might seem a natural consequence. However, in order to satisfy the safety demands, it is required that some kind of signal, emitted by the vehicle, propagates along the track and results in a confirmation of the distance over which this signal did not encounter any obstacles. Of course the complete spectre offered by physics should be considered open for the solution of this problem. In this respect acoustics, for example ultrasound (like bats use), but also inductive systems (coupled loops), or electromagnetic radiation like light, infrared or microwaves are possibilities. Nevertheless, a completely autonomous vehicle on a passive track leaves quite a lot of nasty problems to be solved. How are obstacles on or outside the track distinguished? What (angular) resolution is feasible, taking the sensor dimensions and applied wavelength into account? How to cope with slope changes and junctions? Both for the following of the track as well as in order to obtain a positive confirmation of a "vacant track", a concept of some kind of reflectors seems necessary. These reflectors should be distinguishable from all possible obstacles on or outside the track. Although the construction of specific, recognisable passive reflectors (tags) should be considered fundamentally feasible, the distance to be bridged and the related power to be radiated, caused this option to be primarily discarded. For this reason the alternative of an active track was investigated too.

8.2 Autonomous vehicle on an active track

This range of solutions might (see Figure 4) be compared with a road by night, illuminated with (active) streetlights. By counting the number of lampposts still visible, a driver may get an impression of the length of the road that can be surveyed.



Figure 3.

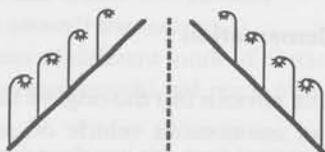


Figure 4.

The "passive track" analogy of this approach, would be verge reflectors which reflect the light from the vehicle. Mentioning this "passive" alternative, clearly indicates again that, although the "active" example presented also has this drawbacks, following curves and slopes is far from simple. However, active systems, when compared to passive ones, may offer many extra possibilities for solving the problems related to following the track. Every active subsystem along the track may, for instance, communicate with its neighbours and thus form an active data link along the track. In case a passing vehicle is able to communicate with at least one of these track-bound sub-systems, a potential data path between all interconnected sub-systems along the track and the vehicle is formed. Thus, this vehicle, at least in principle, may have access to all data collected by all track-bound sub-systems.

A typical example of this approach is shown on Figure 5. Here, the data collected is related to obstacles and the track-bound sub-systems each transmit their (accumulated) data both to the (slanting arrows) track and to the next sub-system. In this example the movement of data is from left to right, thus in the opposite direction of the vehicle movement. This means that all data collected in front of a vehicle may, again in principle, be transmitted to this vehicle. If a communication failure is interpreted by the system as equivalent to a track blocking obstacle, this may add fail-safe characteristics to the system in case the obstacle detectors either are error free or fail safely themselves as well. Of course it is unnecessary and even undesirable to receive all (obstacle) data collected onwards along the track, at any position on the track. After all, more than the status of all detectors along a track length equal to the absolute maximum braking distance would be sufficient to meet the original starting point of a "vacant track". The conceptual approach presented here obviously should be considered capable of satisfying the condition of a positive confirmation of a "vacant track", even without any a-priori assumptions about the sensors or the communication technology. However, the issue of system availability may be a point of concern. A failure of only one transceiver will inevitably lead to a blocking of all traffic on the track, since the next sub-system will interpret this situation as itself being the first one. For this reason adding redundancy is mandatory.

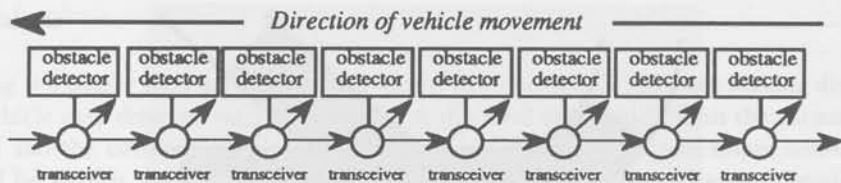


Figure 5.

9. A possible technical implementation

In the previous part it has become obvious that the original starting points can be technically satisfied with the concept of an autonomous vehicle on an active track with a positive confirmation of the "vacant track length" in front. A possible technical implementation of this principle is shown on Figure 6. This figure represents a straight piece of the Combi-Road track, with transceivers on both sides. Each transceiver sends its information to two successive ones at the opposite side of the track. Although maybe not obvious at first sight, the system presented here actually corresponds to a redundant version of the principle shown on Figure 5. The reason that this may remain unnoticed is the apparent absence of obstacle detectors. However, these are implicitly present, since the communication channels may be blocked by obstacles and thus may act as detectors. A clear advantage of the absence of separate obstacle detectors lies in the impossibility of defective ones, as well as the avoidance of the related costs. The system's symmetrical redundance enables it to distinguish defective sub-systems (beacons) and real obstacles. With the assumption that a "vacant track" without an obstacle (see Figure 6) holds two times eight functioning beacons, beacon L8 will receive information of all other beacons with the exception of R8 and L7. This are in total 13 beacons. However, in case a sufficiently big obstacle is present on the track, all information from previous beacons will be lost. A single defective transceiver, in turn, will only result in the loss of its own information and, depending on the propagation distance, the information of an adjacent one. In case of a defective R7, will cause the loss of L6 on L8.

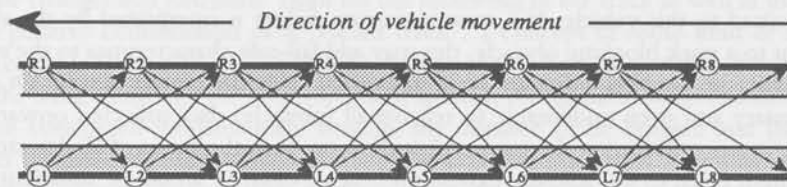


Figure 6.

A passing vehicle will not only block the information exchange between the beacons, it will also intercept the data transmitted. Although depending on many geometrical conditions, a passing vehicle is supposed to always receive at least two different beacons simultaneously. Therefore a continuous and redundant flow of data towards each vehicle, holding (a.o.) the

"vacant track" information is realised. The resolution of this information is related to the interval distance between adjacent beacons, of course. In this fashion, all conditions of the starting points are satisfied.

10. Selectivity and transmission medium

Although the choice of a transmission medium was entirely open, a final decision should take (a.o.) the following important factors into account:

- The final costs of the (many!) transceivers.
- The blocking properties of different kinds of obstacles.
- The imaging accuracy (wavelength) and reach (dirt etc.!) in relation to the desired resolution.

Both with respect to their wave length and the costs μ -wave and RF solutions seem to have drawbacks here. Furthermore, as discussed in the "SMILER" report (DRIVE project V 1002), problems can be expected related to reflections and blocking properties.

Last but not least, these media may relate to potential legal problems and health risks. For these reasons the primary attention was focussed at ultrasound and infrared light and from these two alternatives the first one, based upon its lower propagation speed, seemed to be less attractive. Finally, infrared light with a wavelength of 950 nm was primarily chosen.

11. Feasibility study

Starting from the concept described, an investigation of the practical feasibility was carried out. One of the issues in this study was trying to find a cheap and reliable solution for the problem of distinguishing different transmitters, both at the beacon and vehicle receivers. The following potential solutions were considered:

- In case of base-band transmission:
 - TDMA, T(ime) D(omain) M(ultiple) A(ccess).
 - Spatial (angular) discrimination.
 - Colour (wavelength) differences.
 - Polarisation.
- In case of modulation:
 - FDMA, F(requency) D(omain) M(ultiple) A(ccess).

From these, spatial (angular, optical) discrimination was primarily chosen, with as fall-back scenarios colour differences and polarisation. A final decision should be made, based upon experimental results.

Furthermore the feasibility study recommended (a.o.) an experimental verification of the system's margins with respect to pollution (dirt) and weather conditions (fog, rain, etc.).

12. Protocol development

Following the conclusions of the feasibility study, it was decided to experimentally verify the basic concept of an autonomous vehicle on an active track. As such, a protocol for the messages to be exchanged between the beacons was developed, in which design, next to the "vacant track" information:

- A system was worked out which avoids the exponential length increase, due to the combination of two incoming messages to one outgoing one.
- The age (delay) of the information can be reconstructed.
- Routing and (even complex) branching information can be transferred.
- Data related to the track's slope and condition profile are incorporated.
- A possibility for the exchange of data to and from an optional supervisor is present.
- Data from the vehicle can be sent towards the (active) track. This, for example, in order to shift switches in case a wagon is pulled.

The protocol was designed in such a way that can be implemented on simple and cheap beacon hardware.

13. Realisation of a test track

The theoretical analysis of the chosen technical implementation had not revealed any insurmountable problems. Yet, experimental verification of certain issues was recommended. Therefore, as a natural consequence it was decided to realise a test track with:

- An electrically driven vehicle, next to its drives and power supplies etc., equipped with infrared receivers and transmitters as well as electronics for control and monitoring.
- A sufficient number of beacons with test facilities.
- A supervisory system for the logging of test data as well as for the issuing of commands to the vehicle.

14. Functional decomposition

It was decided to build a layered system with a functional decomposition which suits (a.o.) the different time response requirements as operational control requirements:

- A supervisory system.
- A 215 m long test track with eleven beacons on each side.
- An electrically driven vehicle, next to several support systems and their power supplies equipped with:
 - An electronic driver (ELBE, a Dutch acronym), which translates information from the beacons as well as the vehicle system (VOSYS) into high level commands for the vehicle. ELBE communicates with the track with eight (two times four) infrared receivers mounted on front of the vehicle and two infrared transmitters

mounted on the side/rear.

- A vehicle system (VOSYS, a Dutch acronym) which translates ELBE's commands into actuator control signals. Furthermore, VOSYS takes care of the acquisition and preprocessing of low-level sensor signals in order to transport the resulting information toward ELBE. Last but not least, monitoring, safeguarding and control are functions of VOSYS as well.

- Two fully electronic power converters for the supply of the two three phase vehicle engines.

An overview of the sub-systems mentioned is presented on Figure 7. The description of the signals and data exchanged between the systems provides information with respect to the different layers (see Figure 1) at which the sub-systems are active:

- The supervisor has some kind of SCADA function and is not continuously required in operational conditions.
- The beacons collect and transport track related data and act as a path for (external) communication.
- The electronic driver, ELBE, communicates with the track, computes an estimation for the braking distance on the [alternative] trajectories, interprets the "vacant track" information from it's various receivers and since high-level commands to VOSYS.
- The vehicle system, VOSYS, collects data for ELBE, processes ELBE's commands and takes care that these are carried out. Besides, VOSYS takes care of all (most) basic monitoring and control.
- Both drives convert the 750 V DC supply voltage to a three-phase AC supply with the right voltage and frequency in order to enable both asynchronous traction engines to realise the desired thrust together.

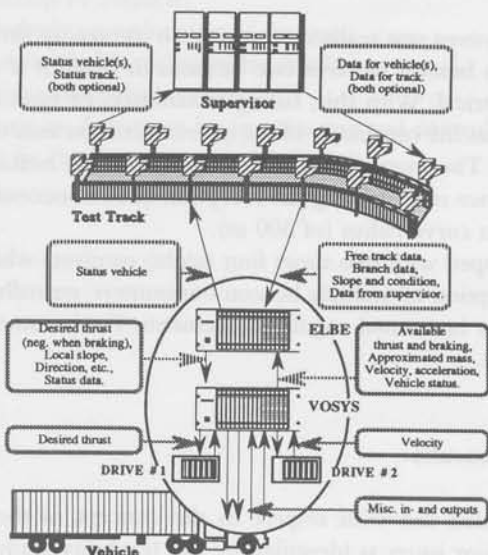


Figure 7.

15. Safety and availability

It was the purpose of the Combi-Road test track to experimentally investigate as many uncertain factors as possible. In accordance with the reasoning presented earlier in this document, the base architecture behind the system was one with an autonomous vehicle on an active track. After all, this concept might satisfy the very demanding safety requirements in relation to the survey distance, branches, slopes, curves and tunnels. At the level of the vehicle's control architecture, the chance on an unsafe failure is very small:

- Defective power electronic at the level of the drives, will probably exclude the correct conversion of the 750 V DC supply into three-phase AC power.
- It is relatively simple to prevent VOSYS from an exchange of acceptable data with either ELBE or the drives, in case VOSYS is not or not correctly functioning.
- The same reasoning as used for VOSYS is valid for ELBE as well. This because ELBE is supposed to continuously exchange acceptable data too.

The total of the vehicle's control electronics, together with the beacon system, should be positioned at the level of layer one in the three-layer model in Figure 1.

In order to perform tests of the (potential) operational availability on the Combi-Road test track as well, several additional measures were taken:

- The vehicle is equipped with its own 40 KW diesel generator, which enables it to continue driving without external supply, albeit with a lower maximum speed but with a still unchanged maximum thrust. Anyway, in case of the test track this autonomous supply is also required to enable prolonged driving outside the (supplied part of) track.
- Two complete drives, with each it's own power electronics and traction engine have been implemented. Failure of one drive will not cause a complete standstill of the vehicle.
- The beacon system was realised according to the set-up shown on Figure 6. This means that each beacon receives two beacons in front of it and that the system is laterally symmetrical. With this, failing transmitters or even entire beacons can be detected, whereas the continuity of the communication and/or the entire system are not threatened. The mutual distance of two successive beacons is 20 m, being the maximum distance still allowing the reception of two successive transmitters in case of the minimum curve radius (of 300 m).
- ELBE is equipped with two times four (eight) receivers which together guarantee the correct reception of multiple beacon transmitters, regardless the vehicle position or it's vertical or horizontal angular movements. Furthermore the vehicle itself has two transmitters.

16. Preliminary test results

Although not all planned test with respect to the concept of the control system were conducted yet, the major issues as identified by the feasibility study, being the maximum attenuation and spatial discrimination, did not present any reason to doubt the chosen

system. Actually, no unsolvable or even difficult problems were encountered during any of the tests.

Concluding Remarks of the Congress

17. Appendix, participating organisations

Combi-Road is a government sponsored (ICES) project, which resulted from an initiative of Hollandia Industriële Maatschappij. Within the first phase of the project, ending with the realisation of a short test track, several teams were active. One of these teams the so called VBBE (Dutch acronym) team was entirely devoted to the vehicle, the track as well as the energy supply and control systems. Within this team the following organisations participated:

- DHV (project office Combi-Road)
- Terberg Benschop bv (vehicle)
- TNO-WT (vehicle)
- Hollandia Industriële Maatschappij bv (track)
- TNO-TPD (control)
- Holec Machines en Apparaten bv (control, energy supply)
- Veiligheidskundig Adviesbureau Kindunos VOF (safety)
- HTS Automobieltechniek, Apeldoorn (vehicle technology)
- TRAIL Onderzoekschool (system concepts)

Next to the named VBBE team, the so called interface and test teams contributed to the actual design and implementation of both the availability and safety issues of the system. The following organisations participated in these teams:

- Project office Combi-Road
- Terberg Benschop bv (vehicle)
- TNO-WT (vehicle, coordination of the tests)
- Hollandia Industriële Maatschappij bv (track)
- TNO-TPD (electronic driver, optics)
- Holec Machines en Apparaten bv (monitoring and control, energy supply)
- Arun projects bv (beacon system, safety issues)

Concluding Remarks of the Congress

Klaas Smit

Chairman of the Scientific Committee

On behalf of Sjoerd Hengst,

Conference Chairman

From the various papers presented and discussions during the plenary sessions, some observations or points of concern are identified. These are: relative safety figures are becoming constant will increase as a result of:

1. "Frog-leap" improvements of safety targets in most of the transportation modalities are required.

Because traffic-volume is increasing and the number of fatalities during an accident are increasing, the ever decreasing relative safety figures, are remaining constant or show an upward trend. Safety-consciousness and -concern of the public is growing and therefore political pressure to improve safety in transportation.

2. Balance safety and economics.

The ever-increasing reduction of cost of design, manufacturing and operation of transportation systems should be balanced against the effects of accidents on the longer term. Investment in safety during design, manufacturing and operation will pay off in increased effectiveness and efficiency and therefore lower life cycle costs or cost of ownership.

3. Common accident and incident investigations methods.

Methods and practices developed in particular modes of transportation are worth to be transferred to other transportation modes.

4. Attention for hazardous goods.

Due to further integration of transportation-modes in particular transportation-chains, e.g. rail-sea and sea-air, more attention should be paid to the integrity of hazardous goods during transportation, transfer and handling.

5. Victim-care.

As a result of the above mentioned growing public awareness and resulting liability cases, more attention need to be paid to the victims and relatives of victims from accidents. It is also human duty for the society and to transportation companies to pay more attention to this aspect.

6. Risky operators.

There are huge differences in safety-records of reliable and risky-operators. Global safety-levels in mode of transportation are largely determined by risky operators. More attention should be paid in the identification of risky carriers and to actions, incentives and support to improve there safety records.

7. Human factors in safety.

As technical causes of accidents are reduced, the human factor as a cause becomes more

predominant. Therefore more attention is required to ergonomics during design and to training and the use of simulators during operation.

8. Incident reporting and analysis.

Transportation systems are becoming more complex and the possible causes and combinations of cause are numerous. As accidents and the resulting lessons learned are limited, the need arises to report and analyse causes of incidents and feed back the lessons learned to the design and operation on a world wide scale within the branche.

Following issues for development have been identified:

1. Systems engineering approach to safety.

A transportation system consists of hardware, software and people-ware. It is not only the means of transportation, but also the related infrastructure and traffic control which are part of the system. Safety need to be considered for the whole transportation system throughout the all life cycle phases, i.e. design, manufacturing, operation and disposal.

2. Development of safety-assurance systems.

Safety assurance can be developed by not only applying the lessons learned from accident analysis, but also from incident analysis. Safety should not only be considered as an technical or operational issue, but as a prime company-objective. It requires safety assurance programs to be developed and introduced, but also another attitude and company-culture. A prime requisite is management commitment to this approach.

3. A structured design-for-safety approach.

In the systems engineering approach, it is required to identify quantitative safety targets. Apply in the design stage risk-analysis and safety-modeling. For these methods input data are required from structured accident and incident databases containing the result of investigations and analysis.

4. Building partnerships.

In order to arrive at above mentioned approaches for safety-assurance the forming of national safe- and accident investigation boards should be encouraged.

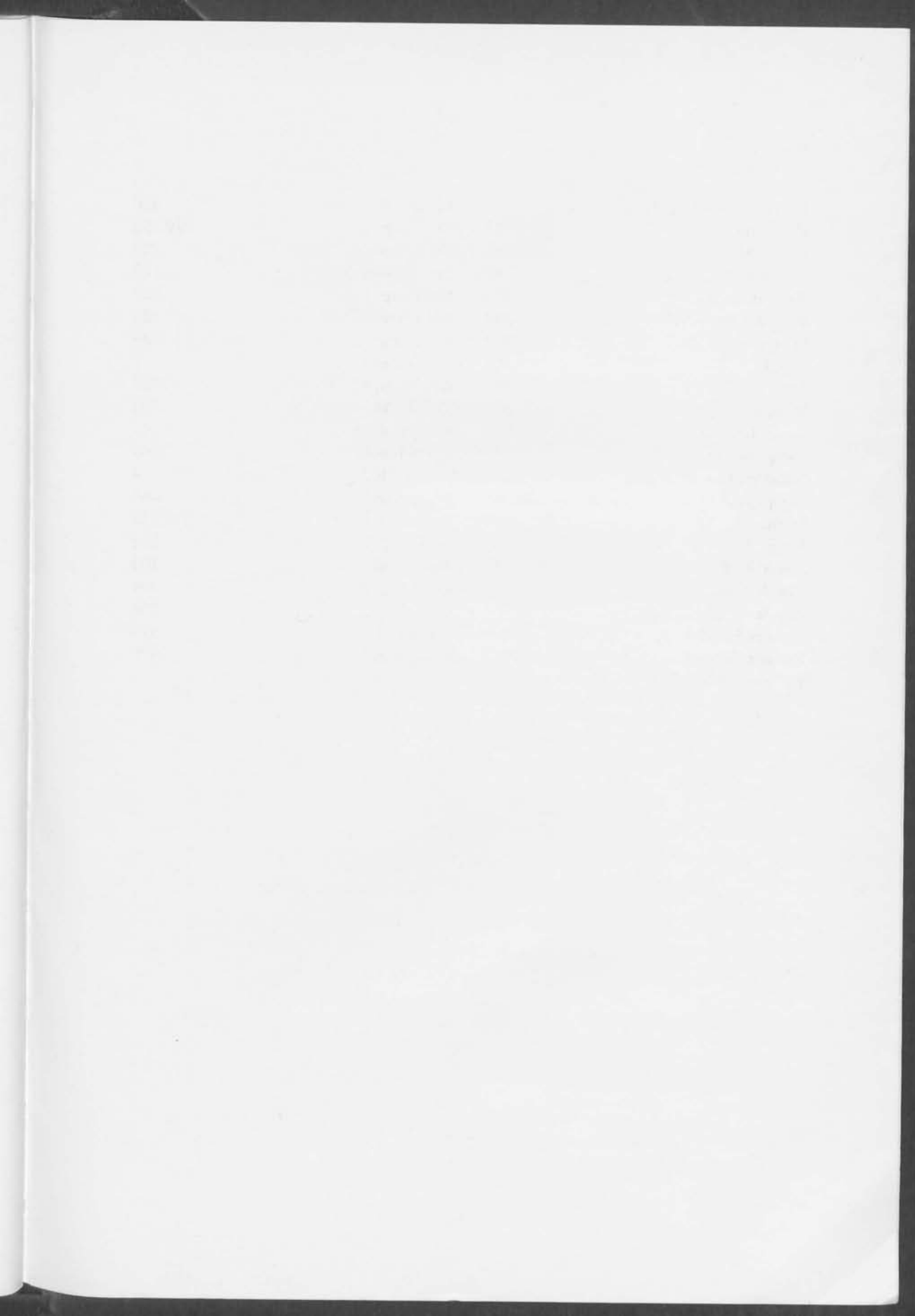
Exchange of experience between national bodies is necessary. ITSA and Universities may play a role in the development of this exchange.

A very effective instrument is the collection and exchange of data between national accident and incident databases. Especially with the view on hazardous goods an intermodal approach need to be encouraged.

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**Second World Congress on Safety of Transportation
Delft University of Technology, 18-20 February 1998**

Imbalance between growth and safety?

About 275 people from 29 countries and all modes of transportation listened to 18 keynotes, discussed over 70 papers, participated in 6 Round Tables and a closing plenary discussion. Participants were coming from industry, policy making, safety boards, research institutes and victim organisations.

The congress discussed a possible imbalance between growth and safety.

During the congress it was acknowledged that modalities can learn from each other, although the state of the art varies. The differences are sometimes considerable with regard to the control of safety and accident and incident analysis.

The congress revealed a trend towards increased involvement of societal parties. This makes safety a considerable societal issue, in particular in transport where recent catastrophies have occurred. Due to increased insight in factors influencing safety, scientific developments can gain by developing methods for analysis and themes for research and development. Such a development can be based on exchanging experiences between modalities and disciplines. The use of multiple information feedback loops could create necessary conditions for succes in research and development.

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