Road Safety in India: A Systems Approach

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ROAD SAFETY IN INDIA : A SYSTEM APPROACH

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1. INTRODUCTION

A recent estimate (WHO, 2013) suggests that worldwide 1.24 million people per year are killed in traffic. This is based on official figures, and this official figure is probably an underestimation. A large majority (92%) of road fatalities occur in the low and middle income countries that have 72% of the world's population and 52% of all registered motorized vehicles. A further 12% of road fatalities occur in low income countries, leaving 8% to high income countries. The overall global road traffic fatality rate (mortality rate) amounts to 18 road deaths per 100 000 inhabitants, while the rate for high-income countries is 8.7, and 20.1for middle income countries. Not only are people killed in road crashes, they are often injured, sometimes seriously. We don't have precise figures, but the WHO (WHO, 2009) estimated the annual number of road injuries as being between 20 and 50 million. These road crashes, fatalities and injuries result in considerable economic costs, estimated to be between 1 – 3% of the GDPs of countries.

This issue can be considered from another perspective than that of economic costs: deaths and injuries have an enormous impact on families and communities. Economically disadvantaged families are hardest hit by both the direct medical costs and the indirect costs such as the loss of wages resulting from injuries (WHO, 2013).

Road traffic injuries are estimated to be the eighth leading cause of death globally. They are the leading cause of death for people aged 15-29 years. This means that road casualties must be considered a very serious public health problem.

About half of all road traffic deaths occur among pedestrians, cyclists and motorcyclists, the so-called 'vulnerable road users'. At 57% and 51% respectively, the percentages are much higher in low- and middle income countries, than in high income countries with an average of 39%. Different traffic mixes in different countries result in different distributions of casualties over different transport modes. For example, in many South-East Asian countries powered two and three wheelers are very popular which is reflected in a high proportion of fatalities using this transport mode. In middle-income countries fatalities among cyclists are substantial (25%). Almost 60% of all global road traffic deaths are between 15-44 years of age.

Many, if not all, countries in the world wish to reduce the number of people killed and injured on their roads. This is a reasonable conclusion which may be derived from the goal set for road safety worldwide by the United Nations. The General Assembly adopted a resolution which proclaimed a Decade of Action for Road Safety with the goal of stabilizing and reducing the increasing trend in road traffic fatalities, saving an estimated 5 million lives during this decade stretching from 2011 to 2012. At the same time, the European Union also decided to use a quantitative target for a decade: reducing the number of fatalities by 50% over a ten year period. Moreover, The EC is thinking about using a separate target for injuries. Many countries worldwide also work with targets, as is illustrated by, for example, the 2011-Annual report of the IRTAD-group (OECD/ITF, 2012).

The number of road casualties per jurisdiction in a certain period of time (a couple of years for example) is changing. In a substantial number of countries an increase has been observed, whereas some other countries show a decrease. The Global Status report (WHO, 2013) presented a decline in 88 countries; 42 of which were high income countries, 41 were middle-income countries, and 5 were low-income countries. But the same report indicated an increase in the number of fatalities in 87 countries.
Sometimes it is stated that an increase in economic growth, resulting in increased motorisation and an increase in kilometres travelled, will inevitably result in an increase in the number of road casualties. This correlation may have been the case for some countries during a certain period of their history. However, in general terms, we have no evidence that such a correlation between economic growth, motorisation, exposure and casualties (or mortality rates or fatality rates) exist. This correlation is dependent on several other factors. And for many countries in the world we have evidence that if, over a period of time, fatality rates go down and if the percentage of increase in exposure (kilometres travelled) is lower than the percentage of decrease of fatality rate, a decrease of the number of fatalities will be the result, given the simple relationship:

[Fatalities] = [exposure] x[fatality rates]
[Fatalities]=[kilometres] x[fatalities/kilometre]

The basic question is why does the fatality rate decrease over time? The answer to this question is not a simple one. Even if there are strong indications which factors and developments make a contribution to this decline, they do not give a full explanation. The following sectuib will introduce the complex phenomenon of time series, not as a result of a regression approach, but to create a better understanding of the processes influencing these trends in casualties.

2. CRASHES WITH FATALITIES AND INJURIES

Sometimes people believe that road crashes are caused by poor human behaviour and that the causes are dominated by intentional errors only, such as violations and traffic offences. And many studies tell us that in almost all crashes the human being is to blame, and only a minority of crashes can be attributed to roads and vehicles. A very illustrative picture came to me when I studied road safety problems in the State of South Australia (Wegman, 2012).

South Australian crash statistics showed that, in one third of all fatal crashes, drivers had a BAC above the legal limit; did not wear a seat belt, or were reported to have driven at excessive speed. This picture was made even more extreme: quite a proportion of drivers involved in a crash had a previous crash history (in which they had been at fault), had a previous history of driving offences, or even a criminal history. A new English word entered my English vocabulary: hoon-driving. This is defined as:

> *"Hoon driving causes a vehicle to travel at very high speed or in a manner that produces burnouts and doughnuts. Dangerous driving, careless driving, failure to have proper control of the vehicle and causing the vehicle to make excessive noise or smoke are also considered hoon-related offences if they are committed in circumstances involving the improper use of a motor vehicle."*

Those who were involved in a crash were criminalized. I learned that the dominant opinion was to blame, if not criminalise, the driver involved in a crash. Two conclusions were presented to me: the first was that road safety can be improved by better detection of hoon behaviour and tackling it, the most powerful tool being that of more severe punishments. The second conclusion: the road safety problem is only related to this selected group of drivers and not to anyone else.

My understanding of road crashes is different from the view presented above. I thought that there could be several explanations for this unexpected view, so my first inclination was to ask researchers from the Centre for Automotive Safety Research CASR to help me understand the nature of road crashes in South Australia and to explain why these causes were different from what I had learned in other parts of the world, such as Europe and North America. Not unexpectedly, the (CASR) researchers confirmed my expectations (Wundersitz and Baldock, 2010). They had used a data set compiled from the Coroner's reports of fatal crashes in 2008 containing information from their own in-depth crash investigations of non-fatal crashes. The researchers had categorised road crashes into two groups: the first, in which extreme behaviour could be identified (high level speeding and drink driving); and the second in which extreme behaviour could not be found. The latter group consisted of ordinary road users, having more or less ordinary behaviour. This group was called 'system failure', in which well-intentioned road users have a crash because of some sort of human error. The researchers also created a third category which they called illegal system failure. This included illegal behaviour, such as travelling above the speed limit or an illegal BAC, but not at what is regarded as extreme levels.

The study showed that the often expressed opinion that crashes are only, or mainly, caused by antisocial road users who grossly disregard all rules, is not confirmed by South Australian data (Table 1). The comparison with Australian findings led to another important result. If we use the same categorization for injury crashes, a similar, but slightly different picture emerges. The distribution is just under 10 per cent extreme behaviour and almost 90 per cent ordinary behaviour. In other words: injury crashes tell a different story than fatal crashes. This means that we cannot rely on fatal crash data only when formulating road safety strategies. We need to include injury crash analysis as well. As I recommended paying more attention to injury crashes in South Australian policies in the future, this focus may open new avenues for policymaking.

We seldom witness a road crash, and, to understand the causes of a crash, we have to rely on (silent) witnesses, for example, by carrying out a crash reconstruction. Causes of crashes are not easy to find in this manner. In the past, we relied on police information which was written down in crash report forms. These forms focused on violations, in order to assist in police activities, as they are supposed to do. However, based on road safety studies all over the world, more specifically in-depth studies,

Table 1 Proportion of crashes based on extreme behaviour or system failure (Wundersitz and Baldock, 2011)

Data source	Extreme behaviour (%)	Illegal system failure (%)	System failure (%)
Fatal crashes 2008	43.4	22.9	33.7
Non-fatal metropolitan injury crashes 2002-2005	3.3	9.9	86.8
Non-fatal rural crashes 1998-2000	9.4	16.6	74.0

we have learned that, in the majority of crashes, more than one cause plays a role. These studies always result in the conclusion that the human being failed in one way or another. This leads us to three questions: which factors increase risk, how can we influence these factors in order to reduce risk, and how cost-effective are these interventions?

Based on this analysis, two main approaches for further improvement can be defined:
• elimination of extreme behaviour
• creation of a Safe System in which human errors are considerably reduced, if not eliminated

The second approach has a positive impact on the first. Assume that in the future we will build cars with a seat-belt lock and an intelligent speed adaptor, in which it will be impossible to drive without proper use of a seat belt and without opportunity to drive faster than the prevailing speed limit. We will then not have to rely on the traditional ways of improving driving behaviour, such as police enforcement. However, as we do not have these locks (yet) and we are not sure whether they will ever become a standard feature in future cars, we cannot eliminate the first approach.

Yet, we can reach one very fundamental conclusion based on the South Australia data, and the picture for other countries will not be entirely different. Fatal crashes seem to be subject to other dominant causes than crashes that result in injury only and this seems to be more so in the case of urban crashes than rural crashes. The large majority of injury crashes is caused by system failures; fatal crashes are caused equally by extreme behaviour and system failures. If we were to use only fatal crashes as a basis, we would not use the complete image of road traffic crashes. In addition, if we realise that in many highly motorized countries the decline in fatalities is much stronger than that in the number of road injuries (IRTAD, 2012).

Another important conclusion arises: policy focusing on a reduction of fatal crashes has been more successful than policy aimed at reducing injury crashes. And we may not deem it a matter of course that the number of serious road injuries will decrease to the same extent as the number of fatalities if the present road safety policies were to be continued. Finally, if we realise that from a cost perspective road injuries are responsible for a substantial share

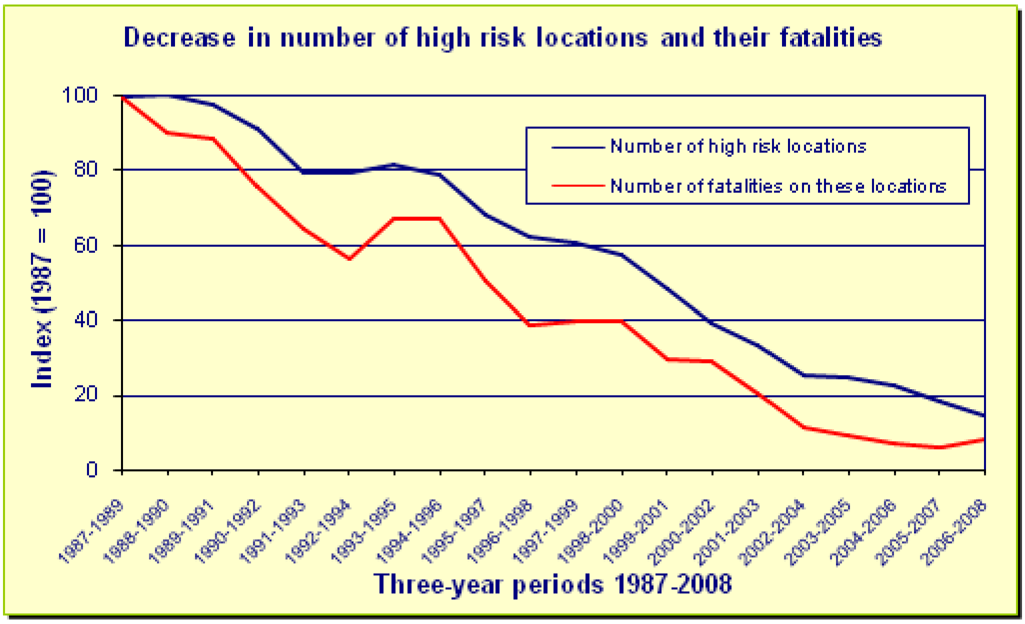

Figure 1. Developments of number and fatalities on high risk locations in the Netherlands

of the costs (more than 50% in the Netherlands), it is obvious that road injuries deserve more attention, both in the analyses and in finding solutions. In other words: road safety policy requires a different approach for the reduction of road injuries than the approach that was used to reduce the number of fatalities.

3. ROAD SAFETY PROBLEMS: HIGH RISKS AND LOW HANGING FRUIT

When analyzing road safety, two types of problem can be identified: *generic* problems and *specific* problems. Specific problems are those safety problems which are concentrated on specific locations, specific road user groups, specific behaviour or specific vehicles.

Generic problems are caused by the fact that road traffic is inherently unsafe: ordinary people are killed in crashes under normal circumstances. This means that everybody can be involved in a crash at any particular time and many of us will be involved in a lifetime, because road traffic has not been designed with safety as an important requirement for the design of the system. To identify generic problems we first of all need general knowledge about why crashes occur and which factors influence the seriousness of their outcome, and secondly we need to identify which conditions/circumstances are inherently dangerous and eliminate, or at least 'treat' or tackle these conditions/circumstances.

Road safety policy has a long history in identifying risk increasing factors and a long tradition in bringing down these *specific risks*. An important assumption behind this approach is perhaps the conviction that a concentration of risks increases the chance of cost-effective measures, because only a small sample of a population, locations, etc. need to be treated. Also in public health this is a well known and widely supported approach: cure those who are ill and identify and treat high risk groups or circumstances. See for example the vaccination strategy to protect 'high risk groups' from the H1N1 virus.

As a matter of fact, much of the past road safety policy was based on high risks, high numbers and frequent causes, on well-identified patterns in crashes. Risks, for example, were determined and divided into age groups, which showed that the young and the elderly have increased risks. The answer that policy has come up with, is the effort to reduce these high risks: smoothing the peaks in distributions. Analysis of road safety was aimed at the detection of peaks (in distributions), explaining them, and finding measures to overcome them. This approach requires high quality road safety data, not only data of crashes recorded by the police, but also 'exposure' data, data on road user behaviour, such as seat belt use in traffic, and data on safety quality of roads and vehicles, etc.

Looking back, how did we identify high risk locations, crash-prone drivers, and near-wrecks? As was mentioned above, we have a long history of identifying and treating locations with a disproportionate number of crashes. Certain individuals were characterized as crash-prone drivers and the policy was aimed at removing them from traffic or, alternatively, teaching them to be better road users. Some vehicles were found to be in such a sorry state that they could not but contribute to crashes happening.

And indeed, crashes are not randomly distributed across our road network. There are locations with a concentration of crashes, and in the past we tried to improve these locations. This was motivated by the idea that circumstances that were specific for a location were partly responsible for the high number of crashes. Location-specific, infrastructural measures would then be taken to decrease the number of crashes, to put a stop to the concentration of crashes at that location. In their Road Safety Handbook, the Norwegian researchers Elvik and Vaa (2009) concluded that this can be an effective approach. Their meta-analysis predicts an 18% reduction of crashes with serious casualties on this type of location.

In the Netherlands, we investigated how this approach had developed in recent years. The conclusion was that it was successful policy. In the period 1987-1989 10% of the fatalities were from crashes on locations that can be labelled 'high risk locations', their number decreased to 1.8% in the period 2006-2008

Therefore, we can say that the least safe locations have been successfully dealt with. But it is hardly possible for such an approach to have a positive effect in the future years. One could say that the approach has become a victim of its own success and will barely make a further contribution to the reduction in the number of road crash casualties in the Netherlands.

Next, there are the crash-prone drivers. They too give rise to the idea that part of the road safety problem is concentrated in a small part of the population which is responsible for a disproportionally high share of the crashes. Lately, this crash-prone driver theory has ceased to be a starting point in road safety policy. And justly so, in my opinion. The first question that could be asked: who are these crash-prone drivers anyway, and how are they identified? Crash-prone drivers are not those who have already been involved in a crash. Having been involved in a serious crash has proved to be a bad predictor of the involvement in another crash. Must crash-prone drivers then be defined as those who have committed many traffic offences? This may be the case: some traffic offenders do break the rules frequently and they are involved in crashes more frequently than non-offenders, but the predictive value at an individual level is low. Therefore, fighting recidivism makes sense, but expecting to identify offence-prone drivers is an unlikely achievement.

And finally, the near-wrecks: bad vehicles with defects. These defects contribute to the occurrence of crashes or their severity. In the Netherlands, serious vehicle defects, especially defective brakes and bold/poor tires, are seen as either a main or a contributory factor only in a few crashes. It is often said that vehicle testing (like MOT) will pick out defective cars, and that the vehicle owner will then have the defects repaired. This sounds logical, but as yet has not been scientifically proved. Vehicle testing can and will trace part of the defects before a crash occurs. But which proportion? If we estimate this to be dozens of percentage points, it will only prevent a few percent of the crashes. There is nothing against this approach, it may just not be very cost-effective.

In my opinion, these three examples (hazardous locations, dangerous road users, and defective vehicles) are reason to conclude that we certainly had 'peaks' or ‘spikes’ in the distributions, and that they have (partly) been eliminated. In theory, those peaks could still be eliminated entirely. However, this will pose practical problems. Of course this always stresses the need to know how efficient a policy really is. If we measure the success of any policy or investment by the extent to which it reduced the number of casualties, this approach of identifying specific high risks and tackling them, can be a very effective and efficient approach. If it is simple to identify safety problems and if it is simple to cure and to eliminate these problems, we speak of low-hanging fruits, especially if the cure is relatively cheap.

If for a moment we ignore the conclusion that proneness is not an attractive area to enter, we must face the fact that not everyone has an equal risk of being involved in a crash at the same place and at the same time. Sometimes the risk is higher, on top of the risk that everybody has: *risk factors or risk-increasing factors* play a role. These (human-related) risk-increasing factors are: lack of experience, psycho-active substances: alcohol and drugs, illnesses and ailments, emotion and aggression, fatigue and distraction. Certain road and traffic conditions carry higher risks; we certainly have knowledge about risk increasing road and traffic conditions. Sometimes speed limits which are not well attuned to prevailing road and traffic conditions lead to higher risks.

A significant example of a *risk increasing factor* is drink-driving. A very direct approach can be used for specific issues: a specific problem is determined and measures are taken that are aimed at solving this problem. In the most recent decades much research has been carried out into specific risk increasing conditions, and with impressive results.This topic has received considerable attentention in the Netherlands. Drink-driving is involved in less than 1% of all kilometres travelled; drink-driving is seen as socially unacceptable by the vast majority of the population, which results in only a small percentage of the drivers being above the legal limit. However, The remaining offenders have a rather high BAC. Our strategies have been successful; now the time has come for a specific policy to identify the 'hard core' offenders and change their behaviour.Strategies need to be completely different from those in the past that were successful. The same is true for seat belt use: policies in the past have resulted in more than 90% of the car occupants wearing a seatbelt.

However, there are still quite some gaps in our knowledge of these human-related risk increasing factors.

Allow me to introduce the simple lack of attention for the driving task. The driver is somehow distracted when is driving. Some years ago, I was alarmed by the results of the 100-car study in the United States. In this study, drivers were followed for a year by observation systems installed in their cars: a black box, small cameras (Dingus et al., 2006). The idea was to observe their everyday behaviour. A wealth of data resulted of which I find the following result the most striking. Nearly 80% of all crashes and 65% of all near-crashes involved driver inattention just prior to the onset of the traffic conflict. This is rarely found on police registration forms, because who would tell the police that a cigarette fell to the floor just prior to the crash and that in a state of some panic he or she was trying to retrieve it? Therefore, I have begun to think that the idea many people have, including road safety professionals and decision makers, of crashes being caused only by traffic offences, as we also rather frequently see on police registration forms must present a distorted picture of the truth.

So, *both (generic) basic factors and risk-increasing factors have been and will be relevant in improving road safety*. Worldwide we have substantially increased our knowledge about the extent to which certain behaviour and specific circumstances affect road safety and we have been successful in reducing specific risk-increasing factors in many countries all over the world. As the nature of the problem will be different, interventions will need to be different in the future than those in the past.

One example to illustrate this: if you have reached 95% seat belt wearing rates by legislation, publicity, and by increasing general deterrence by police enforcement, the policies to accomplish a 100% wearing rate will need to be completely different. Furthermore, I expect that, following the 20-80 rules, traditional policies to tackle 'hard-core' problems will inevitably become less effective. How to reach 100% compliance and how to fight 'hard-core' offenders are questions that have not yet been satisfactorily answered.

When a country has made considerable progress and has taken the most obvious measures, the traditional approach of reducing the peaks will become increasingly less effective and become less efficient. The traditional policies will lose their effectiveness. The change in thinking that is required as a first step in achieving further road safety improvement could be based on economic considerations in terms of whether profitable investments can be realised.

The next step is not to label individual locations, individual persons or individual vehicles as relatively hazardous. Instead the conditions involving high risks need to be identified*: we move from specific risks to generic or inherent risks*. A reasonable case can be made for the relative importance of generic problems having increased over time, while the importance of specific problems has decreased.

Future road safety policies in countries such as the Netherlands will therefore increasingly need to be aimed at the generic character of road safety, and less at the specific aspects. The next phase in policymaking has arrived. This also supports the saying that past success is no guarantee for the future and also gives rise to a question about the efficiency of policy and whether it is not subject to the law of diminishing returns.

However, it must be noted that every country needs to analyse its own road safety problems and its own potential for solutions. For example, it is too simple to expect that Dutch problems and their solutions can be copied on a one-to-one basis to the Indian situation. The so-called SUNflower countries (Sweden, United Kingdom and the Netherlands) are three countries with a mature road safety history and performance record and are the three safest countries in the world. When we compared their road safety, the conclusion was that the three countries have similar levels of safety as a result of continued improvements over recent decades. Policy areas targeted have been similar. But implemented policies differ at the level of detail. And, interestingly enough, although they are the safest countries worldwide, each of the three coutries identified room for further improvement in well established safety fields and they saw possibilities to learn from each other (Koornstra et al., 2002). The Belgian painter René Magritte made a surrealistic painting showing someone looking in a mirror (Figure 2). We don't see his face in the mirror, as expected, but the back of his head. International experts are only able to mirror thoughts and ideas from local road safety professionals as a starting point for policy development. International communication and cooperation is nothing more and nothing less than the exchange of 'evidences' assuming that a recipient country has sufficient capacity to transfer that information to local conditions. The SUNflower-model uses a perspective called 'structure and culture' to reflect the idea that international knowledge should always be adapted to local conditions by local experts (Wegman et al., 2008).

Figure 2. Rene Magritte's painting 'Not to be Reproduced' (La reproduction interdite)

4. A SAFE SYSTEMS APPROACH

There are two good reasons for the departure from more traditional paradigms on road safety. The first reason lies in the fact that serious road crashes will occur as long as the inherent unsafe conditions, the generic road safety problems are not dealt with. Our traffic system is designed in such a way that it cannot (sufficiently) prevent crashes and serious injuries. The most dangerous traffic issues are the large differences in speed and mass together with the human being who has to deal with these differences. The human being is physically vulnerable and, moreover, makes errors and commits offences. And the system is not designed to deal safely with these errors and offences.

A second good reason lies in the fact that our tradional policies have become both less effective and less efficient; this is also the result of the core characteristics of our road safety problems not yet having been addressed.

In the Netherlands, these two reasons triggered a paradigm shift and resulted in *Sustainable Safety* being developed, the Dutch version of a Safe System approach. The increasingly diffuse character of the road safety problem requires a different approach from that of the past. With the Sustainable Safety vision SWOV seems to have found a suitable answer; the main lines of this vision will be explained from here on. More details can be found in *Advancing Sustainable Safety* (Wegman & Aarts, 2006).

The Sustainable Safety approach uses the following key aspects:

- Ethics
  - The next generation should not have to face a traffic system with the current casualty levels The number of causualties must be reduced considerably: *Towards Zero.*
- A proactive approach
  - There is no need to wait for crashes to happen before acting; sufficient knowledge is available that can be applied.
- An integral/holistic approach
  - Man, vehicle and road are to be integrated into one safe system.
  - The whole network, all vehicles, all road users are to be covered.
  - Road safety should be aligned with other policy areas: infrastructure, planning, health, environment, etc.
- Man is the measure of all things
  - Human capabilities and limitations are the guiding factors.
  - “Don’t blame the victim”.
- Reduction/eliminiation of latent errors in the system (system gaps)
  - Which means we are not fully dependent on whether a road user makes a mistake or error in preventing a crash
- Criterion of preventable injuries
  - The criterion of preventable injuries must be used to identify which interventions are most effective and cost-effective.

The Sustaintainable Safety approach, as developed in the Netherlands (Koornstra et al., 1992, Wegman & Aarts, 2005), is the first example of a so-called Safe System Approach (OECD, 2008). Sweden has its Vision Zero and Australia later developed its own Safe System approach (2011). But all three developed a similar approach best fitting into the local conditions.

To introduce this approach, it may help to answer the question why still so many crashes occur. An intentional or unintentional human error plays a role in almost every crash. No matter how well educated and motivated, man makes errors and does not always abide by the rules. Many studies of road traffic crashes wrongly indicate that the factors 'road' and 'vehicle' play only a minor role.

Present day road traffic has not been designed with safety in mind. For avoiding crashes we now are almost completely dependent on the extent to which man is capable of (and sometimes willing) correcting his own errors. And, in its turn, errors are also made in doing so.

Both intentional errors and unintentional errors are made. Intentional errors are committed by the 'unwilling' man; unintentional errors are committed by the 'incapable' man. We do not yet know sufficient about human behaviour to know which of these two error types is dominant in crashes. We assume that both types of error occur frequently and therefore both error types deserve our attention. The often heard opinion that all errors are intentional and that eliminating these errors (often traffic offences) would therefore be sufficient to considerably improve road safety, is not true to reality, as has been clearly illustrated by the work of the South-Australian researchers Wundersitz and Baldock (2012).

Unintentional errors, inadvertence, slackening attention, distraction from the driving task are all very frequent and sometimes lead to crashes. Road safety can be improved by limiting the possibility of unintentional errors, and in the Sustainable Safety vision SWOV has detailed how this can be done.

Furthermore, man also makes intentional errors and traffic offences. It has been sufficiently established that traffic offences increase the number of crashes. It is equally well known that a road user who has been fined for an offence adapts his behaviour for some time, usually a few months. Traffic enforcement supports and improves traffic behaviour. But research has also taught us that the positive effect of enforcement is not so much the result of behavioural changes of those who have been fined - that effect is limited – but of the preventive effect of the possibility of being fined and the punishment that comes with it: the generic effect of traffic enforcement (Goldenbeld, 2005).

A crash is rarely caused by one single unsafe action; it is usually preceded by a whole chain of poorly attuned occurrences. This means that it is not only one or a series of unsafe road user

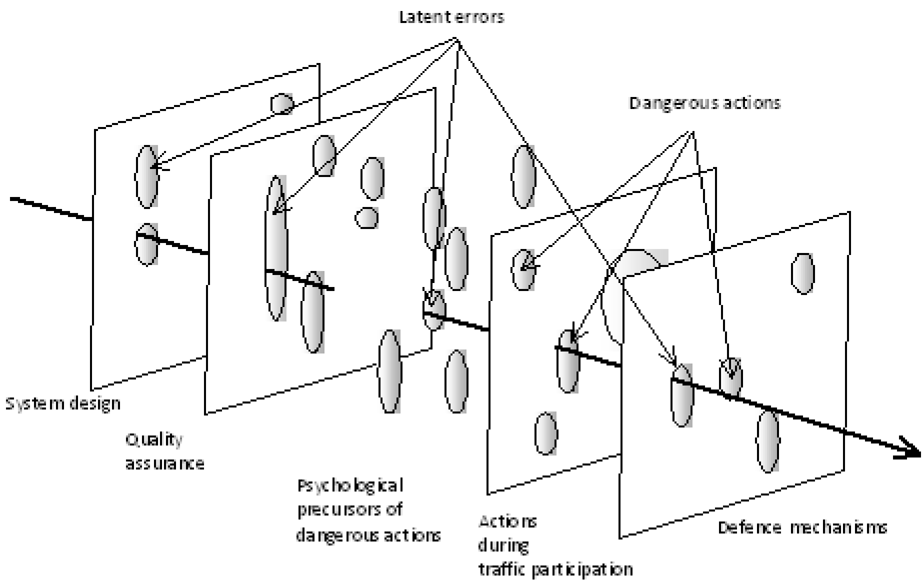

Figure 3. Diagram showing the development of a crash (bold arrow) as a result of latent errors and unsafe actions in the different elements composing road traffic (based on Reason, 1990). If the arrow encounters 'resistance' at any moment, no crash will develop

actions that cause a crash; also hiatuses in the traffic system contribute to the fact that unsafe road user actions can in certain situations result in a crash. These hiatuses are also called latent errors (Reason 1990). In summary: crashes occur when latent errors in the traffic system and unsafe actions during traffic participation coincide in a sequence of time and place. (Figure 3)

As unsafe actions can never entirely be prevented, the Sustainable Safety vision aims at banishing the latent errors from traffic: the road traffic system must be *forgiving* with respect to unsafe actions by road users, so that these unsafe actions cannot result in crashes. The sustainable character of measures mainly lies in the fact that actions during traffic participation are made less dependent on momentary and individual choices. Such choices may be less than optimal and can therefore be risk-increasing.

Adjusting the environment to the abilities and limitations of the human being is derived from cognitive ergonomics, which in the early 1980s made its entry coming from aviation and the processing industry. In all types of transport other than road traffic this approach has already resulted in a widespread safety culture. Further incorporation of the Sustainable Safety vision should eventually lead to road traffic that can be considered as 'inherently safe' as the result of such an approach.

5. SUSTAINABLE SAFETY: A SAFE SYSTEM EXAMPLE

The objective of Sustainable Safety is to prevent road crashes from happening, and where this is not possible, to reduce the severity of injuries as much as possible. This can be achieved by a proactive approach in which human characteristics are used as the starting point: *a user-centric system approach*. These characteristics refer on the one hand to human physical vulnerability, and on the other hand to human (cognitive) capacities and limitations. People regularly make errors unintentionally and are not always able to perform their tasks as they should. Furthermore, people are not always willing to comply with rules and violate them intentionally. By tailoring the environment (e.g. the road or the vehicle) to human characteristics, and by preparing the road user for traffic tasks (by training and education), we can achieve an inherently safe road traffic system.

The most important features of inherently or Sustainably Safe traffic are that latent errors in the traffic system (gaps in the system, as indicated by Reason (1990), that result in human errors or traffic violations causing crashes) are, as far as possible, prevented and that road safety depends as little as possible on individual road user decisions. The responsibility for safe road use should not be placed solely on the shoulders of road users but also on those who are responsible for the design and operation of the various elements of the traffic system (such as infrastructure, vehicles and education).Given the fact that people make errors, not always abide by the rules, and are also vulnerable, it is of the utmost importance that latent errors in the traffic system are prevented so that they cannot be a breeding ground for the occurrence of crashes. To prevent serious unintended errors, the Sustainable Safety vision as much as possible adjusts the traffic environment and the traffic demands that go with it to what the majority of road users can deal with. This to a large extent evokes the required behaviour, tells the road user what is to be expected, and ensures that possible errors are counterbalanced by a forgiving environment. In addition, the breeding ground for intentional and unintentional offences becomes fertile. For as far as offending behaviour can already be detected before traffic participation (e.g. use of alcohol or driving without a licence), the prevention of taking part in traffic fits into a sustainably safe traffic.

Road users must be well-informed and well-trained to participate in traffic. And in situations where their skills do not meet the environment's demands, specific measures must be taken to induce safe behaviour. Road users being capable of correctly assessing their situation-dependent condition and the resulting driving skills, is essential for making adequate decisions that can prevent a possible crash. However, different road users have different skills, the more experienced road users should be asked to consciously use safe traffic behaviour which is aimed at facilitating the less skilled road users. Thus, by making traffic a social system, a forgiving driving style can prevent the occurrence of a crash caused by other road users' errors.

In traffic, the vulnerable human being needs to be protected by his environment, either by physical constructions that prevent conflicts, or by constructions that absorb the kinetic energy which is released in a crash. For this purpose the road users' vehicles sharing the same space should have similar masses. If this cannot be achieved, speeds must be reduced. On the one hand, this system is embedded in a traffic-related taxonomy of high-speed traffic streams, and destination and residence on the other. Between these two extremes, traffic must be guided along correct, sustainably safe roads.

This brings us to the *five central principles* of a Sustainably Safe road traffic: functionality, homogeneity, recognizability, forgivingness and state of awareness. A brief explanation of these principles can be found in Table 2.

These principles have all been based on scientific theories and research methods arising from disciplines such as traffic planning and engineering, psychology, biomechanics etc.

Traffic planning: functionality of roads

Traffic flow organisation manifests itself in many ways and with various and different objectives. As long ago as the 1970s a functional road categorisation system had been introduced which formed the basis for the Sustainable Safety *functionality principle*. This principle starts from the premise that roads can only have a single function (*mono-functionality*)

Table 2: The five Sustainable Safety principles (Wegman & Aarts, 2006 and Wegman et al.(2008)

Sustainable Safety Principle	Description
Functionality of roads	Monofunctionality of roads as either through roads, distributor roads, or access roads in a hierarchical road network
Homogeneity of mass and/or speed and direction	Equality in speed, direction, and mass at moderate and high speeds
Forgivingness of the environment and of road users	Injury limitation through a forgiving road environment and anticipation of road user behaviour
*Predictability*of road course and road user behaviour by a recognizable road design	Road environment and road user behaviour that support road user expectations through consistency and continuity in road design
State of awareness by the road user	Ability to assess one's task capability to handle the driving task

and that they must be used in keeping with that function. The road function can on the one hand be "to facilitate traffic flow" (associated with "through roads"), and on the other hand "to provide access to destinations" (associated with "access roads"). In order to provide a proper transition between "giving access" and "facilitating traffic flow", a third category of function was defined: the "distributor road".

Homogeneity: dealing with physical vulnerability

If road users perform dangerous actions that lead to crashes, the human body's integrity is jeopardised. This vulnerability results from the release of kinetic energy and the body's biomechanical properties.

To deal with the issue of vulnerability in a proactive fashion, Sustainable Safety requires that controls are placed on factors that may intensify the severity of a crash: differences in speed, direction and mass. This forms the foundation of the *homogeneity principle*. This principle states that where vehicles or road users with great differences in mass have to use the same road space, speeds will have to be so low that, should a crash take place, the most vulnerable road users involved should not sustain fatal injuries. In addition, where traffic is moving at high speeds, road users should be separated spatially. Based on both crash tests between pedestrians and cars, and on ideas developed in the Swedish Zero Vision (Tingvall and Haworth, 1999), the Sustainable Safety vision proposes the following safe speeds for these two types of road users for different situations (Table 3).

Unfortunately, we do not yet have sufficient scientific knowledge to define safe speeds for motorised two-wheelers and heavy vehicles. This issue has also not yet been resolved in practical terms. Separation from other traffic would be the best solution, but it is unclear how this can be realised in practice.

Forgivingness: physical and social

The principle of *forgivingness* (a forgiving roadside) can contribute to reducing injury severity in crashes. Forgiving surroundings ensure that the consequences of errors remain limited for example when vehicles leave the road and enter safe road sides: for example safe (matted) shoulders, obstacle free zones or collision-friendly obstacle protection.

Apart from the physical aspects of forgivingness, this principle also has social implications which are more relevant for preventing dangerous actions. Traffic is a social system in which crash causes can partially be traced to the interaction between road users. Social forgivingness has more recently been defined as 'the willingness to anticipate a potentially unsafe action of another road user, and to act in such a manner that negative consequences of this potentially unsafe action are prevented or in any case limited (Houtenbos, 2009).

Forgiving road behaviour, particularly of the more competent road users, could allow for the

Table 3. Safe speeds dependent on road situation and conflict types

Road types combined with allowed road users	Possible travel speed (km/h)
Roads with possible conflicts between cars and unprotected road users	30
Intersections with possible conflicts at right angles between cars	50
Roads with possible frontal conflicts between cars	70
Roads with no possible frontal or lateral conflicts between road users	≥100

less competent road users, such as children and elderly road users. In other words: road users can, by means of forgiving driving behaviour (in terms of being anticipative or defensive), increase the room for manoeuvre of less competent road users. Errors should still be regarded as errors by the less competent in order that they can learn but a forgiving approach should lead to fewer or less serious crashes

Predictability

People can perform tasks at different levels of control: skill-based, rule-based or knowledge-based (Rasmussen, 1983). Generally speaking, the longer people are trained in performing a task, the more automatic their behaviour. The benefit is that task execution takes less time and attention, and that fewer (serious) errors are made (Reason, 1990). To prevent dangerous actions, Sustainable Safety strives to avoid knowledge-based task performance in particular. People have to be sufficiently capable and experienced to take part in traffic but they also need to perceive what is expected from them and what they can expect from other road users. This is manifest in the *predictability principle*, the benefits of which can be delivered, according to the Sustainable Safety vision, by *consistency and continuity* in road design. This means that the design needs to support the user's expectations of the road, and that all components of the design needs to be in line with these expectations.

People not only act dangerously because they make errors unintentionally, they can also exhibit dangerous behaviour by intentionally violating traffic rules. In situations where the road environment does not stimulate proper behaviour, a sustainably safe road traffic system benefits from road users who spontaneously obey traffic rules from a normative point of view. To achieve this, traffic regulations have to fit with the environment, and people have to be educated about the logic and usefulness of rules. Where people still fail to comply with the rules, policing to a level where a reasonable chance of being caught is perceived is the usual measure to enforce compliance.

Another element in the updated vision is that traffic has to be sustainably safe for *everybody*, and not just for "the average road user". Fuller's task-capability interface model (Fuller, 2005) supplies a theoretical framework here. Fuller's model states that road users' task capability is the sum of their capacities less the sum of their impairments caused by their present condition (e.g. because of fatigue or use of alcohol). For safe road use, the task capability has to be large enough to meet the task requirements. These task requirements are primarily dictated by the environment, but they can also be altered by the road user, for instance by increasing or decreasing driving speed.

State of awareness

This principle requires that road users should be able to assess their own task capability for participating in traffic. Task capability can be insufficient due to a lack of competence (e.g. because of a lack of driving experience), or because of - or aggravated by - a state of mind that temporarily reduces the task capability (e.g. because of fatigue, or the use of alcohol or drugs).

Since task capability differs from individual to individual (e.g. inexperienced and elderly road users with underdeveloped or diminished competencies respectively and also fatigued "average" road users or road users under the influence of alcohol or drugs), generic road safety measures are a necessity for safe traffic. However, for the group of road users with a lower task capability in particular, these measures are not sufficient for safe participation in traffic. Therefore, *generic measures* have to be supplemented with *specific measures* aimed at these groups or situations involving them. Specific measures can be found in areas such as regulation, education, enforcement (e.g. banning drivers under the influence of alcohol or drugs), and Intelligent Transport Systems (ITS).

6. SUSTAINABLE SAFETY: IMPLEMENTATION AND EFFECTS

The Sustainable Safety approach uses as a starting point the idea that the present traffic system is inherently hazardous (that serious crashes can happen anywhere and at any time) and that all possible solutions are considered in an integral and rational manner. There is no a-priori preference for improving roads, vehicles or changing behaviour. The rationality should not be restricted to road safety only, but wider deliberations are desirable (congestion, environment, scenery, economic development, health care, et cetera). The purpose of Sustainable Safety is to offer the road user such an environment that the risk of errors and violations is limited considerably. This implies a fundamentally different approach than that used in the past: pro-active adaptation of the environment of the road user considered as a system, following the five principles of Sustainable Safety to meet the characteristics defined by human physical vulnerability and of human (cognitive) capacities and limitations.

The new approach required a system of priority setting. The concept of 'avoidable crashes' was developed for rational decision making (Wegman, 2000). Avoidable crashes are those crashes where we know what caused them, of which we know how to prevent them, where the prevention costs are socially cost-effective and which fit into the Sustainable Safety vision. This approach implies that limited (financial) resources ensure that only cost-beneficial measures are taken and that cost-effectiveness defines the priority setting. This is in line with the Dutch Government's decision making about investments. This concept differs, for example, from the Vision Zero approach, which judges cost/benefit considerations as not relevant.

An exception to this 'avoidable crashes approach' is conceivable if in the framework of management and maintenance the existing road infrastructure is improved and road safety can be included. In those circumstances cost-effectiveness is not a major consideration from a road safety perspective, but a quality assurance approach can be used to give guarantees for a sufficient road safety level.

The essence of Sustainable Safety is that it is a system approach, which means that measures should not only be taken on those locations where crashes have occurred, but that it assumes that crashes can and will happen anywhere. Hence the inherently unsafe character of the system must be adapted (to 'the human measure'). Putting this idea into practice requires political courage, especially from road authorities and from those who work on improving vehicle safety. In the areas of legislation, traffic education, and traffic enforcement, no serious problems concerning realization are to be expected; in the Netherlands it is rather a matter of gaining sufficient support within society, followed by gaining political support, and then choosing the implemetation methods that will make a real contribution to the reduction in the number of casualties. Of course, road users and consumers will need to aspire to a higher safety level. Mobilizing the (latent) demand for a higher road safety level and making it manifest, is an important task for social organizations.

As a matter of fact, there are no real obstructions that stand in the way of implementing Sustainable Safety; it was and is a matter of political leadership to realize it. It was a key adventure to get all key stakeholders behind implementation and to organize implementation not for one year only, but for a considerable number of years. Both support from stakeholders and funding have been obtained.

Another very important aspect was to reach an agreement with all Dutch road authorities and to invite them to come to mutual agreements on implementation. As implementing the Sustainable Safety vision requires their support, this turned out to be a crucial step: in the Netherlands road authorities do, to a large extent, have an autonomous position and a considerable amount of freedom for decision making. As was mentioned earlier, the ambition is to achieve uniform solutions resulting in a predictable road course and layout due to consistency and continuity in road design, a predictable road course results in predicatble road user behaviour and lower risks. Local and regional road authorities were found to have invested substantial amounts in the improvement of infrastructural safety.

Are the other components of Sustainable Safety affordable? The costs of traffic education and police enforcement are modest in comparison with the investments required for safety improvements of roads and vehicle, and therefore their financing does not need to be a major problem. In addition, in the Netherlands the costs of enforcement are paid back by the proceeds from traffic fines. Safer vehicles are purchased by the consumer, and therefore the market controls itself. For the remaining components, however, it is unclear why parties other than the government should make the required investments. The 'bulk' of the financing of the prevention of road traffic crashes will need to be made by the government.

To recapitulate this implementation aspect of Sustainable Safety, we may conclude that the introduction of Sustainable Safety has concentrated on the financing of a Sustainably Safe infrastructure. This is a problem which is felt by all road authorities, especially by the local and regional road authorities. It involves a political choice. There are clear indications that in the Netherlands financing was in the first instance not made available from specific safety budgets, but that other budgets for management and maintenance were used. Additional safety assets, however, can be of assistance. Yet, it is more important to create conditions which allow safe use of these budgets for management and maintenance.

An assessment was carried out to learn if the implementation of Sustainable Safety met the high expectations. In an evaluation study SWOV investigated how Sustainable Safety had been implemented in recent years, and what results had been achieved for road safety (Weijermars & van Schagen eds., 2009, Weijermars & Wegman, 2011). One preliminary observation is in place. Of course we don't know exactly what would have happened if Sustainable Safety had not been implemented. But by making some assumptions, we can reach some conclusions. To do this we have estimated the safety effects of a large number of measures that had been implemented in the period 1998-2007. The policy efforts that were made in the areas of infrastructural investments and traffic enforcement can be called considerable. SWOV has been able to make it plausible that these efforts have resulted in fewer traffic deaths and also, to a lesser extent, in fewer serious road injuries. The fatality rate in the period that was studied, the period 1998-2007, showed an annual decrease of 5%, which is considerably higher than the almost 2% per year in the period 1988-1997. Two scenarios were calculated to determine to what extent the measures that were implemented made a contribution to the decrease in the number of traffic deaths. These two scenarios make different assumptions about what would have happened during the period 1998-2007 if Sustainable Safety had not been implemented, a situation, of course, which we cannot know. In the pessimistic – perhaps more realistic - scenario 300 road fatalities are saved on a yearly basis, in the more optimistic one the saving amounts to 400 fatalities. These are reduction percentages of more than 30% and 40% respectively. Comparison of the costs of the investments versus the benefits of the fatalities, injured, and crashes saved, shows that the investments have been socially cost-effective. The cost-benefit ratio is 4:1.

It is also interesting to see that the reduction in the number of fatalities has been higher than the reduction that was expected at the beginning of the implementation of this policy. An important reason seems to be that the investments that were made by local and regional road authorities like municipalities and provinces were higher than estimated in advance. In addition, the increase in the risk of being caught by intensified police enforcement has also surpassed our expectations.

Therefore, the conclusion was that the high expectations had been met. And, furthermore, it was recommended to continue the implementation and to explore opportunities for higher quality implementation.

7. LESSONS LEARNED

There is not one country in the world for which road safety improvement is an easy task. Lack of high quality data or competent staff sometimes make a thorough analysis of a country's own situation impossible. Road safety is a complicated issue characterized by very different opinions on the causes of crashes or the best measures to prevent them. These measures are often the subject of political discussion and difference of opinion. Often these debates revolve around how these measures are to be financed. Add to this the fact that road safety improvement is not a ' real top priority' in policy anywhere, and the conclusion appears to be that reducing the number of road casualties is not that simple. This is even more so in countries with a rapid economic growth that comes with rapidly growing (motorised) mobility. This issue can become even more demanding if motorised mobility not at all or only to a limited extent takes account of vulnerable road users like pedestrians, cyclists and motorised two wheelers. This illustrates that road safety improvement is not by any means an easy task.

However, when designing road safety policies and when coming to questions which measures to include in these policies it is interesting to look at the experiences with road safety improvement in a country like the Netherlands. Not, as was mentioned earlier, with the intention of copying the approach, but as a source of inspiration. The experiences with road safety improvement in the Netherlands can roughly be summarized as follows:

- Although road safety has never been a top policy priority in the Netherlands, The Dutch Parliament has always shown much interest in the subject. Members of Parliament can place topics on the agenda and make tools available for the implementation of policy. Sometimes a 'champion' can be identified. A real champion can truly make a difference and speed up road safety improvement.

- Road safety improvement is a 'shared' responsibility of citizens/road users and the designers and operators of the road traffic system. Therefore, it is necessary that all stakeholders feel a reponsibility for the road safety problem and want to contribute to its improvement. In order to commit stakeholders to road safety improvement, it is important that politics at the national, regional and local levels clearly indicate that they consider road safety improvement to be an important subject. In addition, it is necessary that top managementmakes clear to each stakeholder that it is committed to make a contribution. As many different organizations (e.g. road authorities, police, legal authorities, legislators, vehicle industry, schools) are required to contribute, it is advisable to make it attractive for organizations to participate, to cooperate, and sometimes to also be willing to be coordinated by a 'lead agency' (without their responsibilities being taken away). It is important that the stakeholders' achievements are being monitored to make sure they 'deliver'.

- Research indicates that setting realistic and ambtious quantitative targets leads to better policy and more rapid road safety improvement (Allsop et al., 2011). Of course, such a quantitative target can only function if a high quality data system is available. Furthermore, it is important that the process and therefore its progress is closely monitored. Mechanisms are required (e.g. an annual report on road safety) to establish whether one is on the right track.

- Using a vision like Sustainable Safety has a number of important advantages. Developing such a vision which addresses specific local problems and which is based on a good insight into what is effective and efficient in a country/district/town.should therefore be considered. The Safe System approach, of which the Dutch Sustainable Safety vision is a good example, can be used to this effect. In the Netherlands the vision has mainly been used by the professional world of researchers, policy makers, practitioners, elected politicians, etcetera, and not so much in the communication with road users.The advantage of the vision was that all stakeholders were invited to commit themselves to the vision and to use the vision as a guideline in their work. In the Netherlands this resulted in a synergy, and therefore an increase in the effectiveness and efficiency of interventions. Another advantage was that it created a long term perspective and that longer term financial sources for road safety policy were made available.

- It is important to put effort into gaining more political interest in road safety policy and to create support for measures among the population and road users. The media has an important role here and it is advisable to consider the media as an important partner in road safety policy.

- Evidence based interventions should be at the heart of each road safety programme. It is therefore to be recommended that a trusted knowledge organization establishes, ex-ante and ex-post, whether interventions are evidence based. In the Netherlands, the independent research institute SWOV has such a function. Furthermore, knowledge should form the basis for all advocacy work within a country. It is important to be aware of the fact that road safety improvement is not only a matter of reducing the number of road fatalities, but also of reducing the number of (serious) road injuries. Policy to reduce the number of road injuries wil (need to) be different from the aimed at reducing road fatalities.

This brings us to the question whether a Safe System Approach is a bridge too far for India or could it be a source of inspiration. I believe that a Safe System could also be of importance for India. Not, of course, in the sense that the measures, as they have been implemented in the Netherlands and in Sweden, could be copied on a one-to-one basis for the Indian situation; the countries differ too much. The vision could, however, be used as a background for the analysis of risks in road traffic in India. Nor can the Sustainable Safety principles be applied in India without any adaptations. The challenge will then be to translate these principles to the Indian (road traffic) conditions and society.

8. LITERATURE

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