

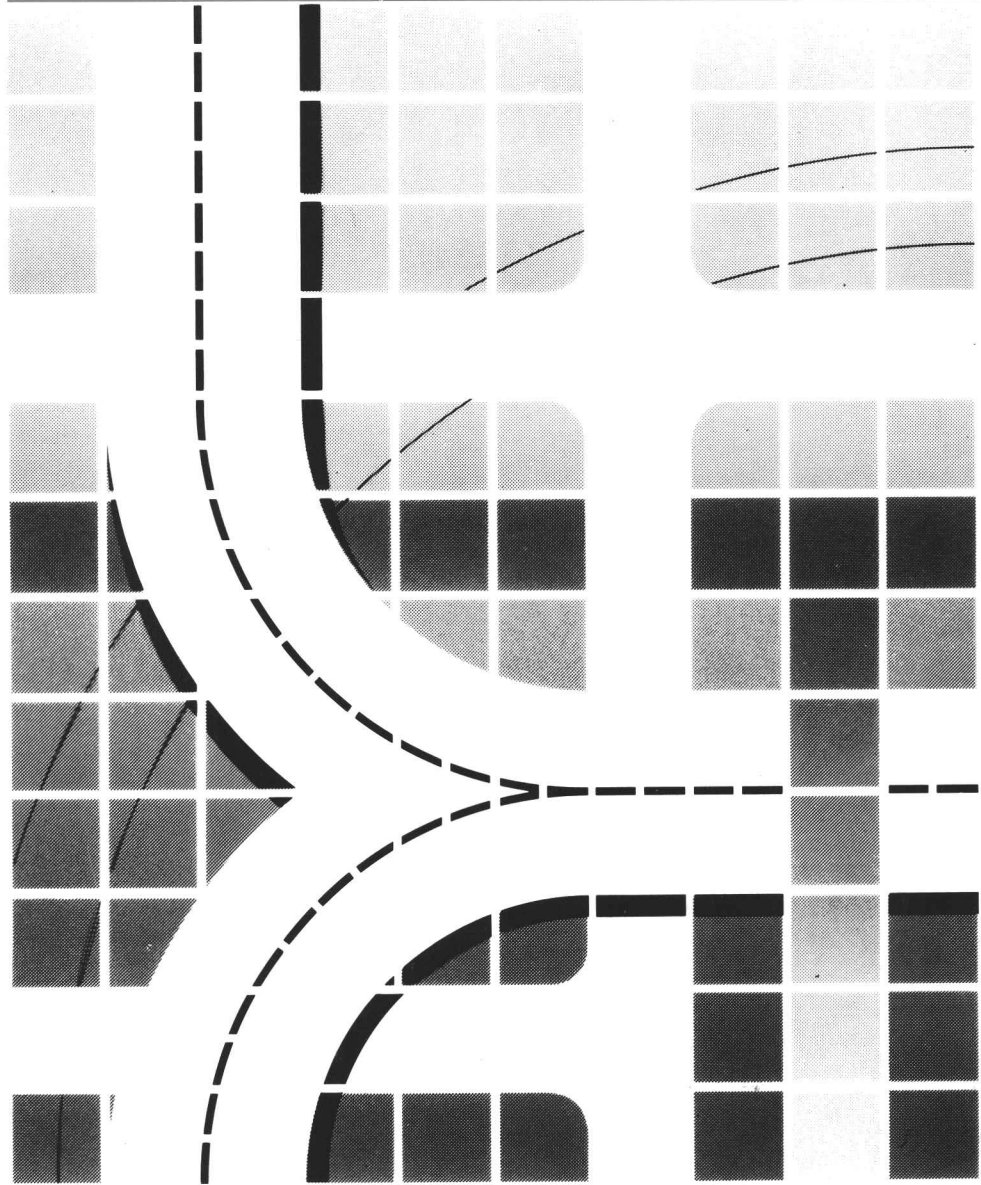
VK 7201-301
ISSN 0920-0592

The traffic safety of the Carin Car Information and Navigation system IA

Literature study: main report

April 1988

G. Blikman




TU Delft

Delft University of Technology

Faculty of Civil Engineering
Department of Transportation Planning and Highway Engineering

Rapp
CT
VK
88-03

1. Rapportnr. VK 7201-301	6. ISSN-nummer 0920-0592	
2. Titel rapport The traffic safety of the Carin Car information and navigation system IA-literature study: main report	7. Thema Traffic Safety	
3. Schrijver(s)/redacteur(s) G. Blikman	8. Onderzoekproject Carin Car information and navigation system	
4. Uitvoerend instituut Delft University of Technology/ Department of Transportation Planning and Highway Engineering	9. Categorie rapport Technical Publication	
5. Opdrachtgever(s) Philips International B.V.	10. Datum publikatie 1988	
11. Samenvatting Aim of the study was to determine the possible positive and negative effects on traffic safety of the Carin Car Information and Navigation system and to define requirements by which the possible negative effects are minimized or possibly eliminated and the possible positive effects are enhanced, thus making the overall effect of Carin on traffic safety a positive one. The Carin system has been analysed with the so-called phase model of the accident process. Possible positive effects that resulted from this analysis are: avoidance of search behaviour, avoidance of detours, avoidance of unsafe locations and situations, and information on the vehicle condition. Possible negative effects were: compact disc changing while driving, distraction by route guiding advices, untimely presentation of route guiding advices, obstruction of the driver's view, illegal route guiding advices, the reaction on a disregarding of a route guiding advice, and (part of) the system causing injuries in case of an accident. On an important part of the above subjects a literature study has been conducted. The findings are discussed and gaps in the present knowledge indicated. Priorities for further study are presented.		
12. Begeleidingscommissie	14. Bijbehorende rapporten The Traffic Safety of the Carin System IB, II, summary report	
13. Praktijkcontacten	15. Aantal blz. 82	16. Prijs f 16,40

The traffic safety of the Carin car information and navigation system IA

Literature study: Main report

G. Blikman

Technische Universiteit Delft
Faculteit CiTG
Bibliotheek Civiele Techniek
Stevinweg 1
2628 CN Delft

778288

Rapp

Ct

VK

88-03

3132752

Delft, 1988

Delft University of Technology

Department of Transportation Planning and Highway Engineering

In assignment of Philips International B.V.

PREFACE

Safety is one of the most difficult and complex aspects of the traffic system. The reason hereof is that safety is not simply a matter of averages, but of deteriorations from the average. In traffic numerous actions are executed 100 thousand times effortlessly, but the one time the traffic process is disturbed, an accident is the result with all possible serious consequences. Accidents seldom or never have one cause. Usually they are the result of a critical combination of many circumstances. Traffic safety research therefore concentrates on locating that critical situation, the chance or probability of occurrence of that situation and the consequences hereof.

With regards to the decision process on traffic safety, three phases can be discerned: the risk analysis, the risk assesment, and the risk control.

The risk analysis is directed mainly at locating critical circumstances, the chance of occurrence and the consequencess hereof with the aim to give a qualitative and if possible a quantitative description or the risks. This report is concentrated mainly on the risk analysis of the Carin system.

In the risk assesment phase the acceptable risk is weighed out against other aspects, such as comfort, accessability, speed, costs, and the like.

The risk control phase is pointed at the optimal design of a measurement.

In a well structured decision process, the decision phases are separated as much as possible. If e.g. in the risk analysis phase other interests such as costs already play a role, no objective impression of the actual risks may be received.

Prof. E. Asmussen,
Delft University of Technology
Department of Transportation Planning and Highway Engineering
Traffic Safety Division

CONTENTS

1	Introduction	2
2	The Carin system	4
3	Traffic safety analysis	7
3.1	Introduction	7
3.2	Travel/transport situation	7
3.3	Traffic situation and encounter situation	10
3.4	Encounter situation	14
3.5	Incident situation	18
3.6	Crash situation	18
3.7	Conclusions	19
4	Selection of subjects	23
4.1	Subjects proceeding from the traffic safety analysis	23
4.2	Subjects for further investigation	24
4.3	Subjects for literature study	25
5	Results literature study	27
5.1	Distraction by route guiding advices	27
5.2	Untimely presentation of route guiding advices	32
5.3	Avoiding unsafe locations and situations	50
6	Summary and discussion	58
	Literature	71

Enclosure: Phase model of the transport and traffic (unsafety) process

1. INTRODUCTION

Traffic safety is influenced by many circumstances. The condition of every element of the traffic system and the interaction between the various elements all have their effect on traffic safety. Even so, unsafety is the result of a critical combination of circumstances. Accidents do not have one cause, but are the result a chain of circumstances.

A skidding accident with serious consequences could e.g. be caused by a combination of a low attention level of the driver, distraction of the driver by other car occupants, unfamiliarity with the location, a sudden sharp bend in an otherwise straight road with only moderate bends, a wet road surface, a road surface with insufficient skidding resistance, the inability of the driver to cope with a skidding car, the car occupants not wearing safety belts, a tree alongside the road that could not be avoided any more, a long time period between the accident and the signalling, a great distance from the nearest hospital, the qualified doctor not being present at the time of arrival in the hospital, and the like.

The removal of any of the above circumstances would have resulted either in the avoidance of the accident or in the accident not being fatal.

From the above, it will become clear that the introduction of a new element into the traffic system, like the Carin car information and navigation system, will certainly have its effects on traffic safety. Firstly, because through the addition of some new circumstances, a combination of circumstances may become critical. Secondly, because the Carin system could remove circumstances from a critical combination of circumstances. In the first case Carin would have a negative effect on traffic safety and in the second case a positive one.

The underlying traffic safety study on the Carin system was carried out in order to register all possible effects on traffic safety and enable an overall positive contribution of Carin on traffic safety by minimising or possibly eliminating the negative effects and enhancing the positive effects.

Fortunately, the study was carried out in the design phase of the Carin system, which enables adjustments of prototypes and a major role of traffic safety criteria in an early development stadium.

This report contains the first part of the traffic safety study on the Carin system, namely a literature study based on a theoretical analysis.

The traffic safety analysis is presented in Chapter 3 after a short

introduction on the Carin system (Chapter 2). In the traffic safety analysis a so-called phase model of the transport and traffic process is used. More interested readers may find a full description of this phase model in the enclosure.

Out of the traffic safety analysis follow a number of subjects for further study, out of which in Chapter 4 the subjects for the literature study are selected.

The results of the literature study are presented in Chapter 5.

In the final chapter all findings are summarized and discussed extensively. Also are priorities given for further studies.

2. THE CARIN SYSTEM

Carin is an electronic car information and navigation system that is currently being developed by Philips. The system determines optimum routes and guides drivers to their destination. The route guidance information is presented to the drivers primarily aurally. A small flat panel display on which schematic pictogrammes can be presented serves as secondary information source. The calculation of the route is carried out before and during a trip when the vehicle-locating segment registers a deviation from the planned route. Once a deviation has been noticed, the system immediately calculates a new route with the actual location of the vehicle as starting point.

The system will be sold in a number of alternatives. The basic system comprises of a compact disc for mass storage of data, a board-computer, a vehicle-locating segment and an user interface section. Optional to the basic configuration are a data link via the car radio for recent traffic information, sensors transmitting data on the functioning of the car to the board computer, and a more luxurious user interface.

The compact disc with the digitized map can be played on a car compact disc drive that has been adapted for the retrieval of a variety of information which may be useful during a trip. On the Carin compact disc the roads have been stored through the so-called vector method. According to this method roads are approximated by a concentration of straight line segments. Consequently, roads are represented by start modes, kink points, and end modes. This economical way of digitising enables the storage of e.g. the whole Benelux on one compact disc, inclusive tourist information, information on hotels, filling stations, and the like.

The function of the board computer is to read the information on the compact disc, calculate the optimum route to a certain destination, determine route guidance advices, and carry out all required calculations.

The vehicle-locating segment determines the actual position of the car. Momentarily, this is done through an electronic compass for the determination of the heading of the vehicle and wheel sensors that measure the distance that is driven. From these data the board computer can calculate the position of the car. The board computer also corrects disturbances that may occur as a result of e.g. tyre wear or affection of the compass by the iron coachwork of the vehicle. Through a map-matching algorithm the disturbances are regularly corrected. The coordinates obtained from the vehicle-

locating segment are related to the digitized road map. Presuming that a car is always on the road, corrections can be calculated if the position estimates deviate from the corresponding road (figure 2.1).

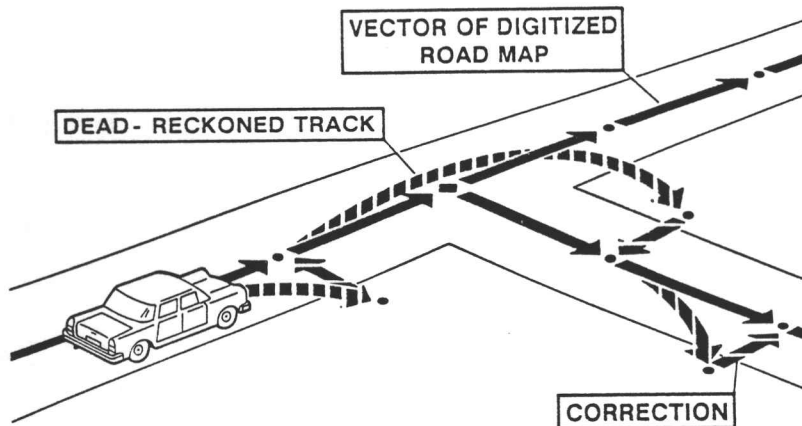


Figure 2.1: Correction of the calculated track.

In the future the vehicle location may be determined through the American satellite navigation system NAVSTAR, that will be completed in 1992 with a constellation of 18 satellites. With the civil part of the system, it will be possible to determine the position within an accuracy of ± 10 m on any time of the day on any position on earth.

The user interface comprises of a simple keyboard, a speech synthesizer chip, and a small flat panel display (figure 2.2).

The keyboard, that can be fitted into a remote control unit, is used for communication of the driver with the system, e.g. for entering the destination.

The speech synthesizer presents the route guiding advices to the driver. For traffic safety reasons route advices are primarily given auditorily, as the driver task is already heavily loaded with visual information. However, in some cases the aural route guiding advice may not be heard or understood. For those cases a visual support of the route advices through a flat panel display is thought necessary. On the dashboard-mounted flat panel display simple route guiding pictogrammes are presented to support the aural route advices. These route guiding pictogrammes are schematic representations of junctions and routes to be followed, comparable to the pictogrammes on sign posts.

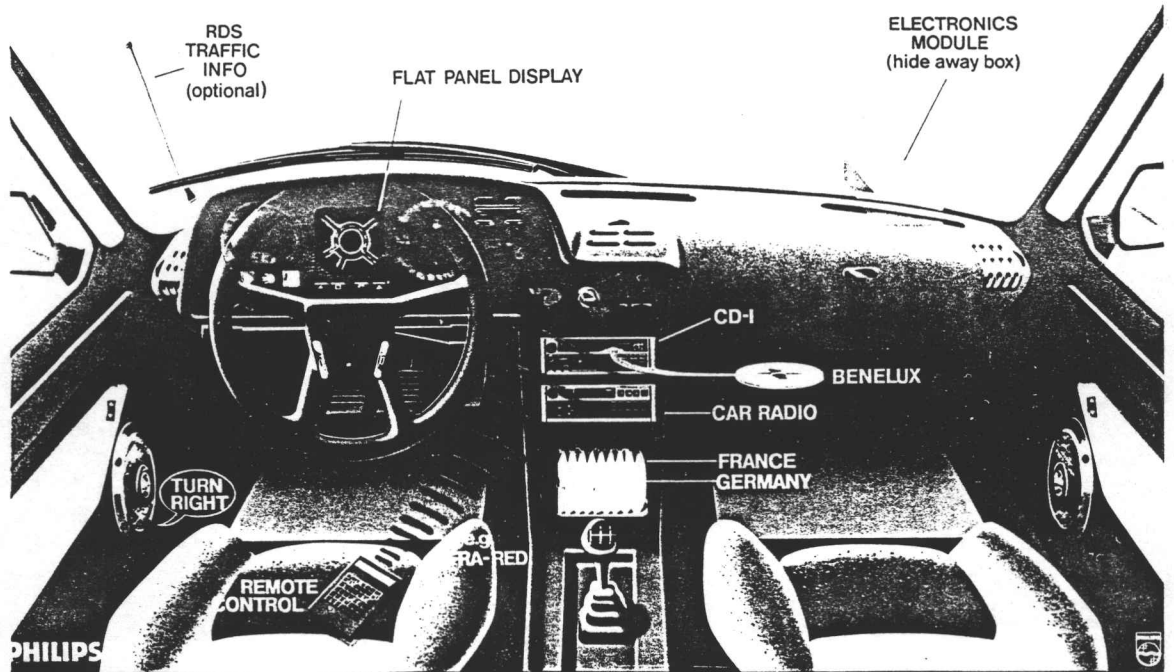


Figure 2.2: Configuration of the basic Carin system.

On option the user interface may be extended with an image display which can show an outline map of the area concerned complete with special locations such as motels, recreation centres, etcetera. For traffic safety reasons, this display is automatically turned off as the vehicle starts moving, which is measured by the wheel sensors. During a trip, the only communication between the system and the driver is the aural route advice, supported by the visual advice on the flat panel display.

The optional data linkage via the car radio can provide actual traffic information that can be incorporated into the route planning process. This information may be on traffic congestions or obstacles. A possible future system hereof is the Radio Data System. Experimental broadcastings with this system are currently being undertaken in various European countries. The link with usual automotive functions can provide additional information to the driver, e.g. on the average fuel consumption or the average speed.



Figure 2.5: Configuration of the basic cabin system.

In order the user interface may be expanded with an image display which can show an outline map of the area concerned complete with special locations such as hotels, restaurants, airports, for further safety reasons, this display is automatically switched off as the vehicle starts moving, which is requested by the local system. Looking a trip, the only communication between the system and the driver is the route advice, supported by the visual advice on the local panel display.

The optional data storage in the car radio can provide actual traffic information that can be incorporated into the route planning process. This information may be an actual congestion or obstacle. A specific future system based on the Radio Data System (RDS) broadcast processing with this system are currently being undertaken in various European countries. The link with usual automotive functions can provide additional information to the driver, e.g. of the average fuel consumption or the average speed.

3. TRAFFIC SAFETY ANALYSIS

3.1 Introduction

The use of a Carin information and navigation system as described in the previous chapter, may have various effects on traffic safety. In this chapter these possible effects are systematically analysed with the aid of the so-called phase model of the transport and traffic (unsafety) process or shortly phase model of the accident process. A description of this phase model is given in enclosure 1.

The possible effects of Carin on traffic safety are displayed in Table 3.1. In this table the possible effects are arranged per phase of the accident process and distinction is made between possible positive and possible negative contributions. As a reference for this categorisation served the situation without a Carin system.

For an overall positive contribution of Carin to traffic safety, it is essential to create conditions to minimise or possibly eliminate the negative effects and enhance the positive effects.

The possible effects of Carin on traffic safety are discussed in the following paragraphs.

3.2 Travel/transport situation

The circumstances under which a driver travels are referred to as the travel/transport situation. These circumstances are determined by the nature of the travel goal, the motive for travelling, the mode of transport and its characteristics, the route, and the time table.

The installation of a Carin system in a car may influence two of these circumstances, namely the characteristics of the transport mode and the time table, which could bring about respectively a change in modal split and more difficulty in estimating travel time.

Change in modal split

With the aid of a Carin system, searching in unknown cities will be able to be avoided, which may tempt drivers to use their cars in cases where previously means of public transportation have been used. The presence of a Carin-system in a car might thus result in travelling by car more frequently. The consequences of this possible change in modal split are not easily foretold.

On one hand, the average risk of getting involved in an accident is greater for car passengers than for passengers of buses, trains and air planes. However, it must be taken into account that traffic risks can be influenced by choice of routes and travel times and is dependent on car populations and the populations of other vehicles.

Table 3.1: Possible effects of the Carin system on traffic safety

phase of the accident process	possible negative effects	possible positive effects
travel/transport situation		<ul style="list-style-type: none"> - change in modal split - estimating travel time
traffic situation	<ul style="list-style-type: none"> - disc changing while driving - distraction by route guiding advices 	<ul style="list-style-type: none"> - avoidance of search behaviour - avoidance of detours - avoiding unsafe locations and situations
encounter situation	<ul style="list-style-type: none"> - disc changing while driving - distraction by route guiding advices - untimely presentation of route guiding advices - obstruction of the driver's view - illegal route guiding advices - reaction on a dis-regarding of a route guiding advice 	<ul style="list-style-type: none"> - avoidance of search behaviour - avoidance of detours - avoiding unsafe locations and situations - information on the vehicle condition
incident situation	<ul style="list-style-type: none"> - distraction by route guiding advices 	<ul style="list-style-type: none"> - avoidance of search behaviour
crash situation	<ul style="list-style-type: none"> - aggressive shape 	

Therefore a comparison of the average risks is not entirely correct. Better would be to compare the risks in specific situations. On the other hand, passengers of a means of public transportation have to go to a stopping place. To do so, they have to walk and possibly ride on a bicycle or a moped and these are means of transportation that are on average more dangerous than car driving. Out of the above it follows that it is difficult to predict the effects on traffic safety of a change in modal split. Furthermore, it must be considered that many users of the Carin system will be fleet owners or public services like the police, the fire brigade or medical services (ambulances, doctors) who can not choose a means of transportation, but have to use cars or trucks.

Estimating travel time

An underestimation of the travel time by the driver, may lead to hurrying when the driver notices his error. This has negative effects on traffic safety, because hurried drivers tend to travel at higher speeds and to take more risks. At encounters with other traffic e.g. they will be more inclined to accelerate in an attempt to pass in front than to brake.

In two ways the presence of Carin may influence the correct estimation of travel time. The first effect is a positive one: through a Carin system search behaviour and therewith search time can be avoided. This will eliminate the hurrying of a driver after a search has taken too much time.

The second effect negatively influences traffic safety. With a Carin system drivers will be inclined to inform themselves less on their route than without Carin. For prior to a journey drivers with a Carin system will not (have to) look on road maps and town plans to find their way, because the system determines the optimum route for them. Thus, drivers with a Carin system will find more difficulty in estimating their travel time as a result of the lack of knowledge of the route. Their only source of information is the travel distance, but they do not know if e.g. they will travel on motorways or secondary roads, through residential area's or outside build-up area's. Of course it will be possible for the Carin system to present estimated travel times based on road classifications, but the disadvantages hereof will be greater than the advantages as the consequences of wrong estimations are great.

For if drivers have to estimate their own travel time, they will account for the uncertainty through a safety margin of some minutes. If drivers on the other hand are presented a travel time by Carin, they will rely on it and not be prepared to take into account a

safety margin.

This would not provide any problems if the Carin system could estimate the travel time fail prove. But it can not.

Firstly, the travel time is dependent on personal preferences of the driver and on the traffic flows on the route, which are both changeable factors that can not be accounted for by Carin. Secondly, the weighing factors that are used to calculate the route with the shortest travel time are related only to the road classification. However, the speed that can be driven on a road of a certain class varies greatly from one country to another. The primary roads in western Europe, for instance, are motorways with design speeds of approximately 120 km/h, while in northern Scandinavia primary roads sometimes even are not paved. It will be evident that, although this does not keep the board computer from determining an optimum route (primary roads stay primary roads), it is fatal for a correct estimation of the travel time.

It can be considered to search for ways to present correct estimations for the travel time, not based on road classification only.

An adequate intermediate solution will be to present not solely the travel distance, but also the road types on which the route will be driven. Thus the estimated travel time can be based on more data and will therefore be more accurate as the driver can account for road situations and personal preferences.

3.3 Traffic situation and encounter situation

In the traffic situation drivers have to undertake relative little action and have a leight taskload: following the road, following a stable traffic flow.

As a result of this leight taskload drivers may be of opinion that an additional task can be executed without any risks. In the traffic situation this is mostly, though not always true. Most problems will arise when the driver arrives at an encounter situation.

In the encounter situation the driver meets other road users arrives at a bend in the road, faces himself with an instability in the traffic flow, and the like. In this situation the taskload is increased considerably as the driver has to account for other traffic and the traffic environment, and has to react timely and adequately. This may be prevented by any additional tasks which a driver may still be wanting execute, either because he thinks he can handle additional tasks also in the encounter situation or because the encounter situation was not foreseen.

Thus, for reasons of traffic safety, additional tasks in the

encounter situation should be avoided as much as possible. In the traffic situation and the encounter situation Carin may influence the task of the driver both negatively and positively. Possible negative effects may be caused by disc changing while driving and distraction by route guiding advices. Positive effects may manifest themselves as a result of the avoidance of search behaviour, the avoidance of detours, and the avoidance of unsafe locations and situations.

Disc changing while driving

The changing of a compact disc while driving may under circumstances endanger traffic safety. Although drivers will be inclined to account for the extra workload of disc changing, for instance by driving slower or keeping a larger distance to the vehicle in front, it is nevertheless quite possible that this disc changing leads to accidents as a result of unforeseen circumstances. Examples of these circumstances are unexpected encounters with other traffic and a longer search than expected for a particular disc.

Therefore disc changing while driving should be made impossible, drivers first should have to bring their vehicle to a halt before changing a compact disc.

Distraction by route guiding advices

A possible negative effect of the Carin system could be that the aural or visual route guiding information distracts the driver from his task to keep course, to account for the other road users and the traffic environment, and to react timely and adequately. Therefore great attention should be paid to the way in which the information is presented.

The aural route guiding messages are likely to distract drivers the least as the human ear is one of the senses that is still hardly used in car driving and therefore has a great capacity left for additional tasks.

Nevertheless, although it is quite well possible to listen and watch at the same time, the human mind is inclined to concentrate on one of the two when great efforts are needed. Examples hereof are conversations of drivers with passengers that stop when the driver has to perform a complicated driving task, like crossing a street with heavy traffic flows. The reverse might also take place. Drivers may start to listen so intensily to the aural route advice that not enough attention is paid to the driving task.

Subjects that may be of influence on this kind of distraction are the contents of the messages and the volume level of the speech synthesizer. The aural messages may be presented in short language style or in more descriptive terms and with or without a preceding

alerting signal.

The volume level may be controlled by the driver or automatically. A combination of both seems preferable: the driver adjusts a particular signal to background noise ratio that then is automatically sustained by the system.

Simple route guiding pictogrammes on a flat panel display can support the aural route guiding advices. However, the chances of distraction by this display are far from imaginary. To prevent this distraction, that may be related to the type of display (size, color coded or black and white, etc.) strong precautions will have to be taken.

It should be well considered what pictogrammes are allowed to be presented on the display. It is conceivable that no oversight should be given of a great number of junctions or a very complicated junction. The length of interpretation times for pictogrammes may have to be limited.

The lumination of the flat panel display has to be paid attention to. On one hand it has to be sufficient for the driver to see the pictogrammes in daylight, but on the other hand the driver must not be blinded at night or when driving on a subway. This can be done through automatic lumination control by means of a photoelectric cell.

The presentation of the visual route guiding pictogramme should be well attuned to the aural route guidance advice. It is important that the visual messages serve only as secondary information and the aural messages stay the main information source. For aural information probably distracts drivers the least from their driving task and imposes the least taskload and stress on the driver. For the human eye is allready heavily loaded with the driving task and besides pointed in a certain direction. The aural senses still are hardly loaded and besides direction-independent.

Therefore, firstly, no visual route guiding messages should be presented on the flat panel display without an accompanying aural route guiding advice. Neither should any aural messages be presented that urge the driver to watch the display for the next route guiding advice. Any aural route advice, how incomplete, is better than no aural route advice at all.

Secondly, visual messages should not be shown before or simultaneously with the aural advices. For this could provoke drivers, especially the onces experienced with the system, to start watching the display at the begin of an aural route guiding advice. Such an action would be very tempting as most visual route guiding advices will be able to be interpreted faster (though with a probable greater distraction) than the same information presented aurally (the time alone to speak

the message may take some seconds).

Avoidance of search behaviour

One of the main positive effects of Carin will be the avoidance of search behaviour. The driver receives his route guidance advices from the system and can fully concentrate his attention on the road, the traffic, and its environment. There will be no need any more to read sign posts, search for street names or special locations, map reading while driving, or stop to ask passes by. Especially under difficult traffic situations (heavy traffic flows, darkness, rain, and the like), this will be an enormous advantage.

Avoidance of detours

Another important positive effect of route guidance by Carin will be that drivers do not get lost anymore. Normally the drivers will follow the route that has been planned by the Carin system and even if they deviate from this route, the system immediately calculates a new route for them. As participating in the traffic process brings about a certain risk, it is evident that a limitation of the travel distance and therewith the total number of encounters, due to the avoidance of unnecessary detours, contributes positively to traffic safety.

It is difficult to precize the reduction of the travel distance. However, previous investigations of a.o. G.F. King and D.W. Schoppert have pointed out that + 30% of drivers in unknown cities get lost at least once during their trip.

Avoiding unsafe locations and situations

Traffic safety may be used as one of the criteria for determining optimum routes.

In the case of two or other criteria equivalent alternative routes, a choice could be made for the safest one. It could even be decided to select the safest route if it were slightly longer than the less safer route. In that case an accurately defined criterion should be determined for the percentage detour that is still accepted for a safer route, even more as detours bring about an enlargement of the risks of a journey (see also "avoidance of detours").

An example where traffic safety could be used as a criterion for determining routes is the choice between a route via a motorway or via a secondary road. On motorways the average risk on an accident with injuries is 0.04 per 10^6 vehiclekilometres. On a secondary road the same risk is 0.25 per 10^6 vehiclekilometre. Therefore, in the case of two routes of the same length, for reasons of traffic safety, the route via motorway should be selected. Even more, if the route

via the motorway is less than $0.25/0.04=6.25$ times longer than the route via the secondary road, it still is safer!

However, the application of the traffic safety criterion may not be as simple as could be concluded from the above. Traffic unsafety is a dynamic process and accidents happen as a result of a combination of critical circumstances. This means that the traffic safety of certain routes, roads, and locations vary with the circumstances (see also enclosure 1: the transport and traffic unsafety process). The circumstances that influence traffic safety are, among others, the purpose of the journey, the weather condition, the light condition, the road surface, the condition of the car, the condition of the driver, the traffic flow, the number and lay-out of junctions, and many more. To take into account all variables that are of influence on traffic safety will be impossible. To at least be able to calculate with some variables, sensors will be necessary to determine the state of those variables.

With the aid of the future Radio Data System it will be possible to present actual information on traffic situations. In this way Carin can help avoiding dangerous situations or at least warn drivers of those situations. Examples in which this could be useful are congestions, road works, black ice, insufficient skidding resistance, and the like.

3.4 Encounter situation

In addition to the possible effects of Carin on traffic safety that play a role both in the traffic situation and in the encounter situation, there are also some possible effects that manifest themselves solely in the encounter situation. These are an untimely presentation of route guiding advices, the obstruction of the driver's view, illegal route guiding advices (all with a possible negative effect) and information on the vehicle condition (possible positive effect).

Untimely presentation of route guiding advices

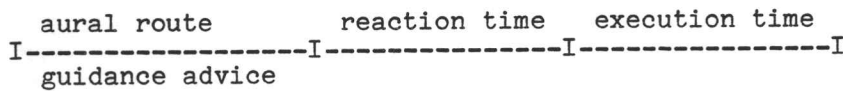
Route guiding advices should be presented to the drivers well before a junction, roundabout, exit road, etc. in order to give the driver enough time to follow up a route guiding advice. The effect of untimely route guiding advices is twofold.

First, the possible positive effect of the avoidance of search behaviour is neutralised. If the Carin route guidance advices are presented too late, drivers will have to search for the required routes themselves, which is even more difficult (and thus more time-consuming) than without a Carin system as the drivers will be less

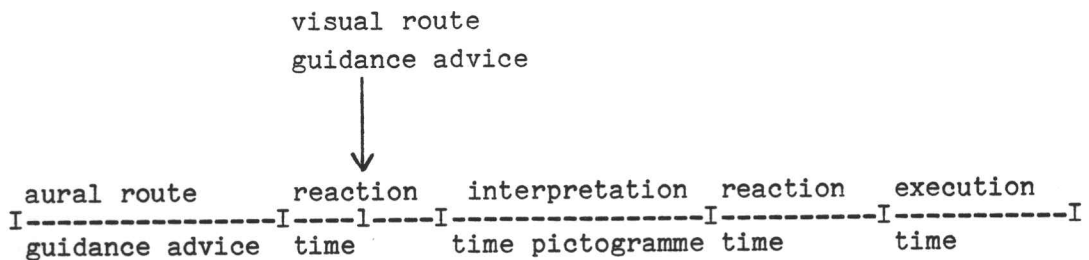
informed on their route.

Second, with late presentations of the route guidance advices drivers possibly are not only distracted by them in the traffic situation, but also in the encounter situation, which has a greater impact on traffic safety as the necessity to watch and react on other traffic is greater in the encounter situation than in the traffic situation.

Presenting route guidance advices in time means that after messages have been given, drivers still have to have enough time to react and execute whatever action is necessary. This is illustrated in the figure below.



However, if an aural route guidance advice is not heard or understood (entirely) and a support of the route advice on the flat panel display is needed, the time between the end of the spoken message and the begin of a necessary action is enlarged with a time necessary for the interpretation of the pictogramme on the display and an additional reaction time. In this case, the time table is as shown below. If the distance between two succeeding junctions is too short for this time cyclus, a compound route advice should be given.



The length of the aural route guidance advice depends strongly upon the kind of advice that is given and upon the way in which it is given. If e.g. a driver has to turn left at the second crossing, the commands "second left" or "turn left at the second crossing" are possible. The advantage of the first command is its shortness. A disadvantage is that the essence of the message is lost if a driver does not hear the first word, although this could be compensated by the, in comparison with visual information, relatively long sensory memory for aural information. On average, until 2 s after its presentation, an aural message can be recalled from the sensory memory before the memory is whiped clean (+ 0,4 s for visual

information).

The reaction time is dependent on many variables, among others the level of attention of the driver, which is related to the velocity of the car and the local situation.

The interpretation time for visual messages on the flat panel display is related to the complexity and the number of junctions that are shown in the pictogramme.

The time that is needed for a necessary action is strongly dependent upon the velocity of the car, the kind of action, the condition of the car, the preference of the driver and the road characteristics. The time calculated by the system should be based upon comfortable decelerations and changes in lateral position. Often 3 m/s^2 is seen as the maximum deceleration that is still comfortable (decelerations above 3 m/s^2 are defined as emergency braking). It is suggested to calculate with decelerations of 2 m/s^2 as these are both comfortable and acceptable from a traffic safety point of view. For stronger decelerations may lead to head-tail accidents as a following driver needs time to react and therefore has to brake more abruptly than the car in front.

It seems justifiable not to take into account the personal preferences of drivers, although drivers with a high level of attention, a high speed, and an incling towards sudden and abrupt movements will prefer and mostly be able to react correctly to late route guiding advices. Three reasons can be put forward for this abundance of personal preferences. Firstly, a high level of attention does not have to lead to short reaction times. The "direction" of the attention is of importance also. If the attention is directed towards the road and the traffic, the reaction time on a route guiding advice may still be considerable. Secondly, because of the high level of attention, the driver is well equipped for early route guiding advices and will normally find no problem in remembering them until the required action is due. Thirdly, although fast drivers may be willing to accept abrupt movements like great decelerations, the situation may sometimes not permit it (wet or frozen road surfaces, worn out tires and the like). In that case, late route guiding advices could lead to unsafe situations (skidding, swerving, etc.)

Sometimes, it may be preferable not to base the presentation time on actual data, but to fix a certain distance before a junction. On motorways for instance, it seems preferable to present the route guiding advices before the first sign post indicating the exit road.

Although route guiding advices have to be given in time, these advices must not be given so early that a driver forgets them before

he reaches the place where he has to follow up the advices. A problem is that the time during which route guidance advices can be stored in the short term memory varies greatly from one person to another and depends on the situation also.

Obstruction of the driver's view

Although it seems evident, no part of the Carin system should under any circumstances obstruct the driver's view. The location of the flat panel display is likely to present the most difficulties in meeting this condition, unless it is built into the dashboard.

Illegal route guiding advices

It will not be possible to avoid Carin from advising drivers to turn into a street where that is not allowed (for instance the wrong side of a one-way street). The problem is that the digital map on the compact disc gets out of date: after the making of the map one-way streets may be installed, the direction of one-way streets turned, the accessibility for motor vehicles made undone, etc.

It will be important to at least point out to drivers that route guiding messages may be illegal and that the route guiding information comprises no commands but advices. The driver will have to check the road, the traffic, and the traffic regulation himself, just as he did before the installation of the Carin system.

Nevertheless it is likely that drivers start following-up route guiding advices blindly: after 1000 legal advices they do not expect the 1001st advice to be illegal. This may lead to drivers following up the illegal advice or becoming panicked when noticing that the route advice that has just been given is illegal. Therefore it should be made clear that should ever a route guiding advice be ignored, the Carin system immediately calculates a new route, starting from the present position.

Reaction on a disregarding of a route guiding advice

Drivers may, under circumstances, disregard a route planning advice. This may be done either on purpose or without notice (not correctly understood route guiding advice and/or road situation). It can be considered to inform drivers of such a deviation from the planned route. However, to avoid any negative effects on traffic safety, it is essential that this information is not presented immediately after the deviation. For this could induce drivers who deviated unwillingly to last moment actions to correct their mistake, with all possible negative effects on traffic safety (sudden stops on junctions, driving backwards on exit roads or hard shoulders of motorways, etc.). To prevent any of those for traffic safety unfavourable actions, drivers should be informed of a deviation of the planned route, if it

is decided to present that information at all, on a location that is so far from the deviation point that any correction of the mistake by the driver is impossible.

It seems best to present that information after a new route has been calculated by Carin and inform the driver of this new route to avoid possible panic.

Information on the vehicle condition

Although not directly related to route guidance, with some addition to the already present electronic equipment in the Carin system, it would be possible to inform drivers on the actual condition of vital parts of the vehicle. The functions that for traffic safety reasons should be subject to this permanent check are the condition of the braking system (brake lining, brake pads, brake fluid), tyre wear, lights, the steering system, and the steering characteristics (in case of over-loading the steering characteristic of a car changes considerably).

To be able to actually install a checking system for vital vehicle parts, a coordination between the Carin design and car designs will be essential. Consultation of car manufacturers will be necessary.

3.5 Incident situation

If no timely and/or adequate reaction has been carried out in the encounter situation, the only way to prevent an accident is for the driver to carry out an emergency manoeuvre like abruptly swerving or an emergency stop.

To successfully carry out this emergency manoeuvre, the driver has to become aware of a danger, recognize the danger, and react adequately. Circumstances that may prevent the driver from becoming aware of a danger and/or recognizing this danger are a distraction by route guiding advices or by search behaviour. Thus it will be clear that a **distraction by route guiding advices** may have a negative effect on traffic safety and an **avoidance of search behaviour** a positive one. For a description of these effects is referred to paragraph 3.3.

3.6 Crash situation

In the crash phase of an accident two subphases can be distinguished: the primary crash and the secondary crash. The primary crash concerns the collision with an other vehicle or the crash into any environ-

mental obstacles. Of importance for the severeness of the primary crash are the crash speed, the angle and point of impact, and the compatibility of the crashing objects.

The secondary crash concerns the collision of vehicle occupants with the vehicle interior or exterior. In this subphase the Carin system may negatively effect traffic safety as collision of occupants with accident two subphases can be distincted: the primary crash and the secondary crash. The primary crash concerns the collision with an other vehicle or the crash into any environmental obstacles. Of importance for the severeness of the primary crash are the crash speed, the angle and point of impact, and the compatibility of the crashing objects.

The secondary crash concerns the collision of vehicle occupants with the vehicle interior or exterior. In this subphase the Carin system may negatively effect traffic safety as collision of occupants with (parts of) the system may case injuries.

Agressive shape

Although little is known on human tolerance, it can be stated that an aggressive shape of (part of) the Carin system like sharp edges or protruding obstacles under circumstances may enlarge the severeness of injuries and thus must be avoided. If that is not possible, the aggressive parts should at least be adjusted in such a way that they break off in case of a collision.

For the remote control unit a container should be designed that is comfortably located in the car. This should prevent the driver from letting it lie about on just any place in the car from where it could be swung to the occupants in case of a collision.

3.7 Conclusions

The traffic safety analysis on one hand has put forward requirements and restrictions for a safe functioning of the Carin system and on the other hand has raised some questions as to what the effects on traffic safety will be and what variables it depends upon.

The results of the traffic safety analysis are summarized in the following.

1. Change in modal split

Carin could induce a change in modal split. The effects hereof on traffic safety are difficult to predict.

1.1 What changes in modal split take place as a result of the installation of a Carin system in cars?

1.2 What are the effects of a change in modal split on traffic safety?

2. Estimating travel time

Through a Carin system search behaviour and therewith search time can be avoided.

It can be considered to search for ways to present correct estimations of the travel time, not based on road classification only.

An adequate intermediate solution will be to present not solely the travel distance, but also the road types on which the route will be driven. Thus the estimated travel time can be based on more data and will therefore be more accurate as the driver can account for road situations and personal preferences.

2.1 How can the travel time be estimated correctly?

3. Disc changing while driving

Disc changing while driving should be made impossible: drivers first should have to bring their vehicle to a stop before changing a compact disc.

4. Distraction by route guiding advices

It is preferable to have the volume level for aural route guiding advices controlled both automatically and by the driver: the driver should adjust a signal to background noise ratio that then is automatically sustained by the system.

The lumination of the flat panel display has to be sufficient for day light conditions, yet not blinding during nighttime or on a subway. Automatic lumination control should provide a solution here.

No visual route guiding messages should be presented without an accompanying aural route guiding advice. Neither should any aural messages be presented that urge the driver to watch the display for the next route guiding advice.

Visual route guiding messages should not be shown before or simultaneously with the aural advices.

Although aural route guiding advices are likely to distract drivers less from their driving task than visual information, questions remain as to the extent of the distraction.

4.1 Does the presentation of aural route guiding information distract drivers from their driving task? To what extent are drivers distracted? What variables are of influence on the amount of distraction (language style, alerting signals, etc.)?

4.2 Does the presentation of visual route guiding pictogrammes distract drivers from their driving task? To what extent are drivers distracted? What variables are of influence on the amount of distraction (number and complexity of pictogrammes,

type of display, etc.).

5. Avoidance of search behaviour

One of the main positive effects of Carin will be the avoidance of search behaviour. Especially in difficult traffic situations this will be an enormous advantage.

6. Avoidance of detours

As participating in traffic brings about certain risks, it is evident that a limitation of the travel distance, due to the avoidance of unnecessary detours, contributes positively to traffic safety.

7. Untimely presentation of route guiding advices

After the start of a presentation of an aural route guiding advice, there has to be time for the advice to be spoken, and for the driver to react on the aural advice, interpret a visual route guiding advice, react on the visual advice, and execute whatever action is necessary.

7.1 What time is necessary to present (each of the) aural route guiding advices?

7.2 What is the reaction time on aural and visual messages?

7.3 What is the interpretation time for each of the route guiding pictogrammes?

7.4 What time is needed to execute a necessary action (decelerating, changing lanes)?

7.5 What are the chances that aural route guiding messages are forgotten?

8. Obstruction of the driver's view

No part of the Carin system should under any circumstances obstruct the driver's view.

9. Illegal route guiding advices

It will be important to at least point out to drivers that route guiding advices may be illegal and that the route guiding messages are no commands but advices.

9.1 How do drivers react on illegal route guiding advices?

10 Reaction on a disregarding of a route guiding advice

If it is decided to inform drivers of a deviation from a planned route, this should be done on a location that is so far from the deviation point that any correction of this mistake by the driver is no longer possible. It seems best to present that information after a new route has been calculated by the system, and inform the driver of this calculation of a new route.

11. Avoiding unsafe locations and situations

Traffic safety may be used as one of the criteria for determining optimum routes.

With the aid of the future Radio Data System it will also be possible to warn drivers off dangerous road situations. The following questions remain to be answered.

- 11.1 Is it possible to use traffic safety criteria? Can and should be accounted for external circumstances? If so, how can this be done?
- 11.2 To which extent should traffic safety be used as a criterion for determining optimum routes? What detour percentage is still acceptable for a safe route?
- 11.3 How (un)safe are certain roads, locations, manoeuvres, and situations?
- 11.4 What dangerous road situations should a driver be warned off?

12. Information on the vehicle condition

With some additional electronic equipment, it would be possible to inform drivers on the actual condition of vital parts of the vehicle, such as the braking system, the tyres, the lights, the steering system, and changed steering characteristics.

13. Aggressive shape

Sharp edges and protruding obstacles on any part of the system should be avoided. If this is absolute impossible, aggressive parts should be adjusted in such a way that they break off in case of a collision. For the remote control unit a comfortably located container should be designed.

4. SELECTION OF SUBJECTS

4.1 Subjects proceeding from the traffic safety analysis

From the traffic safety analysis (Chapter 3) the following subjects remain to be studied:

1. Change in modal split

- 1.1 The changes in modal split as a result of the installation of a Carin system in cars
- 1.2 The effects of a change in modal split on traffic safety.

2. More difficulty in estimating travel time

- 2.1 Ways of estimating the travel time correctly

4. Distraction by route guiding advices

- 4.1 The distraction of drivers from their driving task by the presentation of aural route guiding information.
The amount of distraction. The variables that are of influence on the amount of distraction
- 4.2 The distraction of drivers from their driving task by the presentation of visual route guiding information.
The amount of distraction. The variables that are of influence on the amount of distraction

7. Untimely presentation of route guiding advices

- 7.1 The length of each of the aural route guiding advices
- 7.2 The reaction time on aural and visual route guiding messages
- 7.3 The interpretation time for each of the route guiding pictogrammes
- 7.4 The time that is needed to execute a necessary action (decelerating, changing lanes)
- 7.5 The chances that aural route guiding advices are forgotten

9. Illegal route guiding advices

- 9.1 The reaction of drivers on illegal route guiding advices

11. Avoiding unsafe locations and situations

- 11.1 The possibility to use traffic safety criteria. The possibility and desirability of accountance for external circumstances
- 11.2 The extent to which traffic safety should be used as criterion for determining optimum routes. The detour percentage that is still acceptable for a safe route
- 11.3 The (un)safety of certain roads, locations, manoeuvres, and situations
- 11.4 The dangerous road situations a driver should be warned off

4.2 Subjects for further investigation

Overlooking the subjects of the previous paragraph, it can be concluded that not all subjects will have an equal impact on traffic safety or are equally well to research. For reasons of effectiveness of the investigation, it will be usefull to give the subjects with a probable low impact no high priority. Even more as the time for this investigation is very limited.

Subject 1 (change in modal split) is the first subject that should be given a low priority. Herefore are three reasons.

First, it is probable that the changes in modal split as a result of the installation of a Carin system will be small. For private persons who buy a Carin system will be mainly drivers who already make many vehicle kilometres yearly. Furthermore, many buyers will not be private persons but transport firms, car rental agencies, or public services like the police or the fire brigade, who can not choose a means of transportation but have to use cars or trucks anyway.

Second it can be assumed that the total effects of a change in modal split will be small: a shift from public transport to car transport may result in a negative contribution to traffic safety, but an avoidance of pre- and after-transport to get to and from stopping places could give a positive contribution. It is likely that the total effect is not far from zero.

Third, it will be very difficult and time-consuming to research both the change in modal split and the effects of such a change in modal split. Herefore information would have to be gathered on the means of transportation before the installation of Carin, inclusive all pre- and after-transport, the risks of those transport chains, and the risks of car driving after the installation of Carin. Furthermore, no average risks should be used for the calculations, as this would make the results highly inexact. The risks of the different journeys would have to be differentiated to routes and times of journeys.

Summarizing the above, an investigation on any changes in modal split, would probably be very time consuming and pointing out that the effects on traffic safety are very small, if there are effects at all.

The second subject that will be given a low privity is subject 2 (estimating travel time). For it will be very time-consuming to come to a correct and reliable estimation of the travel time. This would probably necessitate an extension of the number of road classes and measurements of speeds that can be driven on each road class in each

11.4 The dangerous road situations a driver should be warned off

Between the above subjects, distinction has to be made into subjects that have to be researched extensively and subjects that are already well known and for which it is sufficient to study a few of the many works that have been written on them. To the latter group, for which an abridged literature study will be sufficient, belong the subjects 7.2 (the reaction time on aural and visual route guiding messages) and 7.4 (the time that is needed to execute a necessary action).

5 RESULTS LITERATURE STUDY

A list of the literature that has been studied on the selected subjects (see Chapter 4) is given at the end of this report.

These articles and reports were selected through the International Road Research Documentation system on the basis of the abstracts.

The results of the literature study are discussed per subject. In this chapter no conclusions or effects on the Carin system are given yet. Any conclusions or opinions are derived directly from the studied literature. The evaluation of the results is carried out in chapter 6.

A detailed description of each studied report and paper is presented in part IB of this report.

5.1 Distraction by route guiding advices

4.1: The distraction of drivers from their driving task by the presentation of aural route guiding advices

In many of the studied reports and articles it is stated that aural information distracts drivers less from their driving task than the same information presented visually. This statement is made either on the basis of previous researches (Behrendt, 1985 and Priest, 1980) or on the results of own research (Holloway and Wright, 1980)

Holloway and Wright carried out three laboratory experiments in which subjects performed a simulated driving task (steering a model aircraft over a moving paper and pressing a foot pedal to indicate the detection of a $\frac{1}{2}$ s flash of one of a set of peripheral lights). During the test the subjects were presented roundabout information both visually and aurally. The information was always preceded by a warning tone. The subjects were to recall the correct destination and exit. The tests were carried out both a large and with a small preview time for tracking (with and without anticipation)

Although it is questionable whether these testing conditions are sufficiently representative for the driving task in real traffic, they are nevertheless useful in indicating the workload necessary for processing route information.

The workload turned out to be heavier for processing visual information than for aural information. On one hand, the results showed a greater decrement in "driving" performance at the presentation of visual messages than at the presentation of aural information. On the other hand, the subjects' compensation for the additional workload of processing route information was greater when the visual messages

were on than when aural messages were presented (figures 5.1 and 5.2).

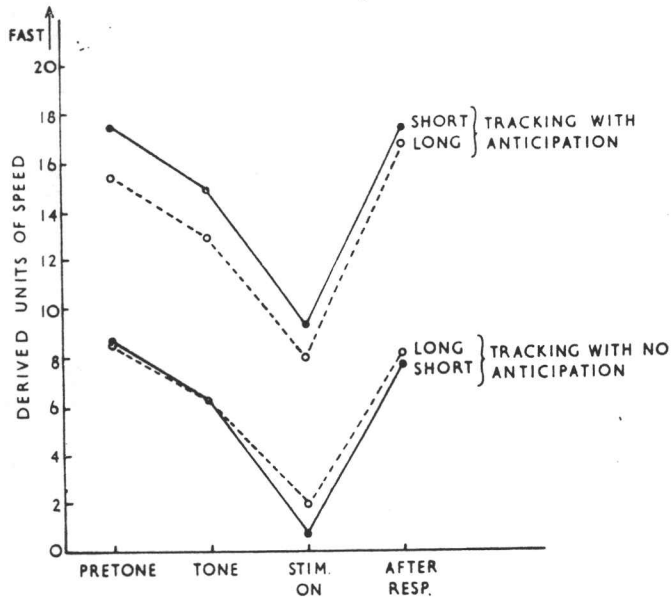


Figure 5.1: Tracking speed while attending to visual messages

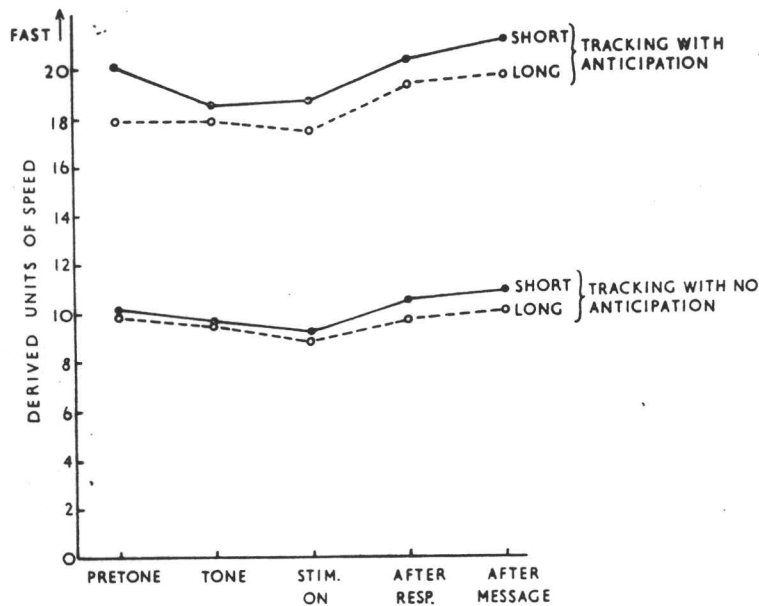


Figure 5.2: Tracking speed while attending to aural messages.

The researches of Holloway and Wright showed that even simple auditory messages, involving only the recognition of a specified word, may cause drivers to slow down or suffer some loss in tracking accuracy. The results also served to emphasize that it is not simple the occurrence of the auditory message which affects performance; a more critical factor is what the listener does to the message, i.e

the amount of cognitive processing involved. As the complexity of the auditory messages increases, so both peripheral vision and tracking accuracy deteriorate. Clearly auditory information transmitted to drivers should be designed to require very little thought or interpretation by the driver before it can be understood and acted upon.

The amount of distraction is probably very dependent on age and sex. When investigating the distraction of car radios, Knust (1972) found that ninetyfive percent of all tested women (3458) declared to be distracted by car radios to the extent of switching off the radio when driving on a motorway or a secondary road. They were distracted both by music and by the spoken word. In contrast with the previous findings, young male subjects declared to be even stimulated by music.

Elderly male drivers declared not to be disturbed by light background music, even at high speeds. These drivers also declared that heavy music or the spoken word did distract them.

This seems to correspond with the findings of Holloway and Wright, as it is likely that the amount of cognitive processing is greater for heavy music and the spoken word than for light music.

Michaelis (1980) stated that as voice synthesizers are a model of a human speaker, along with the actual words also the tonal aspects of the speaker's voice are captured and that it is absolutely essential to learn to evaluate these nonverbal cues, as these also determine the acceptance of the system by the user and the amount of distraction caused by them.

4.2: The distraction of drivers from their driving task by the presentation of visual route guiding advices

The workload for processing visual information is greater than for processing aural information (see the above). The findings of Holloway and Wright (1980) suggest that the processing of visual roundabout information imposes such a workload on subjects that no other heavy workloads like peripheral detection can be executed simultaneously. The presentation of visual information caused both a decrease in speed and an increase in tracking errors. However, the amount of cognitive processing required for the interpretation of the visual information was probably high, as subjects were to read and name the place the correct exit was pointing at.

Next to the report of Holloway and Wright, the report of Blaauw (1984) is the only one in which research has been carried out on the affection of driving tasks by the presentation of visual information. Unfortunelately for this literature study, Blaauw has only studied

the effects on the tracking task and has paid no attention to the task to watch the other traffic and the environment and react timely and adequately.

Blaauw finds a deterioration of the tracking task at night for experienced drivers who simultaneously have to perform a longitudinal task. He ascribes this to the fact that during darkness the visual field is deteriorated and, as a result, drivers have to estimate their velocity primarily through observations of the speedometer, during which no visual information can be gathered on lateral vehicle control.

An indication for the kind of pictogramme which distracts drivers least, is given by Galer, Baines, and Simmonds (1980). An investigation on speedometer displays showed that a digital display was more distracting than an ordinary analogical one, although the digital display performed better on the accuracy of reading. This may be explained by the amount of cognitive processing required, which is likely to be greater for the digital display: each time the display has to be read and it has to be determined whether the velocity is under the speed limit, whereas on ordinary speedometers this can be determined with a quick look through the direction the speedometer is pointing at.

The remaining reports on the effects of visual information in cars do not relate the distraction by the visual information to the tasks a driver has to perform. They in- or explicitly pose that driving is a visual task and thus the time that is spent any additional visual task has to be minimized. Therefore many of the remaining reports are directed towards minimizing the interpretation or reading time for visual messages.

Sometimes a maximum time is mentioned in which a visual message should be able to be interpreted, however without explaining the values of these maximum interpretation times.

Behrendt (1985) e.g. stated that the visual presentation that has been tried until now, resulted in a distraction of the driver of about 3 seconds or more, whereas only 1-2 seconds at the most can be tolerated. In general, visual presentations should be interpretable with only an occasional look.

Erke, Richter, and Richter (1974) found interpretation times for certain direction signs of 3-5 s, which were found for too long.

Two indications for maximum interpretation times can be found in the report of Blaauw. Firstly, the report presents mean interpretation times for speedometer readings of 0,5 and 0,8 s, which are generally regarded as an acceptable form of distraction. However, it must be realised that normally drivers can choose the point of time at which they watch the speedometer freely, whereas they will be more or less

forced to look at a route guiding pictogramme, regardless of the traffic situation or the environment. This is even more important as the results of Holloway and Wright suggest that subjects are waiting for easier stretches of track when this was feasible: when the visual message was presented for 3 s, the mean response latency was 1,1 s, where it was 1,5 s when the message was presented for 10 s.

This is confirmed by Prentice (1974) who states that as a result of the relative long time it takes to read an ordinary speedometer, drivers do not look at their speedometer in heavy traffic or during difficult manoeuvres. In contrast to Blaauw, Prentice reports of average speedometer reading times of 1,6 s.

Secondly, Blaauw showed that drivers were still quite able to control their vehicle when their vision was voluntary occluded during certain periods of some seconds. The found occlusion times which drivers voluntarily imposed upon themselves varied with speed and driving conditions (figure 5.3).

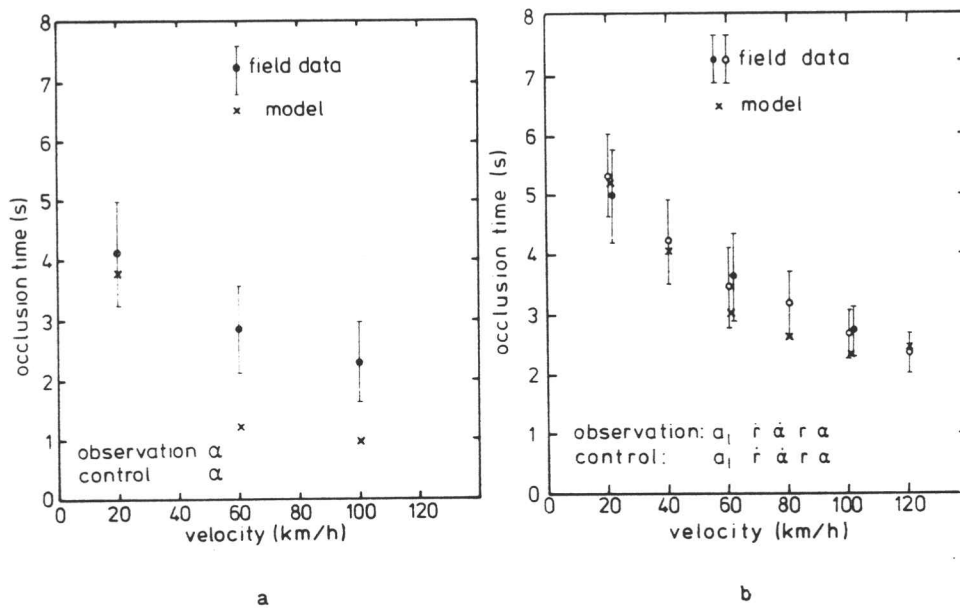


Figure 5.3: Mean occlusion times and standard deviations as a function of speed during the exclusive observation and control of lateral position for inexperienced drivers (figure a) and experienced drivers (figure b) (source: Blaauw, 1984)

Furthermore, Blaauw found, and this was confirmed by other studies, steering wheel reversal rates with dominant peaks in the frequency range of 0,1 - 0,3 Hz, indicating that drivers undertook a steering correction every 3,3 - 10 s and sometimes every 1,7 - 3,3 s (and thus had been watching the road ahead). However, it must be taken into

account that these values were registered during the performance of a tracking task only. Drivers did not have to carry out any tasks to watch the traffic and the environment and react on it.

More information on interpretation times and ways to reduce this time can be found in the next paragraph (7.3: the interpretation time for each of the visual route guiding pictogrammes).

5.2 Untimely presentation of route guiding advices

7.2: The reaction time on aural and visual route guiding messages

Most information on reaction times has been gathered from the extensive report by Triggs and Harris (1982). The most important conclusion that can be drawn from their works, is that there is no such thing as the basic reaction time of drivers on roads.

According to Triggs and Harris, the reaction time increases if

- the number of possible alternatives that can occur rises and the distinction between the alternatives decreases.
- the required accuracy of responses increases.
- the "depth of processing" involved (amount of cognitive processing) increases. For instance, purely physical changes in simple stimuli are coded faster than symbolic information. Symbolic or pictorial information is processed faster than verbal information, as long as the symbols used are highly familiar and legible.
- the association between input stimulus and response codes becomes smaller.
- the expectancy and preparatory processes decreases.

Added to this list can be the following circumstances, mentioned by Meyer (1978). The reaction time increases if:

- it is less distinct which reaction to a stimulus is the correct one.
- if a driver has less experience in a particular situation.
- the length of time between a forewarning and an event is less known.

Meyer further states that reaction times can be reduced by correctly used warning signals, although little is known on the desired duration, conspicuousness, and frequency of the warning signal.

Many values have been given for the actual length of reaction times, but small values should be treated carefully, because they are

usually the result of laboratory studies which are not always applicable in actual traffic situations.

Triggs and Harris explicitly distinguished values from laboratory studies, simulation studies, and in-vehicle studies.

The values found in the laboratory studies varied strongly (\pm 500-2200 ms), depending on the conditions (kind of stimulus, background distraction, and the like). The design response time standard of 2500 ms was found to be suitable.

In most of the simulation studies, subjects were required to brake after the presentation of an unexpected stimulus. The drivers' brake reaction times were found to vary from 500 to 1500 ms. These values are expected to be lower than in real life situations. Herefore are two reasons. First, the subjects only had to perform a simple stimulus-reaction task (in real life a driver has to perform many additional tasks and the required reaction on a stimulus is not always immediately clear). Second, the subjects were in an experimental setting and for that reason can be classified as having a reasonable level of alertness. Simple reaction times were found to increase reliably with age. Mean values of 438 ms were found for 15-19 year olds and 522 ms for 65-69 year olds.

In-vehicle measurements have been conducted both on closed tracks and on public roads. Often referred to in traffic accident and engineering literature are some early reaction time data reported by the Massachusetts Institute of Technology (M.I.T.) (1934). The reaction time when the driver responded to the brake lights of the leading vehicle was 640 ms on average, with 5% of the observations exceeding 1,0 s. A noteworthy result was that one driver in five had response times exceeding 1,0 s on occasion. The reaction times tended to be shorter for audible (warning) signals. Normann (1953) also found a 95% limit of the brake reaction times to be 1,0 s. However, his test subjects were alerted and young. Laurell and Lisper (1978) required subjects to react by pressing a switch on which their foot already rested. The mean reaction time to an auditory signal was 450 ms. This value increased after continuous driving over a long period. The increase was greatest for the inexperienced drivers.

The reaction times as presented above comprise of a time for the foot movement between accelerator and brake pedal. Mean movement times have been found of 149 ms for males and 194 ms for females for coplanar accelerator and brake pedals and 309 ms for brake pedals that are higher of the floor than accelerator pedals. The values were not significantly related to the lateral distance between the pedals. No data have been found to confirm or deny that reaction times are related to speed.

Several observations of real world driving have been conducted.

However, the results tend to be very much dependent on the measuring conditions: values varying from 479 to 4900 ms have been found. In spite of this the literature review did show that data obtained in unalerted conditions on rural roads yielded much higher reaction time values than the estimates from laboratory studies or when subjects were alerted.

To expand the range of relatively unalerted reaction time situations studied in rural or semi-rural environments, Triggs and Harris conducted some reaction time measurements themselves.

Stimuli were presented on suitable crests or in horizontal curves, on which the point of the road was identified where car drivers could first observe the stimulus provided, and on level crossings where red lights were actuated on the approach of a vehicle.

Stimuli presented to the drivers in the curve or on the crest were signs, police cars on the shoulder, vehicles with tyre change in progress protruding on the road, speed control through amphotometers, and car following (measuring brake response times to the brake lights appearing on the leading vehicle).

The results of the experiments show a great variation (figures 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10, tables 5.1, 5.2).

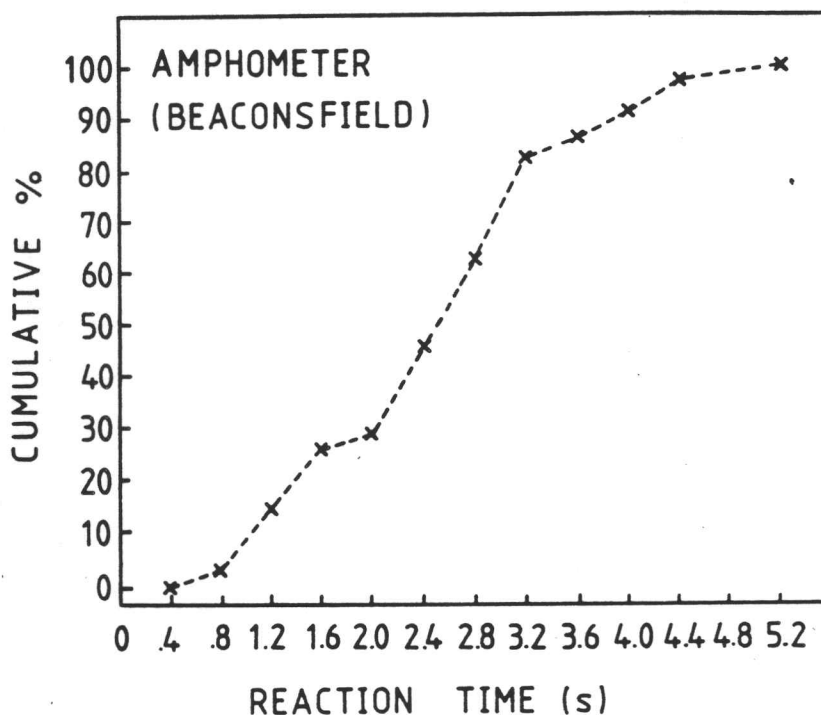


Figure 5.4: Amphometer braking response times at Beaconsfield site (n=35, mean=2.46 s, standard viation=1.04 s, skewness = +0.25); (source: Triggs and Harris, 1982)

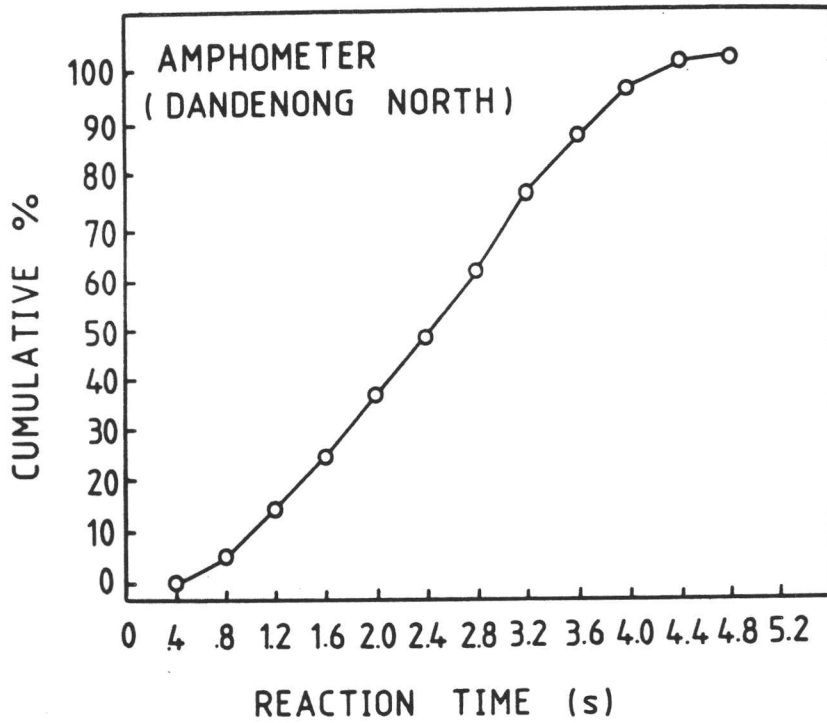


Figure 5.5: Amphometer braking response times at Dandenong North site (n=100, mean=2.45 s, standard deviation=0.92 s, skewness = -0.03); (source: Triggs and Harris, 1982)

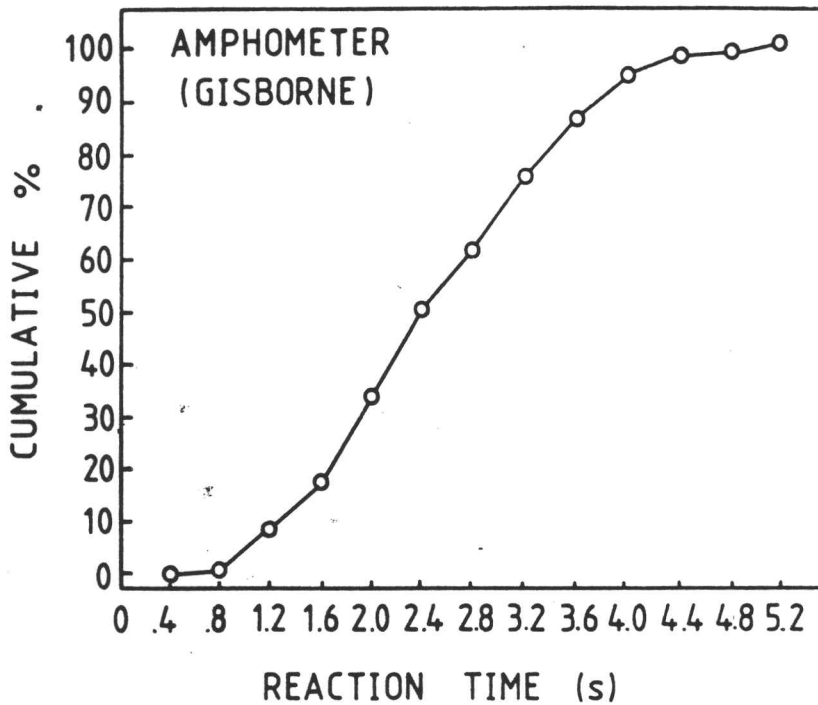


Figure 5.6: Amphometer braking response times at Gisborne site (n=85, mean=2.54 s, standard deviation=0.66 s, skewness = +0.34) (source: Triggs and Harris, 1982)

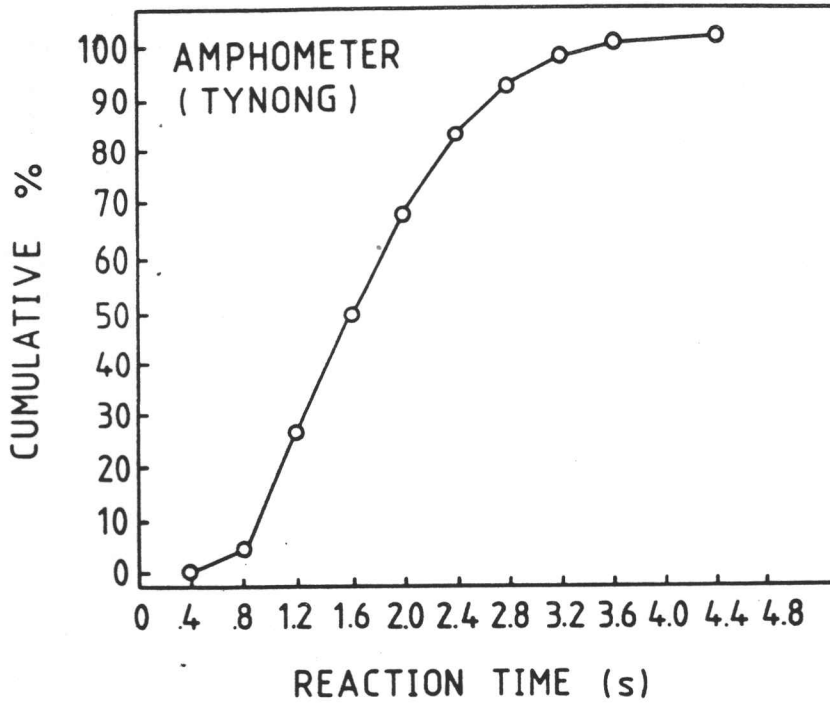


Figure 5.7: Amphometer braking response times at Tynong site (n=485, mean=1.75 s, standard deviation=0.70 s, skewness = +0.64) (source: Triggs and Harris, 1982)

Table 5.1: Amphometer reaction results (source: Triggs and Harris, 1982)

AMPHOMETER REACTION TIME RESULTS					
SITE	RESPONSE RATE	NUMBER OF RESPONSES	MEAN	STANDARD DEVIATION	SKEWNESS
Beaconsfield	30%	35	2.46s	1.04s	+0.250
Dandenong North	24%	100	2.45s	0.92s	-0.027
Gisborne	12%	85	2.54s	0.66s	+0.340
Tynong	31%	485	1.75s	0.70s	+0.637

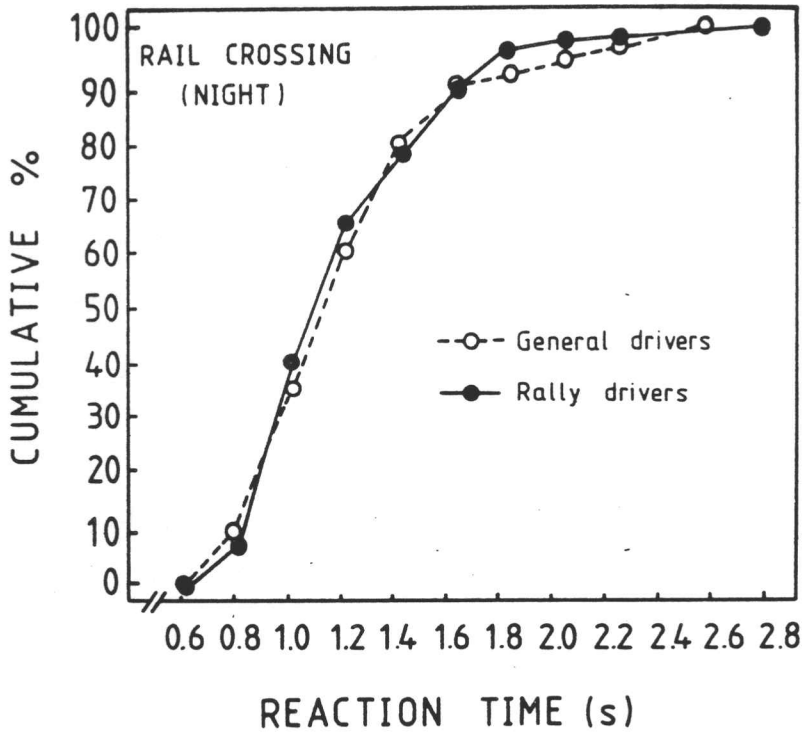


Figure 5.8: Cumulative reaction time distributions for railway level crossing signals for both the general driving population (n=171, mean=1.18 s, standard deviation=0.36 s, skewness = +1.36) and a rally driver group (n=91, mean=1.14 s, standard deviation=0.34 s, skewness= +1.80) (source: Triggs and Harris, 1982)

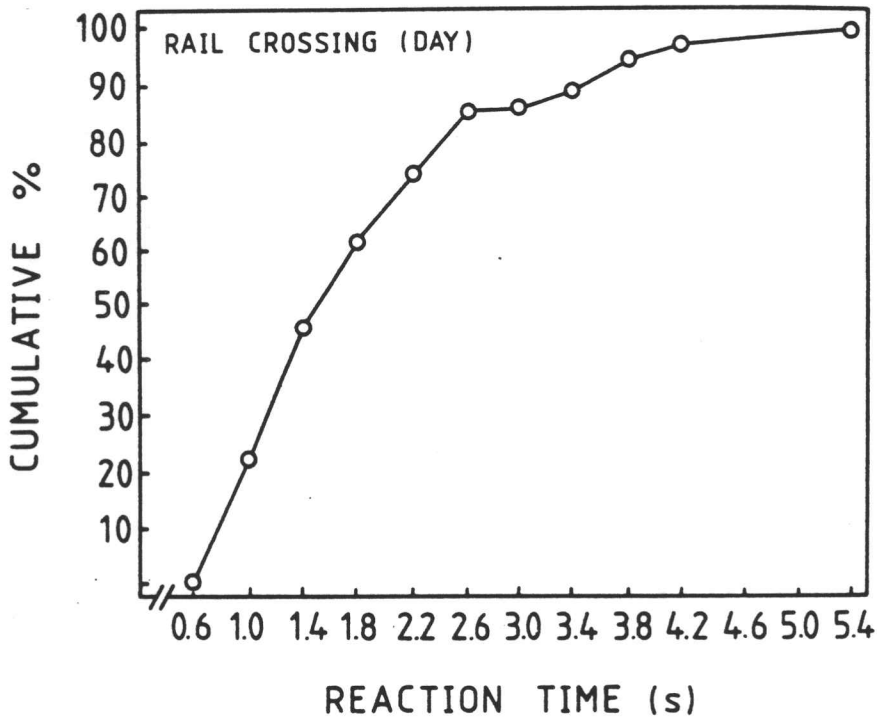


Figure 5.9: Cumulative reaction time distributions for railway level crossing signals during daytime for the general driving population (n=104, mean=1.77 s, standard deviation=0.84 s, skewness = +1.22); (source: Triggs and Harris)

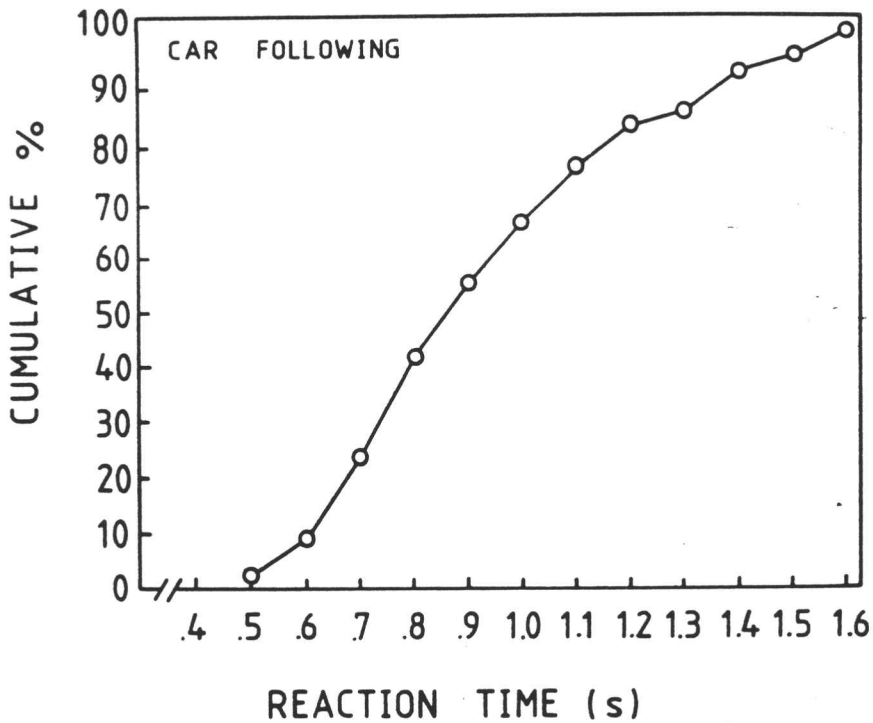


Figure 5.10: Cumulative reaction time distributions for brake light signals on leading vehicles when car following (n=42, mean=0.92 s, standard deviation = 0.28 s, skewness = +0.46)

Table 5.2: 85th percentile reaction time values (source: Triggs and Harris, 1982)

C.R.B. "Roadworks Ahead" Sign	3.0s
Protruding vehicle with tyre change	1.5s
Lit vehicle under repair at night	1.5s
Parked Police Vehicle	2.8s
Amphometer : Beaconsfield	3.4s
Amphometer : Dandenong North	3.6s
Amphometer : Gisborne	3.6s
Amphometer : Tynong	2.54s
Railway crossing : Night (General Population)	1.50s
Railway crossing : Night (Rally drivers)	1.50s
Railway crossing : Day	2.53s
Car following	1.26s

The response time greatly depends on the type of situation, the degree of urgency, and the speed of the vehicle. In more urgent responding situations, most unalerted drivers have shown themselves capable of responding in less than 2,5 s. An increase in response time can reliably be predicted for situations where the critical stimulus is not as discriminable, more complex in structure, or

requires a greater change in cognitive set in order to be responded to.

Driver response times can be expected to frequently exceed the commonly accepted design value of 2,5 s. Excluding the car following, seven of eleven situations produced 85th percentile values above 2,5 s (table 5.2), and four of these had values of 3,0 s or more.

Discriminability of a stimulus played an important role in the recorded reaction times. During the day, the reaction times to flashing railway signals were approximately 50% higher than at night (statistically significant).

The effects of vehicle speed are demonstrated by the amphoter speed control and railway-crossing data. Overall, drivers of higher speed vehicles responded faster than those at lower speed. This effect may not have been due to greater alertness levels only. Faster drivers may have adopted a different criterion for the urgency of braking required. Differences of up to 500 ms were found in the study.

Urgency of the response situation has been found associated with the response time.

The brake reaction times that were mentioned in the reports of Berkvens (1976) and Leijns, Meiland, and Klein Báltink (1979) are not different from the values found by Triggs and Harris.

Gatling (1975) found mean reaction times of 5.76, 5.76 and 5.58 s for the low urgency task to tune into a radio station after the presentation of three different alerting signs located alongside the road.

7.3: The interpretation time for each of the route guiding pictogrammes

Of course no information could be gathered on the actual interpretation times of the Carin route guiding pictogrammes, but much information was received on ways of reducing the interpretation times through an adequate styling method.

General information on search times was received through Carter's report (1979) on the effects of color coding, target class size, target position, and number of background items. In a laboratory test subjects were to identify a target name in number of names on a display.

It was found that search time was reduced by more than 90% when color coding with target class size was used on displays with density 60, compared with the time to search the same displays without color (Table 5.3).

Table 5.3: Effects of target class size and display density
(source: Carter, 1979)

display density	target class size			black & white
	1	10	30	
30	0.97 ^a	2.33	4.82	5.6
60	1.02	2.81	5.66	11.62

^a Mean search time in seconds, n=648

In table 5.3 it can be read that search times are also related to the density, due to the number of background items (density minus target class size).

In a second experiment it turned out that the mean search times were completely unaffected by the number of background items when their color was of high contrast with the target color. However, background items produced a considerable effect when their color was similar to the color of the target.

The position of the target colored items did affect search time. When the target was in a pattern, it was found in about the same amount of time as required on a random display. When the target was out of the pattern it was found faster.

A number of reports discussed the time necessary for reading a list of names or recognizing one particular name in a list.

Although reading a message requires a greater amount of cognitive processing, the general conclusions of these reports may nevertheless be applied to the interpretation of pictogrammes as both are concerned with the retrieval of information from a display.






It was found by Dudek (1979) that reading time of a display is affected by the driver's task load, message load, message length, message familiarity, and display format.






Drivers who have seen a message often will more than likely tend to gloss over familiar elements of the message and concentrate on that part of the message that changes from one situation to another, whereas unfamiliar drivers must read the entire message.

Jacobs and Cole (1978) researched the searching time for a target name in a list of names. They found that the length of a word and the word position were important factors in search time. Words of intermediate length were found less fast than short or long words. A location of the target word in the fourth position of a nine name stack produced the greatest probability of identification. Words at

the top of the stack were identified sooner than words at the bottom.

The interpretation time for traffic information on variable matrix displays, has been tested by Easterby, Cox, and Hughes (1977). In laboratory tests with a simulated driving task response times on the presentation of symbols were tested. It turned out that the differences were small and probably not attributable to any perceptual features of the symbol (figure 5.11), but depend more on aspects of response modality used in each of the studies.

SYMBOL	SLIPPERY ROAD	SHED LOAD	QUEUE	2 WAY TRAFFIC	WIND
RESPONSE TYPE					
Verbal response time. (Secs)	2.03	2.26	2.52	1.90	1.95
Behavioural response time (Secs)	3.94	3.36	3.97	3.67	3.38

SYMBOL	REDUCED VISIBILITY	ACCIDENT	ANIMALS	FLOOD	BREAK-DOWN
RESPONSE TYPE					
Verbal response time. (Secs)	2.62	1.86	1.85	2.49	2.19
Behavioural response time (Secs)	5.41	4.33	3.99	4.85	3.95

5 Subjects
5 Replications

No significant differences

Figure 5.11: Simulated driving task: mean response times (source: Easterby, Cox, and Hughes, 1977)

The interpretation of symbolic route guiding information has been discussed by Jansen (1979) and Erke, Richter, and Richter (1974). Jansen conducted a literature study on route planning and guiding.

The main conclusions he drew from investigations in the United States are the following:

1. Route guiding pictures should not be applied for the representation of complex situations. The impression exists that pictures can be used when unexpected manoeuvres are required, on condition that the pictures are simple.

An important study on this subject was carried out by Eberhard and Berger (1972) who compared five route guiding configurations, among which three with pictures (figure 5.12, table 5.4).


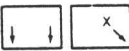
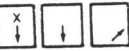

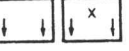
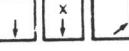


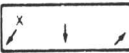
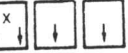
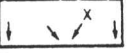





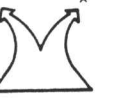













Systeem:	SOORT KONFIGURATIE:					
	Collect./distr.	Direkt opeenvolgende keuzepunten	Linker afrit	Multipiele afritten	Vork	Klaverblad
Konventioneel						
Aangepast konventioneel						
Perspektivisch						
Vogelvlucht						
'Performance' gericht						

Figure 5.12: Route guiding configurations and road situations used by Eberhard and Berger (1972).

Table 5.4: Percentage of correct lane choice as a function of different route guiding configurations and road situations

Systeem	Soort configuratie:					
	Collect. distr.	Direkt opvolgende keuzepunten	Linker afrit	Multiple afritten	Vork	Klaverblad
Konventioneel	-*	88	86	88	82	-*
Aangepast konventioneel	54	94	96	88	72	78
Perspektivisch	50	98	86	78	88	50
Vogelvlucht	70	96	96	82	92	54
"Performance"-gericht	49	92	94	82	92	64

* Gegevens verwijderd omdat de betreffende borden niet exakt aan de konventionele standaard voldeden.

Especially in complex situations like the cloverleaf and the multi-gore the guiding with pictures turned out to be less succesfull than the conventional way of route guiding.

The results of Eberhard and Berger are supported by those of Mast and Kolsrud (1972): very complex junctions are faced with the impossibility to design a picture that is both simple and an exact representation of the geometry; most advantage of route guiding pictures is to be gained at left exits.

2. Drivers need more time to understand route guiding pictures than conventional signs. Besides, the time necessary to "read" the pictures becomes larger more than linear with the complexity of the picture.
3. Pictures can sometimes give usefull additional information on the geometric situation.
4. Out of the investigations, four conclusions can be formulated:
 - The pictures must give only that information that the drivers need to be able to execute a manoeuvre.
 - The amount of information given by a picture should not be too great.
 - The components of the picture should form one figure.
 - The most important road should be accentuated visually.

Erke, Richter, and Richter tested styling methods for direction signs (figure 5.13).

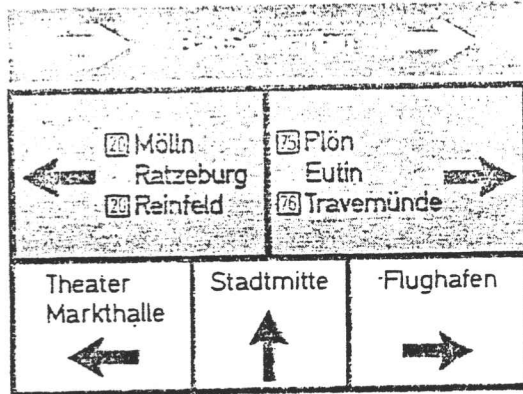


Figure 5.13: Tested direction sign style (source: Erke, Richter, and Richter)

The results showed that the interpretation times for the direction signs in the style of figure 5.13 varied from 3-5 s, which was thought much too high in heavy traffic. The representation of the lanes was difficult to understand for the drivers.

It turned out that stylised direction signs needed a shorter interpretation time than quasi-geografic ones, that separation of color coded names from the remaining names only leads to shorter interpretation times with preinformed test subjects, and that vertical separation is better than horizontal separation. Both the direction signs of figure 5.14 turned out to be favourable.

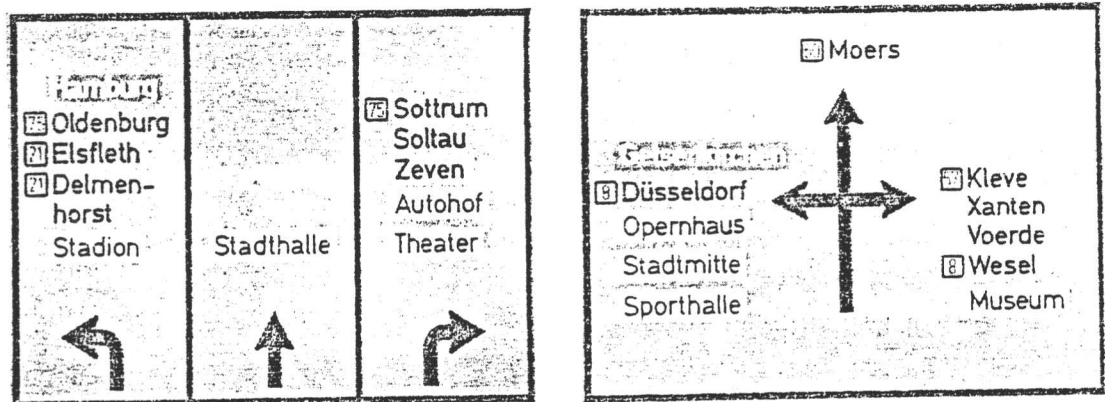


Figure 5.14: Favourable direction signs.

The direction sign of figure 5.15 turned out to be less favourable for a quick interpretation. Besides, this configuration turned out to provoke interpretation failures.

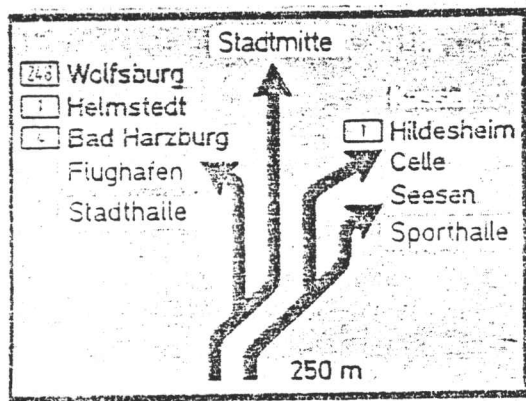


Figure 5.15: Less favourable direction sign

In general it was found that an explanation on the configuration style improves the interpretation of the test subjects and enables a better differentiation of the configuration styles.

7.4: The time that is needed to execute a necessary action

On the time that is needed to execute a necessary action, little information has been found. This is probably due to the character of the actions, which is still comfortable and gradual; more interesting are generally extreme situations in which emergency braking or swerving is necessary.

Most information that was received had a general character. It was put forward by Dudek (1979), that routing and lane assignment must be given in ample time for drivers to respond to instructions. Lane assignments must be made far in advance of the turning point and far enough upstream of any possible traffic queues. This means that under heavy traffic conditions, the lane assignment information must be given far away from the turning point as compared to light flow conditions.

The time to move the foot from accelerator pedal to brake pedal can be fixed at 300 ms, which is the maximum mean movement time as found by Triggs and Harris. The actual value of the movement time is of no importance however, as this value was already subtracted from the reaction time on visual messages.

7.5: The chances that aural route guiding advices are forgotten

In the United States a number of studies have been carried out on message retention in the framework of experiments with Highway

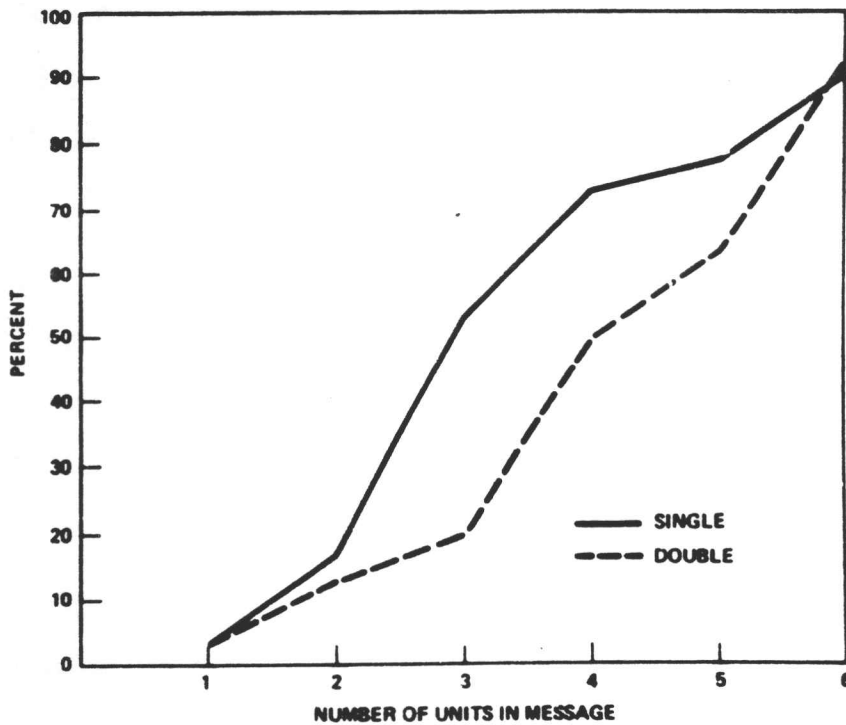


Figure 5.16: Percent of subjects making a route error as a function of message length (source: Gatling, 1975)

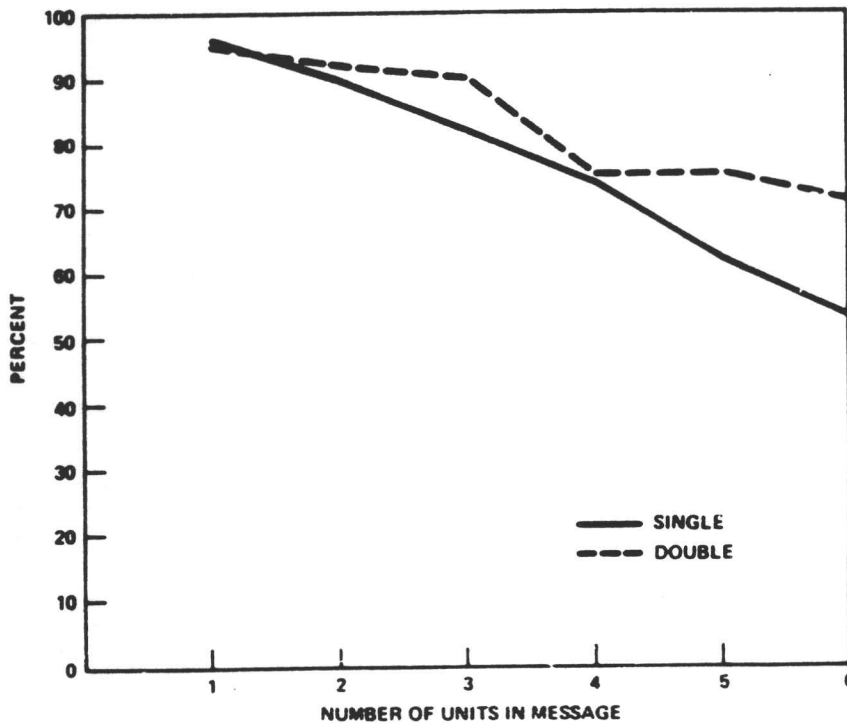


Figure 5.17: Percent of message retention as a function of message length and number of repetitions (source: Gatling, 1975)

It can be noticed that Gatling's retention rates are much lower than those found by Dudek, Huchingson, and Stockton. This may partly be

caused by the differences in retention method. Gatling's figures are based on unaided recall, whereas the retention rates of Dudek c.s. were based on the ability of subjects to actually drive a presented detour route.

Therefore Gatling conducted a second experiment in which the retention of the messages was tested through slides that were projected in front of the subjects. Some of the slides contained a unit of information that was mentioned in the auditory message and the others did not. The subjects were to state of each slide whether it contained some of the aural information. Throughout the experiments the subjects drove on the right lane of a highway. The results of the experiments are displayed in the figures 5.18 and 5.19.

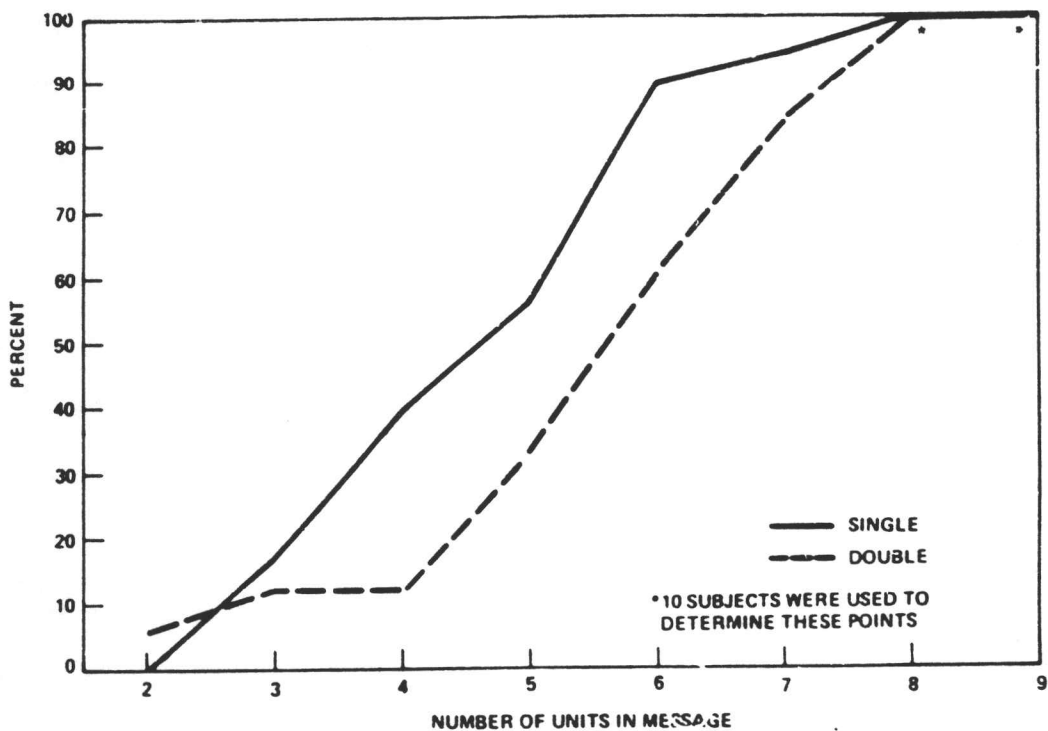


Figure 5.18: Percent of subjects making a route error as a function of message length (source: Gatling, 1975)

In comparison with the figures 5.16 and 5.17, it can be seen that the retention was indeed better than in the first experiment, although still much lower than the figures of Dudek c.s.

This may be explained by differences in the methods. Gatling tested the recollection of distances and route and exit numbers on subjects that had not been given an itinerary, whereas Huchingson c.s. tested the retention of street names on subjects that knew their route.

This positive effect on retention rate of knowledge of the itinerary is confirmed by experiments of Wagenaar en Visser (Labiale, 1984). They found that on average subjects recollected 3.2 units of information without itinerary against 7.5 with route plan.

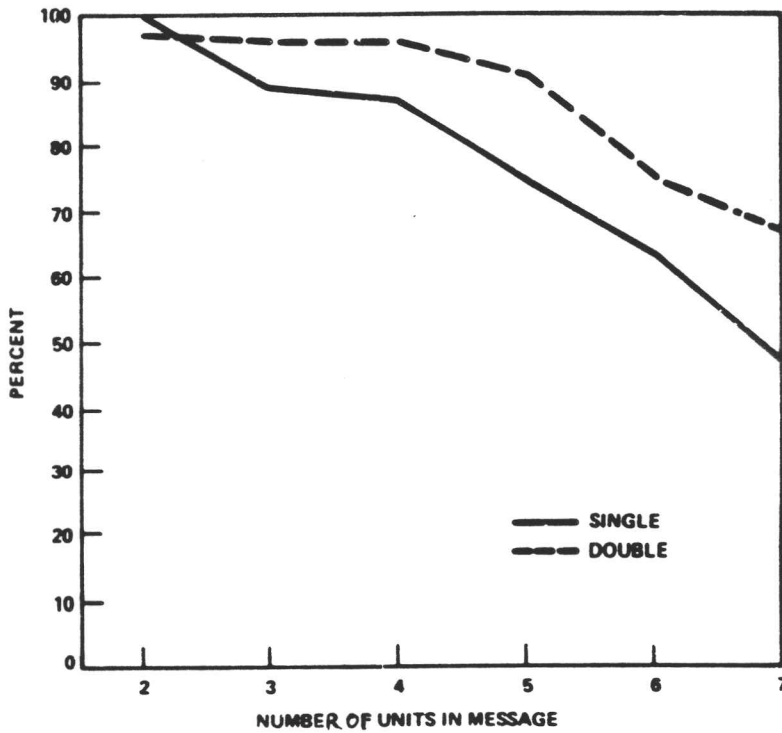


Figure 5.19: Percent of message retention as a function of message length and number of repetitions (source: Gatling)

The age of the subjects was of influence on the recall rate also. From the results of Gatling's experiments (see figure 5.20) and from previous literature, it is likely that older drivers will demonstrate significantly less retention of auditory messages than younger drivers.

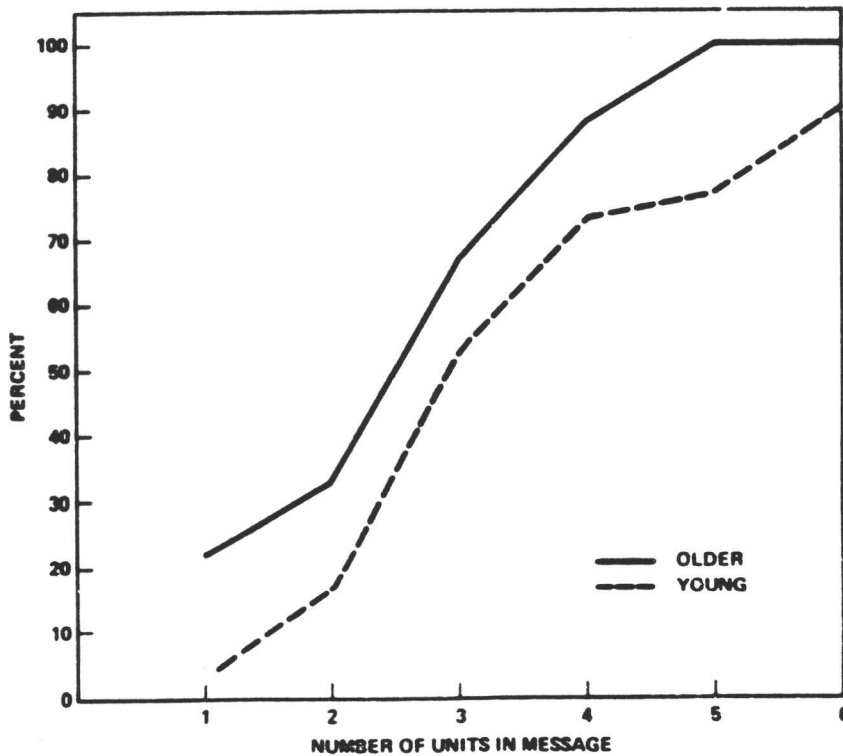


Figure 5.20: Percent of subjects making a route error as a function of message length and number of repetitions. -Older vs. young; single presentations. (source: Gatling, 1975)

The influence of the contents of a message was tested by Gatling also.

36 Test subjects were presented two long auditory messages (10 units of information). The first message contained five route and exit numbers and the second message only one. The results showed that the information with few numbers was retained far better than the information with many numbers. On average 7.2 units of information were retained from the message with one route and exit number against 4.1 from the message with five numbers.

Wagenaar and Visser (Labiale, 1984) found similar results.

5.3 Avoiding unsafe locations and situations

11.1: The possibility to use traffic safety criteria /

11.3: The unsafety of certain roads, locations, manoeuvres, and situations

The traffic safety in the county of Noord-Brabant in the Netherlands has been the subject of an extensive study by the Dutch Institute for Traffic Safety Research SWOV, that was started in the mid seventies and lasted about 10 years. The aim of the research was, besides to reduce traffic unsafety on short notice, to find relations between road, traffic, and accident characteristics for the long term planning. The research was carried out on all roads outside residential areas.

Out of a series of 10 reports on this research, 4 have been selected for this literature study (Hoek, Oei & Poppe, 1981; Poppe & Oei, 1984; Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV, 1984-1 & 1984-2).

In general, the results of the analyses can be summarized along two main lines: the complexity of a traffic situation and the expectancy or attention level of traffic participants. The effects of complexity were most evident at the traffic flow characteristics.

Out of the research, it followed that the traffic should be concentrated as much as possible on roads with high traffic flows and abandoned from roads with little traffic. Traffic safety measures should be different for different roads. On roads with high traffic flows, continuity of road and traffic characteristics should be paid priority to. Disturbances should be avoided as much as possible and junctions should be alike. On quiet roads the effects of continuity were less prominent and there measures for raising attention levels

were likely to have more effect.

The analyses of junctions indicated that many accidents happened on larger junctions with traffic lights and with many potential conflict points. Crossroads were more unsafe than T-junctions, which was explained through the greater number of possible conflict points. The characteristic "presence of traffic lights" turned out to be dominating.

On junctions without traffic lights the traffic flows turned out to have different effects on T-junctions than on crossroads. On T-junctions accidents had happened at high motor vehicle flows in the main direction and high motor vehicle flows in the minor direction. On crossroads a high number of accidents was accompanied by a high motor vehicle flow in the main direction, but a low motor vehicle flow in the minor direction, and a high flow of cyclists and moped riders in the minor direction.

For each of the road types and junction types without traffic lights, the analyses yielded the following data.

Roads prohibited for slow traffic, cyclists and moped riders

Characteristics that were found to be related to a high accident rate per km are:

- a high median motor vehicle flow
- the presence of public lighting along a main part of the stretch, although accidents at night, dusk or dawn took place mainly at roads without public lighting
- a small median distance between obstacles
- a great variance of the motor vehicle flow
- many succeeding junctions with and without left and right exit lanes
- a high road category
- a small pavement width
- many small junctions.

Roads accessible for all traffic

On roads for all traffic many accidents took place in situations with:

- a high median motor vehicle flow
- light traffic flows on crossing roads
- a small median distance between all crossing or merging places
- the presence of public lighting along a main part of the stretch, although accidents at night, dusk, or dawn frequently occurred when there was no public lighting
- a high cycle and moped flow
- a high road category

- a main part of the stretch with concrete pavement
- locations with brick pavement
- a relative long part of the stretch with two lanes
- many succeeding junctions with and without left exit lanes
- many smaller junctions that are hardly visible
- small curve radii

The influence of the sight distance is ambiguous. In general it was found that lesser sight distances and a small number of divisions into halves of the sight distance were related to a high accident rate per km.

However, head-tail accidents and head-side accidents frequently occurred on roads with heavy traffic flows and good sight distances.

Single-carriageway "autowegen"

As a result of the few single-carriageway "autowegen", the results were not always very clear.

The accidents mainly happened at locations that were less good than the other parts of the same road: in curves, at overtaking prohibitions, at speed limits, and at small sight distances.

Head-side accidents may happen at small sight distances on smaller junctions.

Accidents at night, dusk, and dawn did not happen especially at locations without public lighting, but did happen at heavy traffic flows during dawn or dusk.

Dual-carriageway roads

In general, accidents on dual-carriageway roads were not concentrated on a few locations, but rather spread out. They mainly happened at locations where a change in the homogeneous road characteristics took place: at bad sight distances, at overtaking prohibitions and in curves.

Safe curve radii on motorways should have lengths of 1500-3000 m. On "autowegen" the safe lengths should be greater than 1000 m.

The absence of crash barriers in the central reservation was related to fatal accidents, especially at locations with good sight distances but the absence of public lighting.

Head-side accidents mainly occurred at smaller junctions.

Head-tail accidents were mainly related to congestions.

Roads with less than 4000 motor vehicles per day

The most important characteristics that were related to a high accident rate per km are:

- a high median motor vehicle flow (within the category below 4000 per day)
- the presence of public lighting on a main part of the stretch

- a main part of the stretch with obstacles on less than 1,5 m from the pavement
- many lanes accessible for all traffic
- a main part of the stretch with two lanes
- a high road category
- a great variance of the motor vehicle flow
- a small median distance between obstacles

Roads with motor vehicle flows between 4000 and 8000 per day

The accident-related characteristics on roads with intermediate traffic flows are the following:

- a small median distance between all crossing or merging places
- many succeeding junctions with and without traffic lights
- the presence of public lighting along a main part of the stretch
- a small number of lanes for all traffic
- a low motor vehicle flow (within the category 4000-8000 per day)

Roads with median traffic flows of over 8000 motor vehicles per day

Many accidents on roads with high traffic flows are related to:

- many major junctions with a right of way
- many lanes prohibited for slow traffic, cyclists, and moped riders
- a great part of the stretch belonging to a junction
- many succeeding junctions with and without left and right exit lanes
- many junctions with traffic lights

Junctions: vehicles from the same road

Most accidents in which only vehicles from one of the joining roads were involved, are head-tail accidents. Important for these accidents are a great road width, the absence of exit lanes, a wide central reservation, (10 m) and no special arrangements for the right of way.

Junctions: vehicles from two roads at right angles to each other

Distinction was made between crossroads and T-junctions.

On crossroads accidents turned out to be related to:

- great widths of the central reservation (15 m)
- a great width of the right road
- a physical separation of the carrieways of the right road
- a bicycle path along the left road that crosses the right road separately
- an exit lane for turning left on the right road

On T-junctions the most important characteristics that were related to accidents are the following:

- a great width of the left road

- the presence of merging lanes on the left road
- obstacles on the central reservation
- a bad sight distance from the right road on the left one

Junctions: vehicles on roads that are in a direct line with each other

Most of the accidents of vehicles on two roads that are in a direct line with each other consisted of a vehicle driving straight ahead and an oncoming vehicle turning left.

On crossroads the following characteristics played a role:

- a high traffic flow on the south-west road
- obstacles along the left side of the north-east road
- obstacles along the left side of the south-west road
- a good sight distance on both roads from 200 m before the junction

On T-junctions accidents were related to:

- a bad sight on the traffic driving straight ahead
- high traffic flows

Janssen (S.T.M.C, 1985) has followed a different method to determine the safety of roads. He stated that on the basis of the present knowledge on traffic safety, it is (yet) not possible to give traffic safety indicator numbers for any combination of all characteristics and circumstances. Therefore, he made a less detailed distinction. With the absence of more accurate data, the distinction has been made on the basis of road characteristics. Roads were distributed among seven classes outside residential areas and two within.

With the available data and budget, accidents could only be distinguished into two groups:

1. accidents with casualties in which only motor vehicles were involved
2. accidents with casualties in which at least one non-motor vehicle was involved

Traffic flow numbers were only available for motor vehicles on the studied roads. Traffic flows of non-motor vehicles or of crossing vehicles were not known.

The indicator numbers that were determined are based on the average number of accidents with casualties per vehiclekilometre driven on road sections and per junction. It turned out to be hardly possible to relate the accident number to traffic flows. Only for road sections on motorways, moderately useful functions have been determined.

The indicator numbers for the estimation of accidents have been

displayed in table 5.5.

For the estimation of the casualties and deaths also indicator numbers have been determined, which are shown in table 5.6.

Table 5.5: Indicator numbers for the estimation of accidents with casualties; Source: Janssen, 1985

Kencijfers voor de schatting van het aantal letselongevallen					
		voor wegvakken	per kruisingen per jaar		
		per miljoen gere-	totaal	ongevals-	ongevals-
		den motorvoertuig-		groep 1	groep 2
		kilometers			
<u>autosnelweg</u>					
2 x 2 rijstroken	<i>f</i> 1 *		0,82	0,54	0,29
2 x 3/4 rijstroken	<i>f</i> 2 **		1,03	0,92	0,11
<u>autoweg bubeko</u>					
1 x 2 rijstroken		0,08	0,70	0,54	0,15
2 x 2 rijstroken		0,04	1,27	0,81	0,46
<u>gesloten verklaring bubeko</u>					
1 x 2 rijstroken		0,25	0,36	0,24	0,12
2 x 2 rijstroken		0,08	0,68	0,39	0,29
<u>overige weg bibeko</u>	***	0,37	-	-	-
<u>verkeersaders bibeko</u>	***	1,79	-	-	-

* $f 1 = 1,12 \times I^{0,34} \cdot 10^{-3}$; bij $I = 40.000$ motorvoertuigen per dag

$f 1 = 0,040$

** $f 2 = 1,09 \times I^{0,31} \cdot 10^{-3}$; bij $I = 80.000$ motorvoertuigen per dag

$f 2 = 0,035$

*** inclusief kruisingen

Table 5.6: Indicator numbers for the estimation of the number of casualties (deaths and injured); Source: Janssen, 1985

Kencijfers voor de schatting van het aantal slachtoffers						
	aantal slachtoffers			verhoudingsgetal doden		
	per letselongeval			per slachtoffer		
	wegvak	kruising	ongevalsgroep	wegvak	kruising	ongevalsgroep
	1	2		1	2	
<u>autosnelweg</u>						
2 x 2 rijstroken	1,44	1,41	1,04	0,06	0,02	0,03
2 x 3/4 rijstroken	1,46	1,45	1,00	0,05	0,03	0,03
<u>autoweg bubeko</u>						
1 x 2 rijstroken	1,70	1,55	1,08	0,11	0,05	0,17
2 x 2 rijstroken	1,17	1,51	1,00	0,07	0,01	0,17
<u>Gesloten verklaring bubeko</u>						
1 x 2 rijstroken	1,42	1,61	1,08	0,06	0,03	0,08
2 x 2 rijstroken	1,22	1,55	1,02	0,06	0,05	0,07
overige weg bubeko *	1,37	-	-	0,07	-	-
verkeersaders bibeko *	1,13	-	-	0,02	-	-

* inclusief kruisingen

11.4: The dangerous road situations a driver should be warned off

According to Wouters (1985), at the level of traffic behaviour, electronics could help the authorities to distribute and guide traffic flows and detect hazards (traffic control) and to help individual road users through information on routes, recommended speeds, the state of the road surface and so on (assisting road users).

Often the incorporation of electronics causes some problems. Herefore are three reasons. First, input data can not always be measured sufficiently reliable.

Second, for data processing, which includes a good weighing and decision making, a thorough knowledge is required of the traffic and the way in which intelligent systems transform input into output. Furthermore, in order to avoid incorrect decisions, allowance has to

be made for exceptions.

Third, the output has to be processed in some form for further use. If the user is human, allowance has to be made for the specific problems humans have when processing information: problems of capacity, of discrimination and interpretation and of motivation.

Problems of capacity

The human brain has only limited capacity available for data processing, thus humans are inclined to choose all sorts of suboptimal solutions. This can be overcome by representing the problem in the optimum way and applying a suitable but complex decision rule.

Problems of discrimination and interpretation

Perceptual quantities which hardly differ can cause problems of discrimination. If the information is relevant to several traffic processes, a problem of interpretation can occur.

Problems of motivation

Information which is not confirmed by the user's experience can result in the road user ceasing to obey instructions and recommendations. Distinction must be made between tasks performed consciously and tasks performed perceptually-motorically. In the latter case, information designed for consciously processing makes less sense.

6. SUMMARY AND DISCUSSION

In chapter 3 the traffic safety of the Carin car information and navigation system has been analysed with the phase model of the transport and traffic unsafety process.

This analysis has brought forth a number of possible effects on traffic safety, both positive and negative. Further study turned out to be necessary on a part of the found possible positive and negative effects. This was started with a literature study.

In this chapter will be discussed what information has been received until now on each of the possible effects, what consequences this has for (the traffic safety of) the Carin system, and what information has yet to be gathered. Also will priorities be given on the sequence in which further investigation should preferably be carried out.

1. Change in modal split

The presence of a Carin system could provoke a change in modal split from public transport to cars. The effects of such a change are difficult to predict. On one hand, the traffic risks for occupants of a means of public transportation are smaller than those of car occupants. On the other hand, the pre- and after-transport to come to and from stopping places bring about greater risks than car driving. It is likely that the total effects of in change in modal split will be small, as the positive and negative effects may, under the present traffic circumstances, well neutralize each other.

It is probable that the changes in modal split as a result of the installation of a Carin system in cars, will be small. For many buyers of the system will be drivers who already make many vehicle-kilometres yearly, or transportation firms, car rental agencies, and public services who can not choose a means of transport, but have to use cars and trucks anyway.

This subject should certainly not be given a high priority, as both the investigation on the extent of a change in modal split as the investigation on the traffic safety effects of such a change will be time consuming and the total effect on traffic safety probably will be very small.

2. Estimating travel time

An underestimation of the travel time by the driver, may lead to hurrying when the driver notices his error. This has negative effects on traffic safety, because hurried drivers tend to travel at higher speeds and to take more risks.

In two ways the presence of a Carin system may influence the correct estimation of travel time. The first effect is a positive one:

through Carin search behaviour and therewith search time can be avoided. This will eliminate the hurrying of a driver after a search has taken too much time.

The second effect influences traffic safety negatively. Drivers with a Carin system will be inclined to inform themselves less on their itinerary than drivers without Carin and thus will be less able to estimate their travel time correctly.

It can be considered to search for ways to present correct estimations for the travel time, not based on road classification only.

An adequate intermediate solution will be to present not solely the travel distance, but also the road types on which the route will be driven. Thus the estimated travel time can be based on more data and will therefore be more accurate as the driver can account for road situations and personal preferences.

To come to a correct, reliable estimation of the travel time will cost much time. Not only would the number of road classes probably have to be increased, also would measurements have to be made of the speed that can be driven on each road class in each country in which the system will operate. Furthermore, accountance would have to be made for personal preferences and driving styles.

3. Disc changing while driving

Changing compact discs while driving may under circumstances endanger traffic safety and should therefore be made impossible. Drivers first should have to bring their vehicle to a stop before searching for a new disc and inserting the correct disc into the drive.

4. Distraction by route guiding advices

A driver has the task to keep course, account for other traffic and the traffic environment, and react timely and adequately.

A driver with a Carin system may be distracted from this driving task by the presentation of aural and/or visual route guiding advices.

From the literature it follows that aural information distracts drivers less than visual information. Although it is questionable whether all testing conditions were sufficiently representative for the driving task, they are nevertheless usefull in pointing out that the workload for processing visual information is considerably heavier than for processing the same information presented aurally. Therefore, the original intention to have aural route guiding information serve as primary information source in the Carin system and the visual information only as a support, seems justifiable from a traffic safety point of view.

Thus, it is important that in the Carin system the visual messages stay only a secondary information source for cases in which the aural information does not suffice (completely). Therefore, the presentation of visual route guiding messages has to meet two conditions.

Firstly, visual messages should not be shown on the flat panel display without an accompanying aural route guiding advice. Any aural route guiding advice, how incomplete, is better than no aural advice at all.

Secondly, visual messages should not be presented before or simultaneously with the accompanying aural route advice. Drivers should not be given a choice of information source.

Distraction by aural route guiding advices

Although aural route guiding information is less distracting than visual information, no proof was found for a total absence of distraction by aural messages. On the contrary: the literature reports of several cases in which the presentation of aural messages did distract drivers, depending on the messages and the circumstances.

The amount of cognitive processing required is very, if not most important for the extent of distraction: with an increase of the complexity of auditory messages, both peripheral vision and tracking accuracy deteriorate. Thus it will be essential that the Carin auditory route guiding advices transmitted to drivers require very little thought or interpretation by the driver before it can be acted upon. The momentarily considered advices (like "take the first turning left", "take the third exit at roundabout") seem well appropriate.

The age and sex of drivers may play a role also. In a study on car radios, females declared to be sooner distracted than males and elderly males sooner than young males. It must be considered however, that these results are not directly applicable to route information messages, as even the spoken word on car radios is not identical with the presentation of an aural route guiding advice and the results were gathered by asking subjects their own opinion.

Furthermore, tonal aspects of the voice synthesizer may also be of influence on the amount of distraction caused by the aural information.

The volume level for the aural route guiding advices should preferably be controlled both by the driver and automatically: the driver adjusts a particular signal to background noise ratio that then is automatically sustained by the system.

When selecting subjects for a follow-up study, the distraction caused by aural route guiding advices should not be given prime priority.

For it is to be expected that the distraction will be small, as there will be little cognitive processing required to interpret the relative simple aural route guiding advices.

Distraction by visual route guiding advices

In the Carin system the visual route guiding advices will be presented through simple pictogrammes on a flat panel display. The lumination of this display has to be sufficient for the driver to see the pictogrammes in the daylight and yet must not blind the driver at night or when driving in a tunnel. This requires a variable lumination pattern, controlled by a photo-electric cell.

It is to be expected that the extent of distraction by visual route guiding advices is related to the amount of cognitive processing required. However, no confirmation or denial of this hypothesis has been found in the literature.

It is striking that in the studied literature hardly any relation has been placed between the task of the driver and the distraction from this task. In most reports it is im- or explicitly posed that driving is a mainly visual task and that thus the time that is spent on any additional visual tasks has to be minimised.

The only conclusion that can be drawn from the literature review is that under circumstances, the presentation of visual route guiding information may cause deteriorations of the driving task. On the variables that influence this distraction hardly any information is presented.

The remaining reports occasionally mention maximum times in which a route guiding message should be able to be interpreted. Usually values of 1-2 s are mentioned but not explained. It must be noticed however that these maximum interpretation times are not related to (a deterioration of) the driver task.

Overlooking the minimal results of the literature study on the distraction of drivers by visual route guiding information and considering the importance of this subject (regarding the possible consequences on traffic safety of drivers distracted by Carin route guiding pictogrammes), it is recommended to give this subject prime priority in a next study.

5. Avoidance of search behaviour

One of the main positive effects of Carin will be the avoidance of search behaviour. Especially under difficult traffic conditions this effect of the Carin system will increase traffic safety enormously.

6. Avoidance of detours

With the presence of a Carin system, any unnecessary detours will be avoided and therewith the travel distances limited. As participating in traffic brings about certain risks, it is evident that if Carin brings about a limitation of the travel distance, this contributes positively to traffic safety.

7. Untimely presentation of route guiding advices

The Carin route guiding advices should be presented well before a junction, roudabout, exit road, etc. in order to give the driver enough time to execute whatever action is necessary.

Sometimes (e.g. on a motorway), it will be preferable to present route guiding information at a certain distance before a junction, c.q. before the first sign posting.

Mostly this condition means that after the start of a Carin aural route guiding advice there has to be time for the aural advice to be spoken and for the driver to react, to possibly interpret a route guiding pictogramme, to react again, and to execute the necessary action. Each of these time periods are discussed in the following.

Speaking times for aural route guiding advices

The time that is necessary for the aural route guiding advice to be spoken, depends on the actual advices. In this phase of the study no values can be given yet. It will be essential though that the speaking times are measured and accounted for in the calculation of the presentation time of the route advice.

A choice can be made whether for each particular Carin route advice a calculation is made with the actual speaking time of that route advice or whether for all route advices a calculation is made with the maximum speaking time of the longest route advice.

Reaction times

On reaction time lenghts, extensive information has been received from the literature, making it difficult to attribute a particular value to the reaction time. For, depending on the testing circumstances, reaction times have been reported varying from 400 to 4900 ms.

Distinction has to be made between the reaction time on aural messages and the reaction time on visual information. Aural information is likely to be processed less fast than visual information as the "depth of processing" involved is larger for aural information than for visual information and drivers will be more alerted when receiving visual information (they have to decide themselves whether they watch the display or not), whereas in the Carin system aural information is simply imposed upon the driver.

The reaction time for aural message may, in spite of the above, be supposed not to be extreme long. For firstly the drivers may be expected to have a reasonable level of alertness (their alertness is trickered by a dummy word at the start of the aural advice: "take" the first/second....) and secondly the message contains a certain urgency as drivers have great interest in following up the route advice. Regarding these arguments and considering the values that were found by Triggs and Harris in their field studies, it is recommended to have the Carin system calculate with a reaction time on aural messages of 3.0 s, which is slightly higher than the commonly accepted design value (2.5 s). In the tests of Triggs and Harris the value of 3.0 s was sufficient for all test subjects to accomplish the urgent reactions and for 85% of the test subjects to succeed in the reaction tasks with an intermediate urgency.

The reaction time on the Carin visual messages may be expected to be shorter than on aural messages as visual information is processed faster and drivers will be more alert. It is suggested to calculate with reaction times of $1,5 - 0,3 = 1,2$ s, which equals the maximum brake response time of alerted drivers in rather urgent circumstances minus the mean foot movement time from accelerator to brake pedal.

Although the reaction times suggested above are merely hypothetical, no high priority should be given to a reaction time study. For firstly, the reaction times are based on high percentile values. Thus the chances of the estimations being too low are small. Secondly, higher reaction times than suggested can rather easily be compensated by a shorter time for other time periods, for instance by braking with a slightly higher deceleration than the very moderate 2 m/s^2 .

Interpretation times for visual route guiding messages

The interpretation time for the Carin route guiding pictogrammes can be minimal through a good design style.

Generally speaking, a way to reduce search time is color coding. However, it is not to be expected that color coding will be a great help in reducing the interpretation times of the Carin pictogrammes as hardly any searching will be necessary. For the display will contain only one pictogramme against a neutral background.

A good indication of easy interpretable styling methods was given by Erke, Richter, and Richter. Stylized direction signs turned out to require shorter interpretation times than quasi-geographic ones. Both the configuration styles of figure 6.1 turned out to be favourable. The configuration styles of figure 6.2 were less favourable.

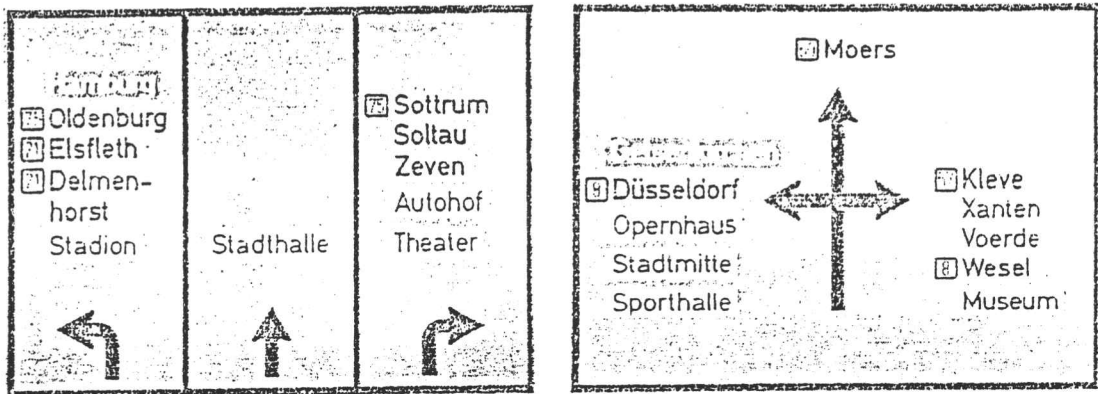


Figure 6.1: Favourable configuration styles (source: Erke, Richter, and Richter)

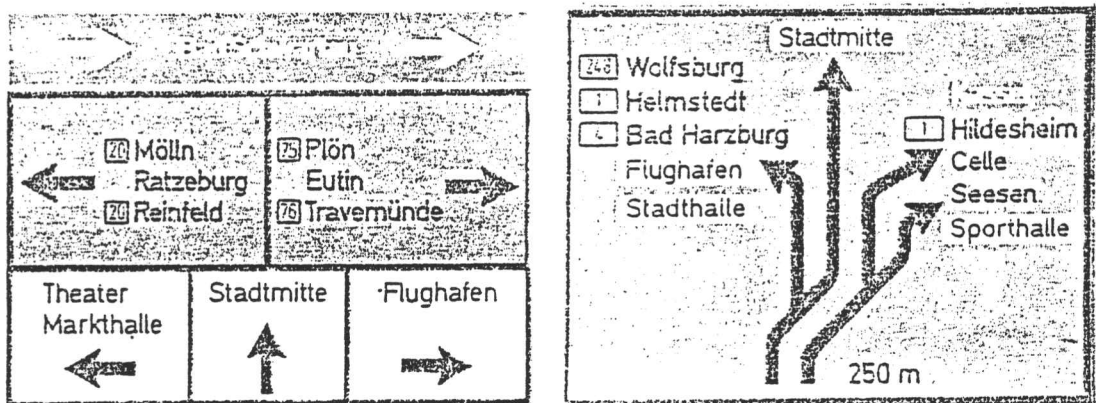


Figure 6.2: Less favourable configuration styles (source: Erke, Richter, and Richter)

From the above configuration styles it can be deduced that the configuration of the Carin route guiding pictogrammes should be simple. An advice containing more than one component should preferably be presented sequentially rather than simultaneously. The pictogrammes must give only that information the driver needs in order to execute a manoeuvre, the amount of information given should form one figure, and the most important road should be accented visually.

The time to read a picture increases more than linearly with the complexity. Very complex junctions are often faced with the impossibility to design a picture that is both simple and an exact representation of the geometry. In complex situations like the cloverleaf and the multi-gore the guiding with pictures is therefore expected to be less successful. It is doubtful whether for these situations a suitable pictogramme can be designed for the Carin system.

Experience with the route guiding pictogrammes is an important factor in reducing interpretation time. Drivers who have seen a message often will more than likely tend to gloss over familiar elements of the message and concentrate on the part of the message that changes from one situation to another.

To decrease the level of inexperience of novice users, it would be usefull to present each buyer a manual with all possible pictogrammes. Better even would be a presentation of the Carin system on video tape including all possible route guiding advices.

Times to execute a necessary action

After the presentation of a Carin route guiding advice the driver will have to brake and/or change lanes. The time period necessary for these actions will have to be accounted for by the Carin system.

For the calculation of the braking time, the following data are required: the velocity of the car, the velocity in the bend, the deceleration, and the foot movement time from accelerator to brake pedal. Of these values, the velocity of the car is measured continuously by the wheel sensors, the deceleration is suggested to be fixed at the comfortable and safe value of 2 m/s^2 , the velocity in bends follows from the road class, and the foot movement time from accelerator to brake pedal can be fixed at 300 ms.

The time necessary to change lanes is not easily determined, as this varies strongly with the traffic flow intensity. Not only will under heavy traffic conditions the merging in a traffic flow on an adjacent lane be more difficult, also will the route information have to be given far enough upstream of any possible traffic queues. Further study on this subject will be necessary.

The chances that route guiding messages are forgotten

The chances on a driver forgetting a route guiding message have been studied extensively in the United States.

The time from the ending of a message to the message recollection has not found to be related to the retention rate (the tested time periods varied from 5 - 45 s).

The smallest error percentage occurred with messages in short style language as compared to staccato and conversational style. Short style language was also preferred by test subjects.

As was to be expected, the message load turned out to be the most critical factor in the message retention. The number of information units that could be recalled entirely without errors, varied from one study to another. According to Gatling only two units could be recalled by all test subjects without failures, whereas Dudek, Huchingson, and Stockton found that 94% of the test subject could correctly negotiate a diversion route containing six units of

information. Although the Carin route guiding messages will contain only one or two units of information, it may not be concluded that those messages will not or hardly be forgotten. For firstly the messages as tested by Gatling and by Huchingson c.s. contained street and exit names, whereas the Carin messages will contain only numbers which were found to be recollected less easy than names. Secondly, age plays an important role also. The percentage of subjects making a route error was found to be 10 - 20% higher for older people than the values of younger subjects presented above.

Further studies on the effects of forgetting Carin route guiding advices need not have a high priority. For it is to be expected that drivers who have forgotten an aural route guiding advice firstly will still be aware of an oncoming junction and adjust their velocity to this situation (they are likely to have forgotten the route advice, not that a route advice has been given) and secondly will probably not need more than a quick glance at the visual display to recall the route advice that had been forgotten.

8. Obstruction of the driver's view

No part of the Carin system should under any circumstances obstruct (a part of) the driver's view.

9. Illegal route guiding advices

It will not be possible under all circumstances to avoid Carin from advising drivers to turn into a street where that is not allowed (for instance the wrong side of a one-way street).

It will be important to at least point out to drivers that the Carin route guiding messages may be illegal and that the route guiding information comprises no commands but advices. The driver will have to check the road, the traffic, and the traffic regulation himself, just as he did before the installation of the Carin system.

Nevertheless it is likely that drivers start following-up route guiding advices blindly: after 1000 legal advices they do not expect the 1001st advice to be illegal. This may lead to drivers following up the illegal advice or becoming panicked when noticing that the route advice that has just been given is illegal. Therefore it should be made clear that should ever a route guiding advice be ignored, the Carin system immediately calculates a new route, starting from the present position.

A further study on the effects of illegal route guiding advices may be quite usefull.

10. Reaction on a disregarding of a route guiding advice

The Carin system should only inform drivers of a deviation from the planned route, on a location that is so far from the deviation point

that any correction of the mistake by the driver is not possible. It is preferable to inform drivers of a deviation after the calculation of a new route and inform them of this new route too.

11. Avoiding unsafe locations and situations

The unsafety of certain roads, locations, manoeuvres and situations /
The possibility to use traffic safety criteria.

In the Carin system traffic safety may be used as one of the criteria for determining optimum routes. However, the application of traffic safety criteria is not simple, as unsafety is a complex dynamic process in which the interaction of a series of critical circumstances leads to an accident.

On accident-related road and traffic characteristics, an extensive study has been conducted by the Dutch Institute for Traffic Safety Research SWOV. This study has been carried out in the county of Noord-Brabant in the Netherlands. The accumulated data, however, are difficult to incorporate into the Carin programme. Herefore are three reasons.

Firstly, the data concern physical characteristics (like e.g. road width), whereas human behaviour is induced by functional characteristics (like manoeuvre space).

Secondly, a major part of the characteristics that are frequently accompanied by a high accident rate are not registered in the Carin system (e.g. the presence of bicycle paths, the sight distance, the presence of traffic lights, and the like). In general, Carin has only very little information on road characteristics and no information at all on traffic characteristics.

Thirdly, the found relations between road and accident characteristics on one hand and accidents on the other hardly contribute to an insight in traffic (un)safety, which may lead to wrong interpretations. An example may illuminate this remark. Out of the analyses it e.g. follows that on junctions with traffic lights more accidents happen than on junctions without traffic lights. However, this does not mean that traffic lights increase the traffic unsafety: a junction with traffic lights is probably more safe than the same junction without traffic lights! Furthermore, the conclusion was based on data from the period 1971-1975, when most traffic lights still had fixed regulations. At present most traffic lights are regulated traffic-dependently, which may well be more positive from a traffic safety point of view, because unnecessary waiting can be avoided and red light negotiations therewith less tempting.

As it is not possible to use in the Carin system the detailed information from the traffic safety studies in Noord-Brabant, it is recommendable to incorporate more general data into the Carin programme. Herefore, the report of Janssen (S.T.M.C, 1985) supplies adequate information.

Janssen calculated the average number of accidents with casualties per vehiclekilometre and per junction for 7 road classes outside residential areas and 2 within. Although the calculated numbers are only very rough estimations for the risks on a certain road, they are nevertheless usefull for Carin. For even if the use of the indicator numbers that are presented in table 6.1, in some cases lead to an underestimation of the risk for a particular journey and in an other case to an overestimation, on average the systematic calculation of "safe" routes with the aid of the indicator numbers still will lead to a decrease of the traffic risks.

Table 6.1: Indicator numbers for the estimation of accidents with casualties; Source: Janssen, 1985

Kencijfers voor de schatting van het aantal letselongevallen				
		voor wegvakken	per kruisingen per jaar	
		per miljoen gere-	totaal	ongevals-
		den motorvoertuig-		groep 1
		kilometers		ongevals-
				groep 2
<u>autosnelweg</u>				
2 x 2 rijstroken	f 1 *		0,82	0,54
2 x 3/4 rijstroken	f 2 **		1,03	0,92
<u>autoweg bubeko</u>				
1 x 2 rijstroken		0,08	0,70	0,54
2 x 2 rijstroken		0,04	1,27	0,81
<u>gesloten verklaring bubeko</u>				
1 x 2 rijstroken		0,25	0,36	0,24
2 x 2 rijstroken		0,08	0,68	0,39
<u>overige weg bibeko</u> ***		0,37	-	-
<u>verkeersaders bibeko</u> ***		1,79	-	-

* $f 1 = 1,12 \times I^{0,34} \cdot 10^{-3}$; bij I = 40.000 motorvoertuigen per dag

$f 1 = 0,040$

** $f 2 = 1,09 \times I^{0,31} \cdot 10^{-3}$; bij I = 80.000 motorvoertuigen per dag

$f 2 = 0,035$

*** inclusief kruisingen

The extent to which traffic safety should be used as criterion for determining optimum routes

With the data of table 6.1 it is possible to compare the average risk of a journey on a certain road with the risks of an alternative route. The extent to which the Carin system should select a safer route is difficult to indicate as this can not be determined objectively.

A way to weigh the advantage of a safer route against the disadvantage of a detour may be to compare the products of the travel time and the unsafety index of two alternative routes. An example of such a comparance is displayed in figure 6.3. To prevent Carin from selecting routes with excessive detours, the maximum detour percentage could be fixed at e.g. 15%.

Route A: motorway; 2 x 2 lanes
length: 90 km; 12 junctions
travel time T: 45 minutes
unsafety index S: $90 \times 0,04 + 12 \times 0,82 = 13,4$ (see table 6.1)

Route B: single carriageway road, prohibited for slow traffic
length: 67 km; 22 junctions
travel time T: 40 minutes
unsafety index S: $67 \times 0,25 + 22 \times 0,36 = 24,67$ (see table 6.1)

T.S (Route A) = $45 \times 13,4 = 603$ T.S (Route B) = $40 \times 24,67 = 987$

➤ According to the criterion of weighed safety, Route A should be selected in spite of it's detour of 5 minutes

Figure 6.3:Comparance of two alternative routes via a weighed unsafety index.

The appliace of the safety criterion within build-up areas on the basis of the values of table 6.1 is not to be recommended for two reasons. Firstly, this would lead to the selection of many rat runs and therewith improper use of minor roads.

Secondly, the low value for the traffic safety indicator number of minor roads is misleading. As a result of the classification into only two road classes, the group of minor roads consists of many very quiet roads that are used only by destination traffic. These roads, on which very little accidents happen, reduce the traffic unsafety index of the group of minor roads. However, the minor roads that

would be selected for the through going traffic would be unsafer than the low value for the traffic unsafety index indicates. Outside build-up areas, roads of a high category coincide with a low traffic unsafety index. This means that usually the fastest routes will also be the safest.

The dangerous road situations a driver should be warned off

Unsafe situations can be avoided not only through the selection of an alternative route, but also by warning a driver. The appliance of the latter solution, however, will not be easy. For, it has been mentioned before, traffic unsafety is caused by a combination of circumstances, meaning that a specific characteristic is only critical in combination with other circumstances. A sharp bend, for instance, will be unsafe in combination with a high speed, worn tyres, and a wet road surface, but absolutely safe in combination with a low speed and a dry road surface.

The incorporation into Carin of an extensive warning system will therefore cause some problems.

Though the application of an extensive in-car warning system may cause quite some problems, the incorporation of an adaption for receiving broadcast out-car warnings may be relative simple. First this information may be rather general and contain only information on traffic jams, road works, frozen road surfaces, and the like (broadcast through the future Radio Data System e.g.). In a later stadium the information may be extended to local information broadcast via road-side transmitters.

12. Information on the vehicle condition

With an adequate coordination between the Carin design and car designs, a continuous check of vital parts of the vehicle could be made possible and the condition of the vehicle be presented to the driver. Submitted to this constant check should be for traffic safety reasons: the braking system, tyre wear, the lighting system, the steering system, and the steering characteristics.

13. Agressive shape

Sharp edges and protruding obstacles on any part of the Carin system should be avoided. If this is absolute impossible, aggressive parts should be adjusted in such a way that they break off in case of a collision. For the remote control unit a comfortably located container should be designed.

LITERATURE

Behrendt, J.

Überlegungen zum Aufbau eines fahrzeuginternen Verkehrsleit- und Informationsystems

Strassenverkehrstechnik, Volume 29, No. 2, pp 64-69

Bonn-Bad Godesberg, Federal Republic of Germany, 1985

Berkvens H.J.F.M.

Nadersnelheden bij kruispunten

Veilig Verkeer Nederland

Hilversum, the Netherlands, 1976

Blaauw, G.J.

Car driving as a supervisory control task, pp 139

Graduating paper for a doctor's degree

Instituut voor Zintuigfysiologie TNO

Soesterberg, the Netherlands, 1984

Carter, R.C. Jr.

Visual search and color coding, pp 5

The Pennsylvania State University

Pennsylvania, United States, 1979

Döring, B.

Analyse des Arbeitsprozesses bei der Fahrzeugführung am Beispiel eines Landeanflugs -eine systemergonomische Simulationsstudie, pp 265

Forschungsgesellschaft für angewandte Naturwissenschaften e.V.

Forschungsinstitut für Anthropotechnik

Wachtberg-Werthhoven, Federal Republic of Germany, 1983

Dudek, C.L.

Human factors considerations for in-vehicle route guidance

Transportation Research Record 737, pp 104-107

Texas Transportation Institute

College Station, United States, 1979

Dudek, C.L. & Huchingson, R.D.

Human factors design of dynamic visual and auditory displays for metropolitan traffic management - Volume I: Summary report, pp 109

Texas Transportation Institute

College Station, United States, 1980

Dudek, C.L. & Huchingson, R.D. & Stockton, W.R.
Human factors design of dynamic visual and audio displays for metro-
politan traffic management, Volume 3 - Highway Advisory Radio, pp 110
Texas Transportation Institute
College Station, Texas, United States, 1981

Easterby, R.S. & Cox, D.E.H. & Hughes, A.W.
The perception of variable message symbolic road signs: reaction time
studies, pp 49
University of Aston in Birmingham, Applied Psychology Department
Birmingham, England, 1977

Erke, H. & Richter, B. & Richter, S.
Psychologische Untersuchungen zu Unfällen auf innerörtlichen Strassen
im Zusammenhang mit Merkmalen der Vorwegweisung.
Köln, Federal Republic of Germany, 1974
in: Forschungsheft zur Verkehrssicherheit 20 (1974) nr.2.

EUCO-COST 30 (European cooperation in the field of scientific and
technical research)
Final report of the demonstration project group electronic aids on
major roads.
Brussels, Belgium, 1984

Galer, M. & Baines, A. & Simmonds, G.
Ergonomics aspects of electronic dashboard instrumentation
University of Technology, Loughborough, Institute of Consumer
Ergonomics
Ford Motor Company Ltd, Research and Engineering Centre
Loughborough/Basildon, England 1980
in: Osborne, D.J. & Levis, J.A.
Human factors in transport research - volume 1 (301-309)

Gatling, F.P.
Auditory message studies for route diversion, pp 66
Federal Highway Administration
Washington D.C., United States, 1975

Gatling, F.P.
Highway advisory radio in construction areas, pp 18
Federal Highway Administration
Washington D.C., United States, 1977

Hoek, H. & Oei, H.L. & Poppe, F.

De verkeersveiligheid in de provincie Noord-Brabant IX C
Het relatie-onderzoek: Resultaten deelonderzoek Analyse raaien.
Institute for Traffic Safety Research SWOV
Leidschendam, the Netherlands, 1981.

Holloway, C.H. & Wright, P.

Assesment of the attentional demands of road information transmitted
aurally, pp28
Medical Research Counsel; Applied Psychology Unit, Cambridge
Cambridge, England, 1980

Jacobs, R.J. & Cole B.L.

Searching vertical stack direction signs, pp 5
Proceedings of the 9th conference of the Australian Road Research
Board, Volume 9, Session 38
Brisbane, Australia, 1978

Janssen, S.T.M.C.

Het verkeersveiligheidsaspect in de prioriteitstelling van rijks-
wegenprojecten voor de middellange termijn - bepaling van kencijfers
voor de verkeersveiligheid, pp 17.
Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV
Leidschendam, the Netherlands, 1985

Jansen, W.H.

Routeplanning en -geleiding - een literatuurstudie, pp 51
Instituut voor zintuigfysiologie TNO
Soesterberg, the Netherlands, 1979

Klijnhout, J.J.

CARIN, RITA, EVA of Lucia?
Verkeerskunde, Volume 36, no.10, pp 457-461
's Gravenhage, the Netherlands, 1985

Knust, D.

Kraftfahrzeug-Innengeräusche aus der Sicht der Benutzer
VDI-Berichte nr. 188: Geräusche in Kraftfahrzeugen, pp 5-8
Düsseldorf, Federal Republic of Germany, 1972

Kumm, W.

Neuartige informationslösungen für alte verkehrstechnische Probleme
Strassenverkehrstechnik, Vol.26, no.6, pp 171-174
Bonn-Bad Godesberg, Federal Republic of Germany, 1982

Labiale, G.

Approche psycho-ergonomique des systemes d'information et de guidage routier des conducteurs automobiles, pp 49

Institute de Recherche des Transports
Brow, France, 1984.

Leijns, R.C. & Meiland, E.C.H. & Klein Baltink, H.G.

Achtergrondinformatie ten behoeve van de actie "dominante verkeersongevallen buiten de bebouwde kom 1979" - Thema "afstand houden", pp 20

Veilig Verkeer Nederland
Hilversum, the Netherlands, 1979

Meyer, F.

Reaktionsanlass und Reaktion im Strassenverkehr

Der Verkehrsunfall 16, Number 12, pp 255-259

Braunschweig, Federal Republic of Germany, 1978

Michaelis, P.R.

An ergonomist's introduction to synthesized speech

Texas Instruments Incorporated, Computer Science Laboratory
Dallas, Texas, United States, 1980.

in: Osborne, D.J. & Levis, J.A.

Human factors in transport research - volume 1

Osborne, D.J. & Levis, J.A.

Human factors in transport research - volume 1, pp 441

Proceedings of the International Conference on Ergonomics and Transport held in Swansea from 8-12 September 1980

Swansea, Wales, 1980.

Oei, H.L.

Route information systems

Man and information technology; Towards friendlier systems, pp 19-27
The Netherlands

Poppe, F. & Oei, H.L.

De verkeersonveiligheid in de provincie Noord-Brabant IC D

Het relatie-onderzoek: Resultaten van het deelonderzoek Analyse kruispunten

Institute for Traffic Saffety Research SWOV
Leidschendam, the Netherlands, 1984.

Prentice, H.A.J.

Drivers' limitations

Transport and Road Research Laboratory

London, England, 1974

in: Report on the 5th International Technical Conference on
Experimental Safety Vehicles, pp 862-867.

Priest, J.

Synthesized speech: ergonomic implications for the transportation industry

Texas Instruments Incorporated, Human Factors Research Laboratory

Dallas, Texas, United States, 1980.

in: Osborne, D.J. & Levis, J.A.

Human factors in transport research - volume 1

De verkeersonveiligheid in de provincie Noord-Brabant IX E .

Het relatie-onderzoek: Resultaten van het deelonderzoek Analyse
strengen

Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV

Leidschendam, the Netherlands, 1984

Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV

De verkeersonveiligheid in de provincie Noord-Brabant X.

Eindrapport, pp 25

Leidschendam, the Netherlands, 1984.

Triggs, T.J. & Harris, W.G.

Reaction time of drivers to road stimuli, pp. 97

Monash University, Department of Psychology

Melbourne, Australia, 1982.

Watts, G.R.

The evaluation of conspicuity aids for cyclists and motor cyclists

Transport and Road Research Laboratory, Vehicle Safety Division

Crowthorne, England, 1980

in: Osborne, D.J. & Levis, J.A.

Human factors in transport research - volume 1.

Wouters, P.I.J.

The application of electronics in traffic risk control, pp 25

Institute for Traffic Safety Research SWOV

Leidschendam, the Netherlands, 1985

Enclosure: The phase model of the transport and traffic (unsafety) process

1. Introduction

Both the transport and traffic process, that can result in accidents, and the crash process can be regarded as a chronological complex of successive, increasingly critical combinations of circumstances and events.

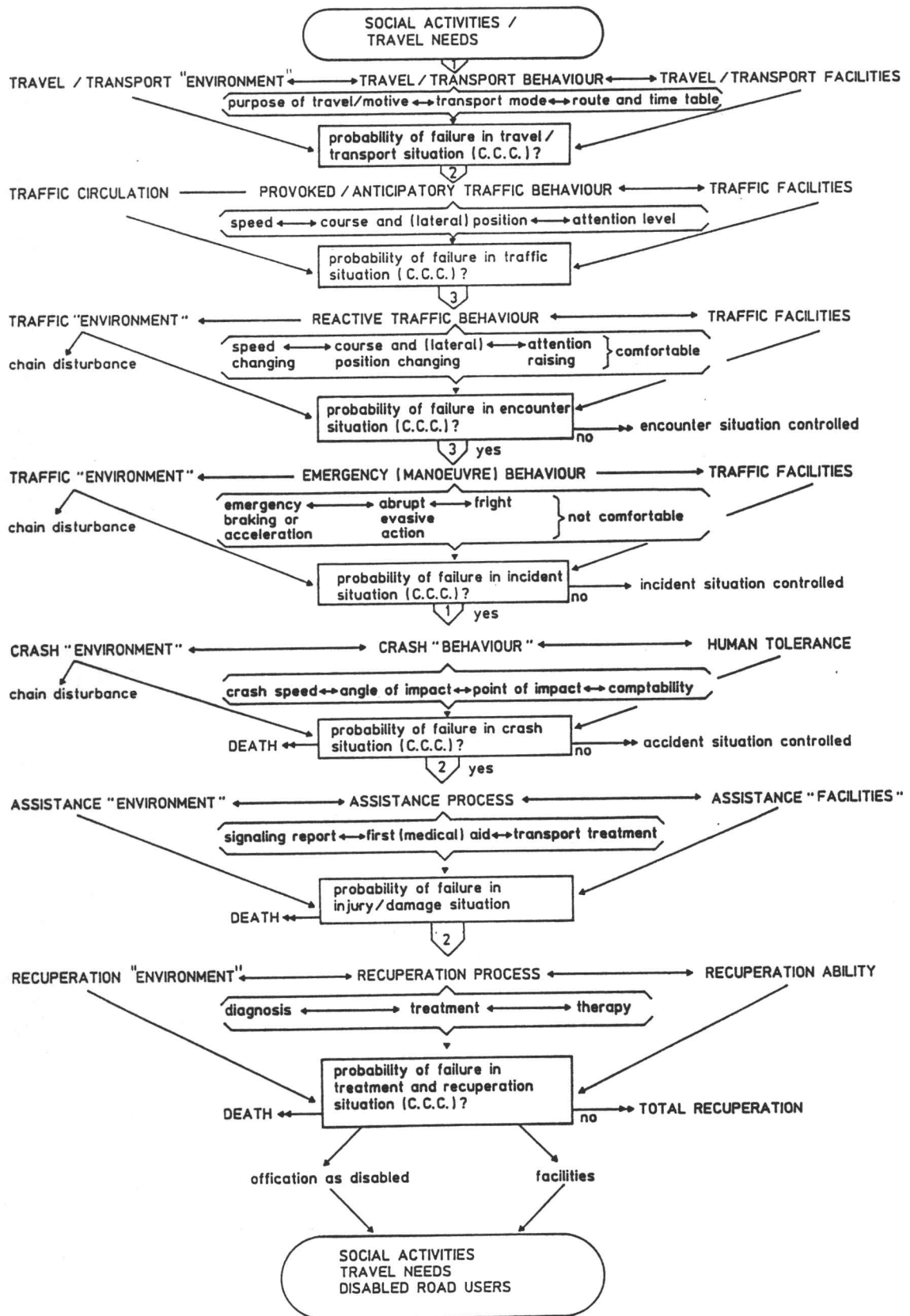
These eventually result in injury and damage, followed by a "recuperation process", in which critical circumstances again can occur. In theory a halt can be called to this "accident process" in any of the phases it comprises of.

To get an oversight of traffic unsafety, is it necessary to order or structure the transport and traffic process from a traffic safety point of view. Such an order and structure of the "accident process" has been found in a conceptual model referred to as phase model of the transport and traffic unsafety process (see figure e.1).








The phase model is based on the following principles.

1. The transport and traffic unsafety process is a dynamic process, i.e. it is a chronological complex of successive critical circumstances and events. Each state observed is a "snapshot" and has a history, a "memory" and a follow-up. The follow-up is determined by the memory, the road user's goal and his behaviour alternatives.
2. It is a model of a process that becomes increasingly critical once a phase is reached where critical states cannot be overcome. In each phase of the process a critical situation can arise which unleashes a chain of critical states which are increasingly difficult to control: the time and room for observing, deciding and acting becomes less and less.
3. Each phase involves different critical combinations of circumstances, different relationships between behaviour and environment. The transition from one phase into the next is a greater or lesser discontinuity, i.e. in a particular phase the road user has behaviour alternatives which differ from those in the previous and the next phase.

Figure e.1: Phase model of the transport and traffic (unsafety) process



LEGEND :

-  addup together
-  determined (too)
-  in connection with
-  critical process ends
-  induce
-  induce/predispose
-  be obliged to

C.C.C. : critical combination of circumstances

2. Description

The phase model of the transport and traffic unsafety process describes the nature of the traffic process insofar as there are critical changes in state with increasing losses in relation to the goal. In it the individual road user is central as the elementary system. Other road users are regarded as part of the individual road user's traffic environment. External control mechanisms, operated by the "collective decision-makers", are designed to influence the internal control mechanism of the individual road user. The points at which this takes place are the critical combinations of circumstances in the various phases which entail a risk of failure for individual road users.

Figure e.1 shows the phases of the transport and traffic unsafety process split up according to discontinuities in critical states and thus by the nature of the behaviour alternatives a road user has to bring an "accident process" once started, or a critical state, under control. These phases are described in the following.

Travel/transport situation

A decision to engage in an activity at another location, e.g. to visit relatives, makes it necessary to travel. The nature of the travel goal, the motive for travelling, the mode of transport chosen, the route, and the timetable together determine the travel behaviour. The circumstances in which a road user travels are referred to as the travel/transport situation. These circumstances can in themselves entail a risk of failure or a potential loss. Two examples: a timetable that is too tight, a journey to an important meeting - result: fast driving and attention already on the meeting. These risks in or as a result of travel behaviour are only manifested in the next phase, at the manoeuvring. The transport or travelling circumstances preordain, as it were, the start of a chain of fresh risks of failure for the road user.

Critical states in travel behaviour influence not only speed, direction and lateral position on the road and the alertness of the road user, they also can make all the subsequent phases more critical. A road user in a hurry has e.g. less peripheral perception and may overlook traffic that crosses his path. In the event of an encounter with other traffic he is more likely to accelerate in an attempt to pass in front than to brake.

Traffic situation

The traffic behaviour of a road user, provoked by travel and traffic circumstances (in particular vehicle, traffic and road characteristics), takes the form of speed, direction and lateral position on the road and in the traffic flow, and alertness. The provoked and anticipatory traffic behaviour can be regarded as a continuous change of state (in speed, course and lateral position): following the road, following a stable traffic flow.

Encounter situation

Every change in state can result in a change in the risk of failure: encounters with other road users, but also instability of a traffic flow, discontinuities in the path of the road, etc. A lot of the risks in these encounter situations can be overcome by timely and adequate reaction: braking or accelerating, deviating to the left or right, and increasing one's alertness are the opportunities available to the road user for reactive traffic behaviour.

Incident situation

The absence of a timely and/or adequately reaction in the encounter situation, owing to misjudgement of the situation or lack of information or experience, results in an increase in the risk of failure. The time for acting becomes very short and the opportunities in many cases very limited: we can speak of an incident. The only way of preventing an accident then is for the road user to carry out an emergency manoeuvre: abruptly swerving, an emergency stop and a call on "survival" reflexes are the types of emergency manoeuvre behaviour available. If the emergency manoeuvre is successful, so that the vehicle remains on the carriageway without hitting anything, we call this a "conflict" - a near miss. Often, however, fresh risks of failure occur during, or as a result of, the emergency behaviour.

A chain reaction may affect other road users if e.g. during an emergency manoeuvre a vehicle crosses to the other side of the road (obstructing oncoming traffic) or comes to a halt on its own side (obstructing following traffic). This effectively starts a new "accident process", now for the other road users.

Crash situation

Every year in the Netherlands alone at least one million emergency manoeuvres are unsuccessful (if they took place at all). High speed at the start of the manoeuvre, inadequate time, not enough distance (including the danger of skidding) produce risks of failure which, if they materialize, inevitably result in a crash (accident).

Fortunately not all of the 1 million yearly Dutch accidents are serious. Nevertheless, the number of registered (!) casualties

mounts up to 1600 deaths and some 50.000 injuries per year. Determinative for the severeness of an accident are the collision speed, the angle of impact and the point of impact. Together these make up the crash behaviour of the vehicle (and to some extent of the occupants or riders) and the object collided with. A chain reaction can also take place here. The risk of damage and injury, the damage and injury pattern, does not depend solely on the crash behaviour of the vehicle and object. Crash circumstances, such as characteristics of vehicle exterior and interior and the resilience of occupants and riders have a considerable influence, as does the wearing of seat belts, crash helmets, etc.

Injury and damage situation

After the crash phase comes the injury and damage situation. This begins with the discovery and the reporting of the accident, followed by first aid (including emergency medical aid), removal of the injured to a hospital and finally treatment. We need not concern ourselves here with the recovery and repair of damaged vehicles. During the entire aid process risks of failure occur which may affect the damage and injury pattern. These generally occur in the timespan between the crash phase and treatment. In some cases the outcome is serious (permanent) damage. The absence of actions needed to save life or incorrect first aid, the stagnation in the removal of victims owing to inaccessibility of the scene of the accident or traffic congestion can entail risks of failure or critical combinations of circumstances which determine the ultimate effects.

Treatment and recuperation situation

The treatment and recuperation situation comprises the medical diagnosis, the therapy, and the after-care. In this situation again possible failures manifest themselves, e.g. as a result of an incorrect diagnosis, or an insufficient organisation in the traumatologic department of a hospital. If the recovery is not complete, permanent effects occur (that may sometimes manifest themselves only after years and often were not confirmed in the diagnosis).

We shall not consider rehabilitation, the social care and training of those handicapped in road accidents, in detail here. They do, however, have to be able to make use of travel facilities so that they can carry out their activities as they did before becoming handicapped.

Bibliotheek TU Delft
Fac. CiTG subfac. Civiele Techniek

c3132752

