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SAFETY EVALUATION OF TRAFFIC SYSTEMS: TRAFFIC CONFLICTS AND OTHER MEASURES

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PROCEEDINGS

ICTCT
INTERNATIONAL COOPERATION
ON THEORIES AND CONCEPTS IN TRAFFIC SAFETY

Austrian Road Safety Board

Safety Academy

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Working group C

Working group D

Working group E

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WELCOME BY THE ORGANIZER

Ladies and Gentlemen,

I welcome you heartly in Salzburg in the name of the Austrian Road Safety Board (Kuratorium für Verkehrssicherheit), which is responsible for the organisation of this Congress and I hope that you will spend interesting days with a lot of yield. We enjoy that we are able to welcome so many outstanding experts from four continents at that Congress! This fact shows that the subject of this meeting namely the check on efficiency of safety measures in road traffic is of great importance. I'll try to show the size of the problem by the example of Austria:

The expenses for immediate safety measures - that are safety campaigns, expert opinions, public works for the removal of black spots, driver training and safety education might be surely more than one billion Austrian Shillings. The expenses for road construction by the federation, the federal countries, the communities and the road-duty-companies are about thirty times as high. But the effort for the evaluation of all those measures is not even one pars pro mille. One relies on general considerations and experiences considered as being useful for traffic safety and summarizes all taken measures, whatever they did, as a success. In many cases that might even be true but it does not at all apply for each individual case. Three examples may prove that:

The success of safety campaigns is often demonstrated thus, that new items are produced for the press and if then reports are published in the medium they multiply the report by the circulation rate of this medium and state: we have reached out up to ten thousand persons. The theoretical reach of a safety message then will quickly be transformed into attitude modification because one beliefs that the contents of the message have been so conclusive convincing and so attitude modification is equated with behaviour modification. One has reached the target and sits down in the director's chair: what have we done all for traffic safety!

That it doesn't work so has been demonstrated by the evaluation study of a very expensive traffic safety campaign carried out 1973 in Austria under the title "Alcohol - car - out" ("Alkohol - Auto - Aus"). The study showed that despite of the theoretical reach the message which has been sent out did not attain the target group and therefore no behavioural change has been produced. Since that time no such evaluation has been carried out so because of that fact it is not possible to declare that all safety campaigns have worked so poor.

Fortunately, there are not only so negative examples. So in the early seventies in Austria driver improvement courses have been implemented for drivers driving while intoxicated. About 10 years after the start of that activity a large efficiency analysis has been undertaken whereby it was possible not only to compare three different groups of treated drivers but also to establish a well organized control group.

The results met the expectations: through the course-attendance the recidivism rate of drivers driving two times under the influence of alcohol could be decreased about 50%, that means that the reprobation rate was only half as high compared with the untreated control group. To the ethical aspects of establishing such a control group I only want to mention that different by change occuring administrative reasons caused to it that the members of the control group stayed without treatment but they corresponded by their characteristics to the treated group.

A third example shows that measures may work in one case but not in others. Within the frame of a large study on "driver behaviour and accident participation of foreign drivers - especially german - in Austria" 12 black spots on the arterial transit routes in Austria were noted. On 6 spots simple traffic-technical measures and traffic regulations have been carried out. The effect has been verified by speed measurements, traffic counts, traffic conflict studies and accident analysis. By the analysis of traffic accidents only a poor effect could be established due to the small number of cases but that slight effect spoke for an improvement of the situation. But the observation of traffic conflicts proved to be a very sensitive instrument at an observation range of only a few days: the number of observed conflicts dropped from 563 to 109 conflicts! But this was not the case at all sites! So it has been shown at the "Trautenfels - crossing" (in Styria) that the taken measures could not extinguish all the existing problems and proved that the traffic organisation of the site should be changed by necessety.

Recently a small study on a portfolio for traffic education devoted for the hands of specialized teachers could be carried out. It could be shown that only a part of the teachers was able to use the documents because they were too much theoretical and therefore the realization by the teachers has rendered more difficult. Now the portfolio will be reorganized and new edited.

This example should stay for the future traffic safety work: All larger projects should be evaluated by routine because of this feed back one's own work can be improved to the advantage of traffic safety, for the smoothness of the traffic system and for the welfare of the citizens. In this sense I ask you to understand this Congress as call for evaluation from all persons working in the traffic sector: technicians, psychologists, PR-managers and politicians etc. The time definitely has passed to live from hand to mouth!

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Fa.Factum
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INTERNATIONAL CONGRESS FOR SAFETY EVALUATION OF TRAFFIC SYSTEMS: TRAFFIC CONFLICTS AND OTHER MEASURES

Introduction *(German version in the annex)*

As every year the ICTCT also organized a workshop in 1993 - this time under the patronage of the "Kuratorium für Verkehrssicherheit" Salzburg. "Workshop" does not really apply this year, because it was a congress in the course of which a couple of workshops (= working groups) took place. The expansion to the dimension of a congress aimed at two groups: science and research collegues who are not members of the ICTCT and civil servants, mainly from Austria, who are working both at regional and national level, were invited to take part in this congress. Therefore the usual workshop dimensions of about 30 - 40 people turned out to be much too limited.

In general it applied for the workshops that the presentations were very heterogeneous. The bond tieing together all the speeches is the discussion, which traditionally takes up a dominant position. This time - in Salzburg 1993 - the contributions were less heterogeneous, although their number was larger than usual. Whereas usually it was thought to be enough to deal with one general topic, for the four main speeches a certain "central theme" was planned right from the beginning and it is reflected in the contributions.

The aim which was followed in the main speeches was to give a social background for describing a traffic system with desirable characteristics. Under the catchphrase "social sustainability" (I would like to translate this with "Sozialverträglichkeit"), Joop KRAAY from the Dutch ministry of transport pointed out which criteria can be introduced at a national level, that is to say: which legal and formal frame one has to create to arrive at a traffic system which evens out conflicting interests between different social groups, and which takes basic human needs into account.

While listening to the speeches it was already possible to spare some thoughts on the effects which new technology-based equipment would have in road traffic concerning the aspects talked about in the previous paragraph, as Christer HYDÉN from the Department of Traffic Planning and Engineering at the Technical University of Lund in the first main speech had in fact given a survey on the different types of equipment that are being developed or implemented at the moment.

Furthermore, the aspect of traffic safety was especially stressed among the many demands, which traffic should meet. This is due to the fact that many of the methods the members of the ICTCT dealt with are orientated on formulations of questions concerning safety. The third main speech consistently also studied possibilities and limitations of accident analysis: Siem OPPE from the Dutch Institute for the scientific research on traffic safety (SWOV) gave a very detailed report on this topic.

And last but not least Farida SAAD from the French organisation for traffic safety INRETS dealt with the analysis of traffic conflicts and other kinds of behavior. Her analysis was based on her own reflections and on a paper from Nicole MUHLRAD (INRETS as well), who could not take part in the congress.

It should also be mentioned here that many experts tend to see traffic conflict analysis as behavior analysis: Although technically defined aspects are the center of research (TTC, evasive action, etc.), it has become a standard that in the course of traffic conflict studies behavior and interaction that preceeded the traffic conflict are described. These data are worked into the reports on traffic conflict analysis. In the further course of this report traffic conflict technique will also be subsumed under the expression behavior analysis (at least in a wider sense) from time to time.

Behavior analysis are methods, which grant a better insight into the behavior und interaction of traffic participants than accident analyses. And even if the - quite often asked for - mathematical relation to data won from accident analysis is missing, they nevertheless represent the methods of the future: The reason for this is that they rather admit steps pointing at a definition of a desirable traffic system than accident data. Secondly, accident data are not reliable (especially the survey on not very serious accidents does not work reliably). Thirdly, they inform about the facticity of events that one would have wanted to avoid in the first place. Moreover they give too little information about the human factors leading to the traffic accidents.

It should definitely not be expressed here that accident analyses are useless. On the contrary it should be stressed that the work for traffic safety should see its purpose in finding out how accidents can be avoided. What you need is more information on what traffic participants think, what they do, how they interact with each other etc. To learn something about the last - mentioned aspects has turned out to become more and more the aim of experts for traffic safety. In Austria this aim is, among others, reflected in new research work of the "Kuratorium für Verkehrssicherheit" - e.g. in the cooperation with the research society dealing with traffic and road problems in developing new RVS (guidelines and regulations for road construction).

The central topics from the key note presentations then were to be followed in group - work for which the aspect "new traffic systems" was planned as horizontal topic: it turned up in all the working groups. Nevertheless did the working - groups' papers not refer to this aspect to the expected amount: The papers were mostly of rather common nature. But this does not contradict the idea that the know - how which has been collected in this way can be used, with little problems even, for the evaluation of new equipment in road traffic - in its prospective ways at least: for one can hardly make predictions on the basis of accident analysis, particularly if the traffic system changes fundamentally. Taking into account the present progress in technology, this is quite probable to happen.

In some working groups the topics "social sustainability" and "traffic safety" together with two extensive considerations on two groups of methods - accident analysis on the one hand and behavior analysis on the other - were chosen deliberately:

Group A described and discussed the way which would make it possible to find out the criteria for a traffic system, orientated on socially accepted values and on social acceptance. The "western" view on traffic with the car in its center was compared with the African perspective: e.g. in Nairobi/Kenia the biggest amount of transport is done by foot. Here it becomes extremely apparent in which way car orientated structures - and it really has been tried to develop them in these countries as well - restrict not only the comfort and the easyness of walking, but also the safety of the pedestrians. This result can at least be deducted from the abstracts sent. (The collegues from Africa had not been able to pay for the journey themselves and it had not been possible to find sponsors for them in Austria).

In group D different possibilities for the use of different types of behavior analysis were presented and discussed, including problems with the consideration of exposure. Obviously there is not only one exposure which gains or loses importance in a linear way. The amounts of traffic, which the amount of accidents are referred to, vary in their importance according to situation, combination (of different ways of moving) and the dimension. During the discussion following a Dutch presentation (Piet NOORDZIJ, SWOV), an interesting point was brought up: According to expert opinion a legal equality concerning the right-of-way rules (according to NOORDZIJ, at the moment the right of way for vehicles approaching from the right does not apply for cyclists in the Netherlands) would result in a lot of killed and injured people - at least during the transitional period. It was also recalled into memory that for quite a long time there had not been an intelligent discussion about legislation, jurisdiction, the philosophies standing behind them and their consequences for traffic in practice to be heard.

Working-groups B, C and E extensively dealt with theories and methods of safety analysis based on behavior and interaction studies. A lot of interesting problems are tied together with behavior analysis. Two of them that turned up in discussions I would like to discuss shortly:

1) One tries to get to an objective definition (and the identification following to this) of mistakes in driving behavior. While doing this one tends to forget that a huge part of the traffic participants' behavior consists of considerations, concepts, motives and attitudes. Each of them can e.g. influence the attention with which you approach to a problem. They all can also be accompanied by the fact that the traffic participant registers certain details of a situation distinctively, which turn the whole behavior in the end into e.g., safe behavior. But they also withdraw from an objective analysis, just like the total amount of all discriminative stimuli one can think of in road traffic (e.g. the aspect that one traffic participant watches the others and draws conclusions from their looking behavior, movements etc.). It would be important to better understand the traffic participants' behavior in its qualitative sense. Quite often such efforts are dismissed as being "not objective". This now leads into the second "interesting problem" chosen:

2) It is demanded from study results won on the basis of behavior analysis that they should be valid with respect to accident criteria. But if you want to prove validity in a mathematical sense, the criteria variable has to be ascertainable in reliable form. Accident data quite often cannot meet this demand. And if you want to understand "validity" as a correspondence between processes, then you would have to be informed better about the accident criteria than we are now: we do know, with the most different accident data at hand, that something has happened. But we do not know what was going on inside the traffic participant before the accident. If we do at all, this is based on reconstructed statements of involved persons or witnesses. The deficits of such reconstructions are well known (e.g., the memory does not work like a video recorder). At the same time one comes back to the problem of subjectivity, which was already talked about under point 1). A good utilization of accident data therefore turns into a qualitative process.

This is why big problems come up, if you want to identify phenomena (these might be an isolated occurence or processes) with the help of observations of behavior and interactions, which objectively (in the sense of correlative) lead to accidents. And trying to do this can probably mean being on the wrong track.

One working group - group E - dealt with traffic conflict studies. One very promising approach here is the video analysis: interaction processes on defined locations can be recorded on video. An input algorithm on the basis of space-time - relations of traffic participants distinguishes between occurrences which comply with the definition of traffic conflicts (compare the article on this matter in this compilation) from the ones which do not. This is how one point for criticism is tuned down: namely that human observers are not able to estimate time and speed well enough and therefore cannot really judge whether an occurrence was "close", "only just worked out again", was dangerous or something similar to this.

What is also true in connection with traffic conflict technique is that the occurrences have to be seen as a part of the traffic participants' concepts for action on a strategical, tactical and operational level. The problem here again is to make these concepts understandable. As long as "scientific" proofs of the validity of observed/ registered processes are asked for - even of processes registered on video with the exact space-time relation - the way for more intensive work into the direction of the understanding of traffic processes while taking the characteristics of human thinking and acting into account as much as possible remains blocked .

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A SUSTAINABLE NETWORK OF TRAFFIC SAFETY RESEARCHERS

ICTCT stands for "International Cooperation of Theories and Concepts in Traffic safety". ICTCT was founded in 1979 because there was felt a need for cooperation in the area of behavioural studies, particularly conflict studies. Different techniques were developed during the seventies and comparisons and calibrations of these techniques were identified as important steps in the further development. Later on the scope of ICTCT was broadened and to-day focus is on theories and concepts in general in the traffic safety area.

One of the initators was Christer HYDÉN, now professor at the Department of Traffic Planning and Engineering at Lund Institute of Technology in Sweden. He has been the chairman of ICTCT since the start in 1979.

Those persons that originally founded ICTCT are still members and in addition quite a lot distinguished researchers have joined. Today no less than 17 countries are represented, covering Canada in the west to Japan in the east. It also includes researchers from a number of east European countries.

ICTCT carries through at least one workshop every year focussing on an interesting problem in the traffic safety area. Quite often special topics on theories, modelling or evaluation techniques are on the agenda. Every third year a large conference is organised, then around a broader theme. This conference in Salzburg is one of these. Eighteen countries participated, which guaranteed a wide variety of experiences and knowledge gathered.

The research front was pushed forward, ideas and experiences were questioned and discussed. The network was really alive!

One of the objectives of KFB - the Swedish Transport und Communications Research Board - is to be informed of where to find distinguished researchers and research teams around the world. In view of this, availability of a network like ICTCT is of greatest importance. KFB therefore joins the group of public organisations, research institutes, individual researchers etc. that already are members of ICTCT.

Thanks to this we can keep us informed in the important area of road user behaviour. At the same time we can meet in a forum where the conditions of research can be discussed, and valuable views and facts can be obtained from those countries represented. That this is not only so in theory is reflected by the fact that the Austrian Road Safety Board was prepared to organize this excellent congress in Salzburg together with ICTCT.

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THEORIES ON TRAFFIC SAFETY EVALUATION CONNECTED TO NEW ROAD TRANSPORT INFORMATICS (RTI)

1. Introduction

I will start my presentation by the following example:
Reflector posts is a common safety measure e.g. on two-lane rural roads. In a recent Finnish study on the safety effects of this countermeasure, among other results the following were obtained: On 80 km/h roads speeds increased in darkness and injury accidents increased by 60%. Why do I start with this? The main reason is that there are some important similarities with the topic of my presentation:

1/ Late evaluation; it seems as if evaluation always is too late. Reflector poles are already implemented in a very large scale in most European countries. The need for early attempts to evaluate the safety effects becomes obvious in light of the negative indications produced by the Finnish study.

2/ Similarities in concept; reflector poles aim at improving the 'dynamic' information to drivers. Many of the Road Transport Informatics (RTI) measures have similar objectives. The results of the Finnish study at least gives a hint that the strategy as such may not prove very successful from a safety point of view. On the contrary there is an obvious risk that the safety effect is adverse. The need for early evaluation is therefore urgent.

3/ Regarding both traditional infrastructural measures and RTI there seems to be a lack of preparedness for comprehensive safety evaluation. Regarding the latter this was clearly demonstrated in a screening of all DRIVE II projects that was carried out by the project HOPES. Very little was actually planned and the (necessary) involvement of safety experts in this process seemed to be lacking almost entirely.

In the following I will deal with the theories and concepts around evaluation of Road Transport Informatics (RTI). The presentation is almost entirely based on results obtained in the DRIVE II project HOPES - Horizontal Project for the Evaluation of Safety, which was started one and a half year ago.

DRIVE II is the second three year period of an EC-programme dealing with RTI. In this period the programme is primarily focusing on the testing of different concepts/-systems developed in the first three year period. HOPES had during the first year a number of work packages defining the framework for safety evaluation as well as the tools to be used. As improving traffic safety is one of the main aims of DRIVE, the importance of HOPES is self evident.

2. Some basic concepts

2.1 Road Transport Informatics (RTI)

Road Transport Informatics (RTI) is a collective term on efforts to introduce electronically based systems for communication between 'roads and vehicles' as well as between vehicles. Big efforts are right now made in almost all developed countries in the world. Europe has been very active, primarily through the EUREKA-programme PROMETHEUS and through the EC-programme DRIVE. In order to give a short but fair overview of the area I have chosen to present what is going on in the DRIVE-programme. DRIVE II is expected to result in field trials in a number of areas. These areas are classified in DRIVE as "main areas of operational interest". They are:

AREA 1: Demand management (road pricing, parking management, public transport and other services);

AREA 2: Travel and traffic information (travel information on alternative modes, road and weather conditions, tourist services, etc., traffic information, trip planning, navigation);

AREA 3: Integrated urban traffic management (integration of traffic control with public transport, of urban and interurban traffic control, etc);

AREA 4: Integrated inter-urban traffic management (incident and congestion detection, road condition monitoring, traffic prediction, etc);

AREA 5: Driver assistance and cooperative driving (driver task modeling, monitoring, supporting or assisting the driver);

AREA 6: Freight and fleet management (mobile data communication, hazardous goods monitoring and control, etc.);

AREA 7: Public transport management (bus priority, passenger information, fare collection systems, etc).

In many of these areas the novelty aspects are big. Concepts are new, both regarding the information transfer technique to the driver and in the means to obtain a change in road user behaviour. The demands on safety evaluation is therefore very big. In many cases earlier experience of similar techniques is very limited.

One particular implication of what is said above is that the objectives of ICTCT - to improve knowledge and understanding of traffic safety theories and concepts - is perfectly in line with the interests and needs in connection with safety evaluation of RTI.

2.2 Safety evaluation

The traffic system may be viewed as consisting of an interaction of the driver, the vehicle and the environment, where the environment includes e.g. the road, the weather, light conditions, road surface conditions and even other road users - vulnerable or not vulnerable. Each road user brings to this interaction a set of beliefs and attitudes which primarily arises from the socialization process.

The introduction of RTI into this interaction adds a new element to this process. It may change pre-existing patterns of behaviour, particularly when the system now acts as intermediary between the driver and other road users or the driver and the road environment. A RTI-system that provides information to the driver on road or traffic conditions or one that intervenes in the driver's control of the vehicle has the potential to make profound alterations in road user behaviour.

The DRIVE Safety Task Force in its Guidelines (1) stressed the need to assess the safety implications at three levels:

1. Systems safety (SS)
2. Man machine interaction (MMI)
3. Traffic safety (TS)

Systems safety deals with the reliability of hardware and software. The MMI level deals with the interaction between the human (i.e. the driver) and a number of elements describing the function of the machine (i.e. the vehicle). The complex interrelations can be described in the following way (2):

*"A specific **user** experiences a **problem** or has a **need** when performing a certain **task**. A technical help/support device is introduced, with which the user has to **interact**. The device has a specific **interface** and specific characteristics. An **evaluation** is necessary in order to reveal if the introduction of the technical device has solved the problem or met the need, and thus led to the anticipated improvement or satisfaction without negative impact on safety."*

As all six system elements included above indirectly could be related to safety issues, they have all to be considered in the design process.

Traffic safety, finally, is the overall safety effect of the system in actual operation. This paper will on-wards deal with the Traffic Safety effects only.

2.3 Traffic safety

The term 'traffic safety' is used in various ways by different people. The use depends often on one's view of the context of the questions to be answered. A politician probably wants to know the overall figures for a year or so, while a an average citizen refers to the danger to him or her (3).

In order to get a good picture of the complete safety problem, it is helpful to distinguish between three aspects:

1/ The threat to the individuals
2/ The feelings and behaviour of individuals
3/ The value attached to these two aspects

Given this background, the level of safety of a transport system can be described by the amount of threat imposed on its users, resulting from the risk of getting involved in an accident, with all its consequences. The description of safety is kept deliberately rather vague and not phrased in terms of a quantitative measure of the transport system, such as the total number of accidents, fatalities or injuries. Firstly because traffic safety is concerned with more than quantities; it also concerns the value attached to these quantities. Secondly, expected loss does not refer to the observed accidents of the past, but to the situation in the future. What matters is not how to describe the unsafe situations, but how to solve the safety problems, i.e. what kind of information from the past should be used to make the best decisions for the members of the society of tomorrow. Another major issue is how to make these persons aware of the real dangers in order to help them to act adequately in unsafe situations.

The term 'traffic risk' is sometimes used instead of traffic safety, and similarly different interpretations are used. Sometimes it is used as a synonym for danger and sometimes to denote the probability of an accident or instead of 'accident rate'. Generally speaking the term risk is used for the expectation of an unwanted event, or events, and their negative consequences.

One main problem with safety evaluation is that there is a long-standing policy of waiting to see what happens during the development of the transport system, and only to intervene when safety problems become obvious. This may be justified from the point that safety as such is very difficult to measure; only lack of safety may be detected afterwards as the occurrence of accidents. The focus on accident occurrence has, unfortunately, often been linked to a view that accidents are the outcome of a random process that cannot be 'controlled'. This is of course not true. Even though accidents are random events the **probability** of accidents varies considerably due to various factors, such as environmental factors, individual factors, etcetera. However, as accidents are rare events and accident conditions rather complicated, it is very difficult to give an unambiguous explanation why accidents occur or to give a reliable estimate from accidents in the past, of the probability of a particular type of accident in the future.

To conclude: it is obviously very difficult to assess how safe a measure in the Road Transport Informatics (RTI) area is likely to be in the real environment because the complexity of the task, and the uncertainties, are so great. There are three main reasons for this:

(1) accidents, the direct measure of safety, are relatively infrequent occurrences in terms of vehicle kilometers,
(2) large samples would be required to identify with reasonable confidence a modest improving or worsening of safety,
(3) it is often difficult to attribute the cause of an accident to a particular factor. This means that the safety aspects of RTI systems must be investigated by other means...

The implications of what is said above is that safety assessment of RTI must focus a lot on the use of intermediate measures instead of 'a simple use' of accident statistics only. This is of course nothing special for the area of RTI-implementations, but it is particularly urgent in this area because of the novelty character of many of the RTI-systems.

2.5 Traffic safety in its social context

We travel because of all kinds of benefits that we get from this. Against these benefits we weigh our possible losses, among which the probability of getting involved in an accident is a major concern which we want to minimize. This weighing of the benefits that we get from travelling against the (possible) losses, may cause people to decide not to travel, or to travel in an alternative way.

It is important to realize that one means for considerable improvements in traffic safety is the replacement of trips by alternative ones. A manager, responsible for the sound financial basis of a public transport system, may object against free travel by public transport for youngsters on weekend nights, but from a traffic safety point of view this could be a very effective measure and save a lot of lives. These societal benefits are hardly weighed in discussions about the costs of public transport systems.

Another example pinpoints another problem; if elderly people do not dare to go out in the streets, this of course have safety implications <u>not</u>, however, detectable by accident analysis. Still, we all agree that this is an example of a standard that we would not accept ourselves. Therefore, in evaluating traffic systems, we also have to take such possible negative side-effects into account.

A phenomenon that needs very special attention - and therefore is given special notice in my presentation - is the so called "behavioral adaptation". By an OECD scientific expert group (4) the phenomenon was defined in the following way:

"Behavioural adaptations are those behaviours which may occur following the introduction of changes to the road-vehicle-user system and which were not intended by the initiators of the change"

The experts reviewed a number of research projects and concluded that behavioural adaptation does occur although not consistently. The magnitude and direction of its effect on safety can not be precisely stated. However, the studies reviewed suggested that behavioural adaptation generally does not eliminate safety gains from programmes, but tends to reduce the size of the safety effects. They also concluded that it is more readily identified following vehicle and road system changes.

My interpretation is that behavioural adaptation is a critical element in the development of RTI. Up till now the principles introduced are - as I said before - rather similar to the ones tried in changes of the infrastructure. My example from Finland - i.e. the negative safety effects of reflector poles - therefore strongly supports the idea that behavioural adaptation can be of great danger for the safety outcome of RTI introductions.

To give some idea of the complex mechanisms behind the phenomenon I will briefly present some of the more important mechanisms:

Delegation of responsibility
If people consider situations to be uncontrollable, they get feelings of helplessness. They want to know who is "responsible" for certain events; they want to "delegate responsibility". In case of RTI the driver might delegate responsibility to the system. For example, a warning device may lead to the conclusion that it is no longer necessary for the driver to be making evaluations of potential hazards.

Behaviour diffusion and imitation
With new RTI-equipment, there is a danger that drivers of non-equipped vehicles will imitate the behaviour of equipped drivers. This could be a major problem with certain kinds of warning devices or vision-enhancement devices.

Isolation effects
Communication is an essential part of human society. In road traffic communication between road users is severely hindered for different reasons. New RTI-systems might reduce the opportunities even more; communication between driver and equipment would supplant communication between driver and other road users (other drivers or vulnerable road users).

The examples given clearly demonstrates the complexity of the problem. It also highlights the difficulties in detecting the problem and predicting the effects. There exist some different theories that try to describe the phenomenon of behavioural adaptation. The problem, however, is that they are neither validated against "safety" in any direct way, nor very operational in the sense that they can be used for predicting the effects of RTI-measures. Instead one must rely on more qualitative tools, such as the "PRO-GEN traffic safety checklist".

The social context of traffic behaviour can be called the 'traffic climate'. It reflects the quality of interpersonal communication on the road, including the safety of all partners involved, the fluency of traffic and the emotions of the users and by that the comfort of use. These aspects are often correlated. From a social-psychological point of view this traffic climate provides the most important preconditions for the willingness of road users to behave considerately and to meet other people's (safety) interests. Together with the traffic laws and the design of roads, interaction between road users is the basis for the smoothness of traffic processes. 'Smoothness' must not be confused with 'speed'. Traffic can move at a lower speed level as well, but it should 'move' for all road users and not only for cars. The traffic climate is based on communication, which is more than information exchange. These principles are very fundamental for the application of Road Transport Informatics. Supporting systems for car drivers must not disturb this communication process or violate the rights or expectations of the other road users, which might cause danger if neglected.

To conclude, the social context is something that has to be included in an evaluation procedure, otherwise there is a great danger that RTI will be directed in wrong directions causing new and severe problems for certain road user groups.

3. Safety evaluation strategy

3.1 The evaluation framework

A framework for the assessment and evaluation of traffic safety effects of ATT systems and the problems of man-machine interaction was elaborated during the first year of the HOPES project.

As a basic principle, it is important to understand that whether or not they are designed for safety reasons most ATT-systems that will be introduced will have an influence on safety. The influence may work through the user of the system (directly or indirectly), the drivers of other vehicles, vulnerable road users, or the whole traffic system in general.

Safety assessment/evaluation must therefore be a continuous process from the first idea of the system through design, prototype, field trial, partial implementation to the full-scale implementation. This process can be divided in two major parts:

1/ Prospective safety analysis, i.e. assessment in the design and pre-trial phases; before the real world implementation of the project. Prospective analysis is important because it should play the role of warning designers and implementers about possible negative safety effects before the pilot project stage. This may entail redesign or a change in strategy. Prospective analysis is also important in that it can raise issues and hypotheses for the retrospective safety analysis. In a new area, such as DRIVE, the retrospective evaluation can be made more efficient if it can be informed by hypotheses raised by an early audit process on the system or implementation (5).

2/ Retrospective safety evaluation deals with evaluation in the field trial and implementation phases, when the system is already implemented. This is safety evaluation in its more traditional meaning.

3.2 Main areas of possible safety impact

RTI systems may have impact on the safety of the users of the system as well as any other road user in many different ways. The mechanism of generating behavioural change and influencing safety by that can be extremely varied. Below is an attempt to describe and analyze the main groups, the main areas of possible safety impacts, based on the Guidelines for Planning Safety Evaluation (6). These areas cover frequently the secondary, side-effect of systems, that were not intended by the designer, and therefore the effect is quite often negative. The primary, deliberately aimed at safety effect e.g. by local speed enforcement, violation registration, etc. usually has a well defined hypothesis that should support the development of the system.

In the following of this chapter I will give a short description of the areas and how it can influence safety, systems that are likely to have such an effect, the level of field trial by which the safety impact on the given area can be tested, methods and tools that can be used for the evaluation of the possible safety impact, and indicators of the safety impact applicable on the area.

Direct effects of an in-car system on the user
Such direct effect can be expected from driver assistance systems (monitoring environment and road, monitoring driver, monitoring vehicle, vision enhancement, collision risk estimation, actuator control), navigation systems, route guidance systems and dynamic route information systems.

The general and direct influence of any in-car system on the driving task is that it will influence the distribution of attention used for the various aspects of driving. The addition of an RTI application into the often well-balanced man-machine-environment system formed by a driver in his/her car on the road, will change the distribution of attention and mental load. This change is very often aimed at, especially driver assistance systems, improving safety by having direct effect on the driver. Depending on the driving sub-task that is performed at a particular moment, the driving task can be, however, influenced also in a dangerous way. To formulate hypothesis about this influence with regard to a particular system various aspects should be taken into account.

It is possible to divide the in-car systems into two general classes: (1) systems that give only advice or information to a driver, and (2) systems that actually take over control. This division is not mutually exclusive, but may be used as the extremes of a scale. It is possible to hypothesize that the level of direct effect of a system on the driving task depends on the level of taking over control.

Evaluation may be carried out in an increasing degree of reality, step by step. Early in the design stage a mock-up study may be performed. This is especially advised for applications that use visual display and/or require the input if information by dials, buttons, touch-screens etc., since these modes of operation require much conscious attention of the driver in a way that normal driving already occupies. Further on simulator studies should be performed to assess the response of drivers to the application in situations that are controlled and set-up to provoke a systems reaction. Finally closed-track studies should be performed before the system is used in real traffic.

Various indicators are available within these testing methods, such as driving parameters, second-task performance, physiological measurements of attention, eye movement recordings, on-line verbal risk ratings etc. A well-balanced combination of indicators may be used to assess the impact of a system on safe driving and the driving task itself.

Direct effects of a road-side system on the user
Road-side systems that may have such a direct effect are e.g. navigation systems, dynamic route information systems. What holds for in-vehicle systems holds in general also for road-side systems. It may be hypothesized that these systems have a less profound impact on the driving task since they do only inform the driver about aspects of the driving environment, such as weather conditions, incidents and routing, or give an advice about a particular driving parameter. In case of an exchange between road-side and in-vehicle applications a hybrid situation may exist that combines aspects of both systems. For a road-side system only the situation may be compared with an in-vehicle system that gives advice and/or information by visual display. The same type of influence on driving behaviour may be hypothesized: a change in the distribution of attention and mental load, which may influence safe driving by interfering with the requirements of aspects of the driving task.

Even in this case evaluation should be carried out step by step during the whole cycle from design until production. This may be done by various mock-up and simulation / simulator studies, and later on in a closed-track study. Whenever possible a with-without comparison should be made with sufficient subjects of various age and experience level.

Efficient methods and tools are e.g. instrumented vehicles, behavioural observation, conflict studies at locations of road-side systems, simulator studies and on-line self-ratings, and indicators may be various measures of driving behaviour, secondary task performance, physiological indices of attention and mental load, and eye movement distributions.

Indirect, behavioural adaptation effects on the user
Examples for systems that may have such an effect are: hazard warning systems with monitoring environment, road and traffic (road surface, road geometry, visibility, road regulations, incidents), vision enhancement, collision risk estimation, driver and vehicle monitoring).

Behavioural adaptation can in practice appear in many different driving manoeuvres, in the change of following distance, way and frequency of overtaking, way and frequency of lane changing, change of speed, etc. It is especially important to take into consideration when behaviour adaptation is hypothesized and tested, that it is an effect that do not appear immediately when the environment is changed, but usually appears only after a settling in period.

Behavioural adaptation can be tested mainly in real environment, but also in controlled experiments. Examples on methods and tools that can be used are instrumented vehicles, behaviour observation, traffic conflict studies on the spot, and in-car, driving simulator studies, traffic safety checklist.

Indirect, behavioural adaptation effects on the non-user (imitation of the user)
First of all those systems may have such an effect which modify the behaviour or driving style of the equipped driver, such as: hazard warning systems with monitoring environment, road and traffic (road surface, road geometry, visibility, road regulations, incidents), vision enhancement, collision risk estimation.

Behavioural adaptation effects can apply not only to the direct users of a new RTI system, but also to non-users, who perceives some modification in the total traffic environment, and imitate the new way of driving of those who are assisted, warned or informed by the RTI system.

This kind of behavioural adaptation can be tested in real environment, where users and non-users of a system interact in an integrated traffic milieu. The same tools and methods as in the previous area apply here as well.

Modification of interactions between users and non-users
Systems that may modify interaction are: collision risk estimation by relative position determination, conflict zone monitoring, safety margin determination and critical course determination.

Communication between the different participants of traffic is an indispensable condition of safe road user behaviour. Some equipments could interfere with such communication in such a way that communication between driver and equipment would supplant communication between driver and other road users (other drivers, cyclists or pedestrians).

The modification of interactions can be tested in real environment, where users and non-users of a system interact in an integrated traffic milieu, e.g. with the help of instrumented vehicles, driver behaviour observation or traffic conflict studies.

Indicators: change of looking behaviour, change of eye-movement patterns, change of communication patterns, hazardous interaction situations.

Modification of accident consequences
Modification of accident consequences can be expected from accident detection systems, hazardous goods rescue service, emergency call management.

Improving traffic safety is possible not only by active safety measures, i.e. by systems that help preventing that accidents occur, but also by passive safety measures, i.e. by systems that decrease accident consequences by e.g. damping impacts, improving rescue, etc.

This kind of safety impact can be tested both in real environment and as a prospective assessment of expected safety effect, with methods and tools like in-depth accident analysis, analysis of accident patterns and Delphi method. Feasible indicators are e.g. accuracy of accident detection, speed of rescue activity.

Modification of exposure
Exposure can be modified by route guidance systems, demand restraints by area access restraints and road pricing and car pooling.

Traffic safety, i.e. the number of accidents occurring is highly dependent on the frequency and length of travel, i.e. exposure. RTI systems may have a strong impact on exposure, in both ways. Systems that influence queuing, the distribution of traffic over the network and the comfort of travel, may have an unplanned secondary effect of increasing travel demand, and by that influencing traffic safety.

Modification of travel demand can be tested in the real environment and also as a prospective assessment of change of people's attitude and behaviour, with methods and tools like traffic counts, interviews and questionnaires, gaming techniques.

Modifying modal choice
RTI systems that may have such an effect are first of all: demand restrains (area access restriction, road pricing, area parking strategies), supply control by modal interchange and other public transport management measures, travel information systems.

Different travel modes have different accident risks, therefore any measure which influences modal choice, has also impact on traffic safety.

Modal choice modification can be tested mainly in real environment, but also as a prospective assessment of expected impact by behaviour observation, traffic counts, interviews and questionnaires, Delphi method and gaming techniques.

Modifying route choice
RTI systems that may modify route choice are: demand restraints by route diversions, route guidance systems, dynamic route information systems, hazard warning systems monitoring incidents.

Different parts of the road network, i.e. different categories of roads, have different accident risks, therefore, any measure which influences route choice by diverting traffic to roads of different category, has also impact on traffic safety.

This kind of effect can be tested in real environment, but also in controlled environment and by modelling, by behaviour observation, interviews and questionnaires, and traffic models.

Modification of speed choice
Modification of drivers' speed can be expected first of all from hazard warning systems and driver assistance systems, such as monitoring environment, road and traffic (road surface, road geometry, visibility, road regulations, incidents), vision enhancement, collision risk estimation, driver and vehicle monitoring.

Speed choice of the drivers in different traffic situations has a tremendous effect on traffic safety, both by influencing the probability of avoiding an accident to occur in a critical traffic situation, and by having influence on the impact of collision and on the outcome of an accident. Speed choice is also crucial as a means by which the driver can trade safety for efficiency and vice versa, therefore modification of speed can be a sensitive indicator of safety impact of different RTI systems. The speed distribution characteristics, such as variation in speeds, are also safety relevant, because these influence the interaction between road users, even if the mean speed remains the same.

Change of speed can be tested mainly in real environment, but also in controlled environment, such as in driving simulator. Methods and tools are speed measuring, instrumented vehicles, behaviour observation, driving simulator studies.

4. Final comments

I hope I have made it absolutely clear that traffic safety evaluation is a very complex task. Solutions to evaluation problems are never easy to find and, particularly, the interpretation of results is filled with difficulties.

One major problem is the lack of proper understanding of the traffic process, road user behaviour included. It means also that the different elements and indicators are very seldom validated, especially as far as their importance for safety is concerned. So for instance one must ask what a decrease of focussed vision on a specific type of target actually stands for in any kind of safety related terms. And, what does increased heart rate mean in safety terms. The list can be made very long. Thus, these indirect indications are very difficult to interpret even individually. Therefore a proper evaluation must include a number of measures like the ones I mentioned. Then another problem of course pops up. What do these measures mean together. And what happens if one of them changes in a 'favourable direction' while others develop in a 'non-favourable direction'. Nobody actually knows. And, I think that we will never come to any final solutions to these problems. We simply have to increase our knowledge and understanding of the processes gradually and, also gradually, try to link our knowledge about the processes to how they are linked to 'safety'.

It is very important for all parties involved to understand what I tried to say above. For the practitioners it is important because they always look for "the easy answers" (is it 'good' or not?). The researchers must increase their attempts to operationalise and verify their attempts. In this area there is still a lot to do. The degree of multidisciplinarity is still not at all sufficient. Behavioural scientists work on their models and theories and engineers do the same, both in their own spheres. Just to give one example. I think it is necessary that the different disciplines more explicitly are forced to 'do the job together', i.e. to work on the same contract with the same objectives.

Road Transport Informatics has produced a kind of opening in this respect. Never ever before the demand for safety assessment and safety evaluation has been so big. This does not mean, however, that there will be a lot of proper safety evaluation but still, the demand is clearly outspoken. Let us in ICTCT keep on promoting the importance of safety evaluation, and let us also keep on working with the concepts themselves. Our role is definitely not less important to-day than it was ten years ago. On the contrary!!

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SUSTAINABILITY IN TODAY'S TRAFFIC IN THE NETHERLANDS

Introduction

Like any other major organisation, The Netherlands' Directorate-General for Transport has formulated a policy mission-statement. It comprises two themes: the care of the physical infrastructure and the care of the competitive position of The Netherlands as a transport and distribution centre in Europe.

The Directorate-General for Transport, which is the policy part of the Ministry of Transport, has two main tasks within this mission-statement:
- facilitating, managing and directing vehicle use by creating the right conditions in the transport sector;
- promoting safer transport.

The most important item on the agenda for the 1990s is the implementation of the "Transport Structure Plan", which was approved by Parliament in 1990. Road safety is an integral part of this, and this is set out in a special policy document on "Long Term Policy for Road Safety".

The general policy involves curbing unnecessary car use and promoting public transport and the bicycle, while maintaining the existing road infrastructure adequately. This means meeting demands and aspirations in an ever changing political, administrative and social environment. To implement this policy, therefore, wide public support from different interest groups is essential.

In western European countries attitudes to vehicle use, the environment, and amenity values are changing. The roles of the private car, public transport and freight are widely debated. Political and economic conditions are changing. Technological innovations are gathering pace, and the internal European market with its new competitive relationships is now in place. These developments present The Netherlands with both opportunities and threats. Economically, it is vital for The Netherlands that access to and from the main ports of Rotterdam-harbour and Amsterdam-airport continues to be guaranteed.

Present situation

The growth in car transport does not look like slackening. In 1950 the Dutch drove 6,210 thousand vehicle kilometres; by 1992 the figure had reached 97,500 thousand kilometres.

Transport problems are greatest in the conurbations in the west of the country - in the area known as the Randstad. Main road capacity here falls far short of demand in the rush hour, threatening accessibility to urban destinations. Business and freight traffic - particularly to the vital seaport at Rotterdam and airport at Amsterdam - suffers particularly because of the volume of commuter traffic.

Many people still do not regard public transport as a real alternative to the motor car. Longer journey times and the inconvenience of having to change are important factors in this perception. Public transport is not yet able to attract large groups of passengers. For too many people, the car remains the obvious choice.

Overcapacity and low profit margins have dogged the freight business for years. And the just-in-time principle is difficult to operate in the congested Randstad - 60% of companies report problems with traffic jams here compared with the national average of 40%.

Road safety continues to give cause for considerable concern. Acid rain affects the health of man and animals, and damages crops, woodland, buildings and materials. Motor traffic currently depends almost exclusively on oil-based fuels. In the long run, this will lead to the exhaustion of finite reserves of oil. And new road construction reduces wildlife habitats, which can lead to the extinction of some species.

Local authorities are not in a good position to solve transport problems. The authorities concerned are ill-equipped to solve traffic and transport problems. The latter are complex, and provincial and municipal councils do not have the expertise to deal with them. Solutions are elusive, and not all measures are equally easy to sell to a conservative public. The trend towards decentralisation also means that central government has less power over lower-tier authorities. And finally, the financial resources needed to implement an effective policy are becoming ever scarcer as the recession deepens.

If we do nothing

Forecasts of motoring trends and the concomitant increase in congestion are giving great cause for concern about accessibility not just in the Randstad, but also in other parts of The Netherlands. The root cause of congestion is the rapid growth in the use of the private car. If we do nothing, private car use will increase by 70% by 2010.

The sharp growth in car use is not a peculiarly Dutch problem - the same is true in western Europe as a whole. The United Kingdom predicts a growth of between 80% and 140% in the next thirty years. Planners in the Paris region assume that the number of daily journeys will increase from 21 million to 28 million in the next quarter century.

The increase in car traffic on the motorways is out of all proportion to the growth of transport as a whole. In general, the use of the relatively safe motorway network is to be welcomed. Relieving the burden on comparatively unsafe minor roads by transferring traffic to motorways is the right goal to aim for. The problem now is that the motorways are becoming congested. In the interests of economically vital links, we need to look again at the use of this infrastructure.

Forecasts show that over the next few years, traffic bottlenecks will extend further out from urban areas (especially in the vicinity of motorway interchanges) reducing the accessibility of urban destinations. A plot of future congestion probabilities looks like a series of ever larger circles centred on cities, and moving out to the edge of the Randstad.
Commercial vehicles have to cope not just with congestion on the motorway, but increasingly difficult access to industrial areas caused by delays on minor roads.

Both business users and commercial vehicles need fast and safe road links between economic centres. The connections between the main ports of Rotterdam and Amsterdam and the hinterland are particularly important. Given the importance of exports in the Dutch economy, and The Netherlands' position as the gateway of

Europe, good international links from the Randstad through Germany and Belgium to southern and eastern Europe are also vital.

Road haulage in the Netherlands is forecast to grow faster than private motoring. The tourist industry is also experiencing strong growth.

Poor access caused by congestion is detrimental both to the human environment (nature conservation and road safety aspects) and to the economy (affecting business location decisions and productivity). The Netherlands' position as a distribution centre for Europe hangs in the balance here.

Sustainable society

Given its geographical location and economic position within Europe, The Netherlands has a strong incentive to minimise or eliminate the problems outlined above.

Any strategy designed to solve the problem has to strike a balance between the demands of individual freedom, economic accessibility and the quality of the human environment.

The Netherlands now tests all policies against the yardstick of the sustainable society. In the sustainable society, all developments meet the needs of the present generation without compromising the ability of future generations to meet theirs. In the design of transport systems, this means that traffic problems and other problems to do with the human environment are not passed down to future generations.

This calls for a new vision of transport, a new policy, a different balance, and the political will to change. This new approach has been incorporated in the Transport Structure Plan. The plan is a distillation of the ideas of government and the public. Some 300 organisations, companies and key figures were consulted in its preparation.

The new policy entails setting limits to the adverse effects of transport growth - limits on air pollution, limits on land use, limits on energy consumption, and limits on road hazards. Transport policy should also continue to ensure good access, but not necessarily for the private car. Vehicle use therefore has to be influenced - mobility management in other words.

A sea change in thinking

In the past, the solution to traffic problems was deceptively simple. If new capacity was needed, it was built. The construction of facilities for road, water or public transport depended primarily on the amount of money available. Agreement on what should be built was usually reached via much shorter planning procedures than we have today.

With the Maastricht Treaty and the EC, we now have to contend with another set of competitive opportunities and threats. Having main ports like the harbour of Rotterdam and Amsterdam airport in The Netherlands has major consequences for Dutch transport policy.

Concern for the environment and amenity values are imposing new requirements which we must include in our consideration of the functioning of society as a whole. Dutch society and the way we run our country are changing rapidly with the trend towards decentralisation. Custom-made solutions to transport problems are necessary on a region-by-region basis, and the public expects to be given more say.

This means that the role of central government is also changing radically; it is becoming more of an enabling force at a distance, creating the right conditions.

With the Transport Structure Plan, The Netherlands is following a new road towards preserving the human environment in the long term. Instead of merely building more road capacity to meet traffic demand, the growth in traffic is to be curtailed in the interests of the environment. Traffic demands will not automatically be met for every means of transport. Selective expansion will be permitted only within the finite environmental space available.
The ministry's job is to ensure ease of movement within The Netherlands, while meeting the conditions for a sustainable society.

A major component of the access problem is commuter traffic in the rush hour. Government policy is therefore aimed particularly at achieving a more sensible use of the car and discouraging solo commuting.

Defining the task

As well as setting out its long term strategy, the Dutch government has defined objectives for the year 2010. The following most important tasks have been set:

- the 72% forecast for the growth in car traffic between 1986 and 2010 to be reduced to 35%;

- a target of 2% probability of congestion on the motorways from the main ports to Germany and Belgium by the year 2010; the target for other motorways is 5%;

- the car occupancy rate in commuter traffic to be increased from 1.2 to 1.6 persons by the year 2010;

- a restrictive parking policy to reduce motoring by 6%;

- an 30% increase of 3,500 million kilometres to be cycled by 2010, compared with 1986 figures;

- a 20% reduction by 2010 in commercial vehicle kilometres to be achieved by better transport management; by 1995 all companies and government departments employing more than 50 people to have a company transport plan;

- NOx emissions (contributing to acid rain) from private and commercial transport to be reduced by 75%;

- emissions of CO_2 (contributing to the greenhouse effect) to be 20% less per kilometre travelled;

- noise pollution from motor traffic to be at least 5 D(BA) less;

- half the number of road accident fatalities and 40% fewer injuries.

The tasks summarised here are examples and the complete overview is to be find in the Transport Structure Plan.

The approach

The Transport Structure Plan sets out five steps for achieving these targets. The overall objective is to guarantee The Netherlands' economic accessibility, both from outside and within the country in the year 2010 while preserving environmental and road safety standards.

1 Tackling the source
This means having the cleanest, most economical, safest and quietest vehicles possible and persuading people to drive in a way that promotes environmental protection and road safety. If we want to preserve amenity values in urban areas and prevent damage to wildlife areas, some areas must be out of bounds to motor traffic.

2 Reducing and influencing vehicle use
This involves reducing the distances people travel and influencing the modal split in favour of public transport, the bicycle and car pooling; so discouraging solo commuting. The methods include public information campaigns, land use planning and pricing policy.

3 Better alternatives to the car
For people, this means better facilities for public transport and better infrastructural provisions for cycling and car pooling. In freight transport, it means better facilities for rail, waterways and combined transport.

4 Selective access on roads
Infrastructural provisions for roads, waterways and railways are being reviewed for each major transport axis, in the light of The Netherlands' leading role in the transport and distribution sectors. In particular, the need for special road freight facilities is being examined. Priority is to be given to links with the German and Belgian hinterlands. In congested areas, special lanes are being provided for commercial vehicles, freight transport, buses and who car-pool.

5 Strengthening ancillary services
This involves improving essential services ancillary to transport such as communications, liaison with local authorities, financing and research.

This paper covers just some of the most important policy options, and not all of the Transport Structure Plan. First I would like to explain how vehicle use can be reduced by means of pricing policy and land use planning. Then I will look at private motoring - a problem being tackled with a package of measures including company transport plans, parking policy and the promotion of cycling. I will also say something about infrastructure policy, traffic management and traffic safety. Finally, I also shall describe how implementation of the Dutch policy is to be organised.

REDUCING AND INFLUENCING VEHICLE USE

Influencing the cost of journeys and bringing the workplace closer to home.
Making travel by public transport, combined transport and the bicycle more attractive than driving.

* *Pricing policy*
The current low price of vehicle use bears no relation to the true costs in terms of infrastructure use, the environment and health (including traffic accidents). The low price actually encourages greater vehicle use rather than curtailing it. While pricing policy is not an end in itself, it is an important device for influencing supply and demand in the mobility market.

Pricing policy is a generic term for a number of instruments used to affect vehicle use. The following developments are envisaged:

- Reduction of the growth in car use in general - the "volume" policy;

- Influencing vehicle use according to time and place - congestion management;

- Reducing the use of the private car as a means of transport.

As far as the private car is concerned, this translates into a real increase in the variable costs of motoring. On one hand, the motorist is encouraged to make more sensible use of the car in terms of the number of journeys made, the distances covered, and the way he or she drives; on the other hand there will be incentives for cleaner and more economical cars. Measures in this area include:

- higher taxes on motor fuel;
- a steady reduction in the parking space available in cities and at work, and more pay parking at higher rates;
- a rush-hour surcharge on certain roads in the Randstad to be introduced in 1996;
- greater differentiation in the price of new cars and road tax rates, favouring smaller, cleaner and more economical cars;
- tax incentives to promote car pooling;
- changes in commuter travel allowances.

The aim will be consistently to make car travel relatively expensive compared with public transport. The idea is that public transport should be cheap enough to encourage motorists to make the change.

**** Land use planning***
Careful land use planning can produce a more balanced distribution of traffic. By integrating land use planning and transport planning, car use can be controlled and infrastructure used more efficiently.

Planning measures can ensure that where people have to travel to work or to visit other facilities, there are good public transport connections. For companies, major government departments, large educational establishments and cultural centres, the availability of public transport should be a primary factor in the choice of location. Conversely, labour-intensive industry or amenities visited by large numbers of people should be discouraged from locating at sites reached easily by car but not by public transport. Three kinds of site are recognised in Dutch land use planning: A category sites are on a public transport link; B category sites can be reached either by car or by public transport; and C category sites are accessible mainly by car.

A category sites can be reached from considerable distances by public transport, and are situated at interchanges of train, metro, tram and bus lines; i.e. at main line stations. Parking at these sites is strictly limited to discourage people from driving to work.

B category sites are on public transport interchanges at urban or suburban level. They might be at suburban stations on the outskirts of major centres, or at the junction of several bus routes in a small town. Equally they could be just off a motorway exit. The amount of parking depends on the degree to which the businesses or amenities depend on the motor car.

C category sites impose no conditions on public transport, although collective forms of transport (car pooling and staff buses) are encouraged. These sites tend to be on the urban fringes.

This policy is already run jointly by central government, the provinces and the municipalities. They have at their disposal land use plans and planning law. Land use planning for businesses and amenities becomes a strategic means of influencing vehicle use. The aim is to make sites attractive for businesses looking for a site. The accessibility profile of the site is adapted to fit the mobility profile of the firms locating there. This is achieved through a careful selection of sites, and by guaranteeing good accessibility using public transport, collective transport or road transport. Planning applications for locations which do not contribute to a reduction in unnecessary private car use are opposed.

* *Transport management*

This means any activities undertaken by a firm itself to reduce unnecessary use of the private car. This applies both to commuting and business trips. The national target is to reduce this commercial component of traffic by 20% by 2010.

The following examples are ways of doing this already used to some extent:

- making as many service calls and business trips as possible by train and taxi;
- providing public transport season tickets for people who do not drive to work;
- providing a staff bus;
- requesting the bus company to bring the bus route nearer;
- providing car poolers with parking places close to the main entrance;
- providing company bicycles, wet weather clothing, changing rooms, showers, and bicycle sheds;
- nominating one member of staff as a full or part-time transport coordinator (there is a government subsidy for this).

Transport plans on these lines have already shown that reducing vehicle kilometres cuts costs because less travel allowance has to be paid.

* *Parking policy*

A planned parking policy is another effective way of reducing car use. Parking policy should go hand in hand with better alternatives to the car, such as the train, suburban services, the bicycle, car pooling and company transport. Parking policy is primarily a municipal matter, and should match the policy of the Transport Region concerned. Measures taken in this area should produce a reduction in the forecast growth of car kilometres between 1986 and 2010 of at least 6%.

These measures include:

- reducing the number of parking places available;
- charging higher parking fees;
- favouring short-term parking over long-term;
- giving car poolers and disabled people priority in parking;
- introducing more permit schemes for residents and inner-city businesses.

Replacing free parking with short-term pay parking is already a general trend.
The instruments for ensuring the proper social and economic use of parking places relate to numbers, price, location and time period.

The allocation of parking for the three categories of site described above is as follows: A category sites in the Randstad may only provide 10 parking places for every 100 employees; other A category sites (outside the Randstad) can have 20 places per 100 employees. For B category sites, the norm is 20 parking places per 100 in the Randstad and 40 elsewhere.

Revenues from parking fees go to Transport Regions, which use the funds to provide alternative forms of transport, such as public transport, commuter buses, supertrams, cycling facilities, Park-and-Ride pick-up points etc. Car-free areas can then be established, and expensive land in city centres can be used for higher value economic functions.

* *Cycling policy*

The bicycle is back on the political agenda. The bicycle is the second most used mode of transport in The Netherlands.
There are also great opportunities for increasing bicycle transport, especially for journeys up to 7km. Remember that 60% of all journeys in The Netherlands are shorter than 5km, and 45% of all car journeys are under this distance. Cars also

cause relatively more pollution over these shorter distances, particularly when the engine is cold.
The purposes of the bicycle policy can be described as following:

- to indicate a coherent central policy in order to stimulate bicycle traffic;

- to contribute to the development and implementation of effective measures;

- to stimulate other governments, institutions, public transport companies and other companies to take appropriate steps.

The objectives of the Transport Structure Plan refer to the changeover from car to bicycle, the changeover from car to bicycle and public transport, road safety, theft and promotion. The changeover from car to bicycle leads to the following objectives for the bicycle approach.

- The number of kilometres covered by the bicycle will be increased by 3.5 billion (30%) by 2010; this will account for 8.75 % of the desired reduction of motor traffic;

- the travelling time for cyclists to economic and crowd pulling centres will have been decreased by 20 % owing to the construction of short cuts by improved infrastructure;

- the travelling time by bicycles for distances up to 5 kilometres will be shorter or equal to those by car;

- by 2010 the number of journeys by bicycle in commuter traffic will be increased by 50 % compared with those in 1986;

- connections between bicycle routes and public transport will be improved.

Cycling policy is aimed at getting motorists to make greater use of the bicycle for these shorter distances. The cycling infrastructure must be adapted and expanded to achieve this. If more use is to be made of the bicycle in combination with public transport, cycling must be safer, better provision must be made for secure bicycle storage, and theft must be combated.

A lot of measures are in progress. Businesses can support this policy by providing bicycle parking facilities for their employees, sometimes in combination with the issue of free public transport season tickets. For example, all civil servants in the city of Apeldoorn are issued with bicycles worth NLG 1,000. This is part of the 1993 agreement with the unions on conditions of employment. Once a bicycle has been issued, the employee is no longer entitled to a car travel allowance. Employees who need to take work home are also issued with pannier bags.

A strong growth in bicycle use is forecast for the next few years.

ORGANISING IT

Central government policy is implemented by giving more powers to local authorities which are generally closer to the public.

*** Transport regions**
With the trend towards more and more decentralisation, the government would like to regionalise transport policy. A number of central government functions are therefore being transferred to new regional transport authorities. Traffic problems

and transport issues can then be tackled where they occur. Local knowledge in the regions will be indispensable for this.

A Transport Region is a cohesive functional and administrative unit for dealing with transport matters. Typically the Transport Region covers a territory where several municipalities have joined forces to work together on transport policy. Relations are usually good between the different tiers of government - central, provincial and municipal - and the regional authority works closely with the local business community.

Transport Regions draw up regional traffic and transport plans which relate national policy to local conditions, translating it into concrete measures. So local and inter-local public transport, infrastructure, traffic management, parking, road safety, cycling facilities, access for goods traffic and conformity with local planning will all be addressed at regional level. The regional transport plan is designed to guarantee the accessibility of the region and at the same time preserve amenity values.

Five functioning Transport Regions with their own regional plans have now been recognised and others are being set up. Eventually The Netherlands will have 28 Transport Regions.

Road infrastructure policy

As one of the means of ensuring continued access to economic centres, road infrastructure policy is an important aspect of the general Dutch approach.

The road infrastructure should enable road users to make fast and safe journeys in pursuance of their everyday economic and social functions. The aim is therefore to strike a balance between the function of the road, its design, and its use in relation to access to the infrastructural space. This means that infrastructure should be provided where it can make an optimum contribution to economic and social objectives.

The demand for infrastructure always exceeds supply. Nevertheless, we do try to match the two, and the trick is to provide the minimum amount of infrastructure that will satisfy the required mobility efficiently, without any of the disadvantages of congestion and loss of amenity value. The relationship between the main road network, minor roads and the urban environment is also important for a balanced road transport policy. Ultimately infrastructure proposals should be integrated into regional plans, together with other policy elements. Regional plans are, as we have seen, the means by which national transport policy is to be implemented.

Clearly it is not feasible to expand the road infrastructure to provide Dutch drivers - commercial and private - with completely congestion-free conditions by the year 2010. The few new road schemes planned will only reduce congestion marginally. Some congestion is unavoidable. We aim to clear the worst bottlenecks and fill some of the gaps in the motorway network.

The decision not to build a great deal of new road infrastructure is political and has been taken for the following reasons:

- The land available for new roads is limited, and roads already occupy a great deal of space in such a crowded country;

- More roads lead to greater fragmentation of the countryside; The Netherlands already has 240 m of roads for every square kilometre, compared with 230 m in Belgium, 160 m in Germany and under 100 m in Britain and France;

- Urban areas cannot cope with the extra traffic;

- It takes ten years to process planning applications for new roads, often in the face of fierce public opposition;

- New roads take a long time to build and only create demand for yet more roads;

- Financial resources are scarce and likely to become more so as the recession deepens.

All in all, we accept that a new road building programme will not solve the problem of congestion. Providing more roads just increases the demand. Government policy is therefore to curb the demand for more roads. Central to this is the policy of influencing the modal split by encouraging travel by public transport and bicycle instead of the private car. For investments in infrastructure, this policy translates into improving the capacity of the existing road network and making public transport faster and more efficient.

Existing roads will have to be used in innovative ways. The important point here is that delays must be predictable, whatever form the congestion takes. We can tackle this with better traffic information, using the radio for example. Being able to predict delays is particularly important for the increasing number of commercial hauliers operating just-in-time services.

Traffic management

Infrastructure policy is designed to ensure that traffic does not come to a complete standstill, and as such involves the quality of traffic systems.

To date, in facilitating infrastructural provisions very few attempts have been made to discriminate between different categories of road users. If costly infrastructure is to be put to the best use, this will have to be done in future to time and place and in considering target groups as car-poolers, freight transport and public transport.

It has also been accepted that the road system does not need to be completely free of congestion, provided that delays are predictable. This means that unexpected traffic jams should be minimised, and the road user should be provided with accurate information on journey times and possible delays. In other words, optimum use must be made of the road system with the quality of the journey matching different road users' expectations.

Dynamic traffic management and using a target group approach to control road use, will ensure that we get the most out of the existing road system.

Controlled use attempts to solve the problem of temporary limited capacity at bottlenecks. Methods of controlling use include motorway control and signalling systems, traffic jam advance warning systems, flexible route information, facilities for public transport such as buslanes, ramp-metering, traffic bulletins on the radio, dedicated lanes, fog detection and incident management. DRIVE programme projects should serve as examples.

The target group approach entails giving priority to economically important and environmentally friendly traffic over other vehicles which will have to sit in traffic queues for longer. Measures such as separate lanes for lorries, buses, business use, car pooling and taxis have to be custom-designed depending on time and place.

It is estimated that this combined approach could result in a 15% increase in the capacity of the main road network by 2010.

Central government has very little scope to influence matters, since with decentralisation lower authorities will be responsible for infrastructure in their own regions. Besides the relaying of knowledge and the development of new concepts, the role of central government will be mainly to set up and grant aid pilot projects. Central government will also be responsible for disseminating the results of these trials.

Clearly, infrastructure policy can only be implemented at regional level, and then it should dovetail with the secondary road network. For this reason, it will be up to the new Transport Regions to ensure good access and the proper functioning of the traffic system. National transport policy will in future be implemented via the Transport Regions. This will be the meeting point between wider general policy and specific measures for particular regions.

Road safety

Road accidents are one of the adverse effects of road transport. Over the years, accident prevention has received more and more attention as the danger of traffic has increased. However, most road safety campaigns have only addressed existing situations with regard to physical infrastructure or the behaviour of road users. In other words, only the symptoms have been treated.

The SWOV Institute for Road Safety Research has estimated the economic loss from road accidents in 1991 at 9,000 million guilders. NLG 7,000 million of this was actual loss and NLG 2,000 million was the cost of accident prevention. Actual loss is made up of damage to vehicles and infrastructure (57%), loss of production through premature death, injury or invalidity (32%), medical costs (6%) and other losses (5%).
These figures do not include losses incurred by businesses and hauliers as a result of the congestion and delays caused by accidents. These costs have been estimated at NLG 250 million. On top of that there are the costs of mostly long-term traumatic consequences and psychiatric treatment, which have been estimated at about NLG 1,000 million.

Investment in safe infrastructure therefore returns extra productive capacity to the system. Accident prevention costs money, but ultimately results in savings in real terms.

The traditional approach to road safety may have been necessary, but it certainly has not tackled the core of the problem - that of making the roads as safe as other forms of transport. Travel by rail or air is between 100 and 200 times safer than by private car. Safety standards in the workplace, in power stations, and in schemes designed to provide protection against natural disasters assume risk factors many times - sometimes thousands of times - smaller than the probability of death on the roads.

As policy-makers and researchers it must be our job to call a halt to the annual slaughter of 50,000 people and the 1.5 million serious injuries every year on Europe's roads. This is the equivalent of a town the size of Gouda being wiped out every year.

In recent years there has been a shift in thinking from tackling the symptoms to a more systems-oriented approach.

Sustainable safety

As noted above, sustainable safety is part and parcel of the sustainable society. And so the policy report on "Long Term Policy for Road Safety", for instance, is an essential part of the Transport Structure Plan.

Sustainable safety means that we think it is unacceptable to have an unsafe transport system and that it is equally unacceptable to saddle our children and their children with our appalling road accident statistics.

This implies that we have to incorporate safety in all policy areas that affect it, and not just look at the issue as an afterthought. Safety should be an integral part of the process right from the design stage, with the safety consequences of any design being evaluated automatically. Only then will we be able to achieve a systematic and planned approach, involving everyone at just the right moment. In these times when many matters relating to transport and road safety are being decentralised, we should be paying more attention to the management of resources, giving advice to other bodies, and keeping abreast of current knowledge. The new regional road safety bodies will be important in this context, since it is at regional level that national policy will be implemented.

The main aspects of policy on sustainable safety are as follows:

- Road safety is inseparable from other policy areas such as transport, planning, the environment, economic growth, education etc.; its objectives should therefore conform with those of other policies; safety depends especially on road infrastructure policy and here the government has a heavy responsibility to the road user; this responsibility will devolve to the authorities concerned with road management in the new Transport Regions;

- Roads will be classified more strictly and made safe for the particular function selected; the authorities concerned with road management in the new Transport Regions will be especially responsible in this field;

- More attention will be given to the potential for better active and passive safety features on vehicles; the car industry will be involved here;

- A new public education plan will be developed for modifying road user behaviour; the emphasis will be on better education and license for cyclists, moped riders, and car and lorry drivers, as well as road safety instruction in primary and secondary schools;

- Other spearhead policies which will continue to get attention include driving under the influence of drink or drugs, speeding, speed limiters (in 1994) on heavy goods and public service vehicles, road safety for cyclists and moped riders, the compulsory wearing of rear seat belts and the fitting of airbags;

- Methods of legal enforcement are being considered; other authorities have asked for a clarification on the conditions to be met by sustainable safety; guidelines backed up by legislation may become desirable in the future.

Road safety targets

The following targets have been set for road safety:

- the 1986 figure for road deaths should be reduced by 15% by 1995, by 29% by 2000, and by 50% by 2010;

- for road injuries the target reductions are 10% (1995), 27% (2000) and 40% (2010).

Achieving sustainable safety
As already noted, the design and construction of roads is a major factor in achieving sustainable safety. The infrastructure is after all the medium along which traffic moves, and which limits its flow.

Infrastructure is also a factor in the choice of transport (the modal split) and in the choice of route. It determines traffic behaviour to a large extent. Clearly then, we must pay a great deal of attention to the infrastructure in our approach to sustainable safety.

Sustainable road safety can only be brought about by applying the same standards that we apply to nuclear power stations, oil refineries, air travel and the railways. Measures need to be taken to relate the infrastructure and the rules for its use more closely to the characteristics of the road user. The policy should not simply address the individual components of the transport system -people, vehicles, roads, motoring law, and highway organisation - but rather should adopt an integrated approach. First, a relationship between function, design and potential conflicts needs to be established in order to minimise the risk of road users making mistakes. Then the road must be designed so that the seriousness of accidents which do occur is minimised.

The safe road traffic of the future will use an infrastructure designed to take account of the limits of human error. Vehicles will be fitted with devices to simplify the driver's job and will be built to protect passengers in an accident. Road users will be properly trained, informed and - where necessary - controlled.

The safe infrastructure will perform three functions:
- a flow function: dealing with through traffic rapidly;
- an access function : making other parts of town and the country easily accessible;
- a residential function: providing access to homes, shops and offices while ensuring that the street remains a safe place.

Each road type must be designed for optimum performance of the functions assigned to it, while also guaranteeing maximum safety. Different road types must conform to a common set of safety principles to minimise the chance of potential conflicts. The following three safety principles should be incorporated in all road designs:
- functional use: prevent unintended use of the function of that road infrastructure;
- homogenous use: prevent large discrepancies in vehicle speed, direction and mass at moderate and high speeds; reduce the possibility of serious conflicts in advance;
- predictable use: prevent uncertainty amongst road users and enhance the predictability of the road's course and people's behaviour on the road.

The concept of sustainable safety demands that roads be designed for their particular function. Functional mixes - flow, link and local functions together - are to be avoided. To ensure that use and behaviour are predictable, each road type should have a distinctive design. Roads will have to be classified for a strictly limited number of functions. The design of junctions should also be such that road users recognise immediately which categories of traffic are involved. Lane definitions, road markings and traffic control systems must be unique to a particular classification of road or junction. Each road class should also have a strict speed regime; the road infrastructure should induce correct behaviour from users automatically.

Only motorways, pedestrian priority areas in city centers, woonerfs and 30 km/h zones currently meet these functional requirements, ensuring adequate safety. Dutch accident statistics show that urban arterial roads and rural roads are respectively 20 times and nine times more dangerous than motorways.

Simply formulating policy objectives for road safety in regional transport plans is no guarantee that the ultimate project proposal will meet the requirements. Too often, road safety is pushed into a later phase of the project with the result that the consequences and real costs only become apparent then. Road safety ought to be an explicit component in an integrated approach just as much as, say, the environment is. Large-scale infrastructure projects in The Netherlands ought to be subject to a mandatory "road safety impact assessment" similar to the legal "environmental impact assessment".

A mandatory safety impact assessment would provide a better understanding of the consequences of a particular policy. Given the importance of the government's role in large-scale infrastructure projects, a road safety assessment would only be useful if safety aspects were approached from several standpoints. Other interests would have to be considered, and public consultation would be an essential part of the process.

A road safety assessment should be a reasonably powerful and effective tool. The need for such an assessment arises because policy alone does not offer a sufficient guarantee of the safety aspects of a road design.

Pilot projects

As we have seen, the government now has less opportunity to direct the regional transport programme because of increasing decentralisation. Responsibility for implementing national policy is being delegated to the regions where the problems exist, and central government funds are being transferred to those authorities involved. The government's role is increasingly an "enabling" one - creating the right conditions by the following means:

- collection and dissemination of knowledge;
- modest support for innovative projects;
- running pilot projects which will subsequently have a wider application as part of regional transport plans. Financial support here will also be modest;
- evaluating regional transport plans in the light of aspects of national policy such as reduced private car use or better road safety;
- setting prices, taxes, motoring regulations and standards nationally.

Clearly, well designed pilot projects will give a strong stimulus to the regions to carry out central government policy. Imitation, after all is the sincerest form of flattery. Consequently the government is now working on several projects designed to translate the concept of sustainable safety into concrete measures.

Some examples follow.

A. Principles of sustainable safety being applied on national highway 57 in the province of Zeeland. This is a two-lane regional road (not a motorway) with several conflicting functions. Besides its main function for through inter-regional traffic, highway 57 has a link function for the district, and a local function for agricultural vehicles which need to reach adjacent farmland. This mix of functions is the main cause of the large number of accidents on the road.

Safety on this link road is first evaluated by testing the entire regional road network against the three principles of road safety design listed above. The function of highway 57 is then decided in consultation with the regional authority. Next, new design features are incorporated to eliminate potential conflicts - head-on collisions, side collisions, collisions between fast and slow moving traffic etc. Forecasts are made of the effect of a number of different designs.

B. Sustainable safety on 80 km/h roads.
This class of road is infamous for its dangers. Other factors play a role here in addition to the mix of functions. Sudden changes of direction or speed arise because of ungraded T-junctions where drivers meet oncoming traffic. Different road users, moving at vastly different speeds and with different degrees of manoeuvrability use the same traffic space. SWOV has carried out a number of theoretical studies designed to improve road safety on this class of road.

The following pilot projects were set up to support the role of the transport regions in implementing national policy.

C. Sustainable safety in Utrecht and Arnhem-Nijmegen transport regions.
Experiments are being carried out in these two transport regions into ways of incorporating road safety explicitly in road planning and funding priorities, in the same way as environmental or accessibility aspects. A checklist and simulation models of the impact of transport plans are being developed as planning tools. A first rough checklist is already available, and this is being improved in the light of experience.

D. Prototype study of Arnhem-Nijmegen transport region.
A study of sustainable safety is being carried out for all classes of road in the entire transport region. This study will eventually lead to recommendations on road safety, and should serve as a model for similar studies in other transport regions. The following is an outline of the design of the study:
- drawing up a theoretical road network that would serve the needs of future traffic flows; this involves a knowledge of vehicle provenance and journey destination, reason for travelling, and the mode of transport; the three primary functions of roads - flow, link and local - are used here; one of the most important results in this phase is producing a set of criteria to assist with road classification and design;
- comparing the actual network with the ideal network; this highlights potential problem areas, which might be missing links in the network or unsuitable road functions; this is done using existing information about present use; the ideal road network as seen from a road safety point of view is then compared with the draft plan for the Arnhem-Nijmegen transport region; the inevitable compromise will be the target scenario; the discussions which take place in this phase in the planning process are part of the learning curve;
- further improvement of the existing road network from the point of view of road safety; this will lead to a list of supplementary measures to guarantee safety and the proper use of the road network;
- predicting the safety effects and calculating the cost-effectiveness of the package of measures proposed;
- implementing the measures over a five-year period;
- finally, the whole process will be evaluated and recommendations made for sustainable safety in other Transport Regions.

Progress so far

It remains government's job to evaluate policy in practice and make any necessary adjustments. The first evaluation of the Transport Structure Plan took place in June this year, with the following results:
- the present set of measures will produce the 35% target reduction in the growth of car use by 2010; without any change in policy the increase would be 70%;

- congestion will not improve sufficiently to meet the objectives; rather, there will initially be a marked increase in congestion although in the Randstad this will be limited because of the introduction of a rush-hour surcharge in 1996;
- forecasts for the growth in rail travel give lower numbers of passengers than predicted;
- a slight fall in the number of passengers on urban and suburban transport is expected;
- bicycle use will increase sharply;
- freight transport by rail and inland waterway will increase sharply. Road haulage will increase by 110%, against an estimate of 42%;
- target NOx reductions will be achieved for private cars, but not for lorries;
- CO_2 emissions from road traffic will remain above target and give cause for concern.

The results for road safety are as follows:
- road safety improved in 1991 and 1992, with fewer deaths and injuries requiring hospital admission; the reasons for the fall were mainly the use of seat belts and technical improvements to vehicles; the total of all injuries caused on the roads appears not to be decreasing;
- target scenarios for the year 2000 will probably be achieved by measures already set in motion; however, these measures alone will be inadequate to meet the targets for 2010;
- target scenarios for road safety in the year 2010 will only be reached by introducing measures of sustainable safety; extra effort is therefore required to achieve a rapid translation of sustainable safety into concrete plans and measures.

Cooperation from many different groups will be required, especially the new Transport Regions. These authorities must incorporate plans for sustainable safety in their planning. This is already happening, albeit on a modest scale.

Conclusions

- The first point to note is that the new policy enjoys wide public support in The Netherlands. A recent study showed a large majority of people are aware of the problems caused by the motor car. More than 85% of people believe that environmentally friendly forms of transport should get priority if a choice has to be made between cars, public transport, bicycles and pedestrians. The same picture emerges for measures to restrict car use and parking in city centres; a small majority is even in favour of raising the cost of car use. In other words, the public has undergone a revolution in thinking and there is support for the new transport policy.

- Three major problems will face us in transport in the second half of the 1990s. First, the growth in traffic volumes around major centres will overload the road network. Secondly, access to major economic centres will be threatened. This applies not just to the Randstad in the Netherlands, but to other European centres such as Paris, Hamburg, Antwerp and Milan as well. Thirdly, road haulage is set to double.

  Solving these problems is not just a matter for transport engineers. Other professionals are needed, such as road safety experts. In the short term we need measures to increase capacity using dynamic traffic management and better road classification. This would allow us to tackle the access problems and would produce road safety benefits.

- It is possible to create a road transport system in The Netherlands with a lower accident risk and lower probability of serious injury in those accidents which do occur. SWOV believes that such a system is possible even with the present state of knowledge and current levels of investment.

On this basis, sustainable safety could be achieved within thirty years. Pilot projects currently being carried out in the Netherlands also indicate that the transport system with sustainable safety is possible. SWOV's forecasts indicate that road deaths can be reduced to less than 10% of the present figure and injuries to less than 20%, assuming a 35% growth in traffic between 1986 and 2010.

By investing in road safety, the economy receives a return in the form of extra productive capacity. Investment in road safety costs money but has an economic return.

For road safety policy to be effective, it is recommended that a legal road safety impact assessment be made to test the regional transport plans. This is necessary because simply including a policy on road safety in the transport programme is not a sufficient guarantee that the final design will have no adverse consequences for safety. In this way, unacceptable safety risks can be identified. The assessment will also help in striking the balance between the costs of accessibility, the needs of the environment, and road safety.

- If this is possible in The Netherlands, then it must also be feasible in other countries. This could be a job for FERSI, the joint forum of European road safety research institutes with already twelf member-countries of the EG and EFTA and which envisages scientific collaboration in the transport field. One of the aims of FERSI could be to elaborate the concept of sustainable safety, both at the common level and for each member state, influencing policy makers and administrators, and so radically improve road safety in Europe.

- A recent development was the setting up in April of this year of the European Transport Safety Council (ETSC). The members so far are the Dutch Council for Road Safety (Raad voor de Verkeersveiligheid), the German Council for Road Safety (Deutscher Verkehrssicherheitsrat DVR), and the British Parliamentary Advisory Council on Transport. Their job is to advise European authorities on transport safety. Working with this organisation will be essential if the various national governments are to create the support they need for a safer Europe.

And finally, it is my strong opinion that ICTCT has to make the step from being a scientific board for road safety research and information dissemination to become a lobby for influencing the European channels of FERSI and ETSC in realizing that road safety comes back on the European agenda!

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ANNEX. Summary of policy and measures in the Transport Structure Plan

OBJECTIVE	MEASURE
Reduce vehicle use	Pricing policy for cars - raising fuel taxes - raising road tax - rush-hour sticker - parking fees Teleworking Planning policy - conditions for business location - fewer parking places Public transport interchanges Cycling policy Promoting public transport
Influencing vehicle use	Redesigning urban areas - residential areas with low car density Staggering-commuting/shopping/delivery times Traffic management Suburban public transport Train taxis/teletaxis Parking policy Urban freight distribution centres
Increasing vehicle occupancy	Higher load ratios on commercial vehicles Freight cabotage Car pooling Rush hour buses
Increasing road capacity	Traffic management - control and signalling systems - ramp metering - interchangeable lanes - limited access roads - electronic route information - incident management - radio traffic bulletins - fog warnings Traffic management target group approach - separate lanes for commercial vehicles/ car pooling/bus/taxi
Organisation	Transport regions Legislation - planning regulations - road planning act - town plans/land use planning Finance - Infrastructure Fund

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POSSIBILITIES AND LIMITATIONS OF ACCIDENT ANALYSIS

1. Introduction.

This paper is primarily based on personal experience concerning traffic safety, safety research and the role of accidents analysis in this research. These experiences resulted in rather philosophical opinions as well as more practical viewpoints on research methodology and statistical analysis. A number of these findings are published already elsewhere. References or (adjusted) citations will be given. The purpose of this paper is to describe my personal view on the possibilities and limitations of accident analysis.
The more philosophical remarks are primarily concerned with the role that accident analysis plays for policy makers and practitioners in the process of traffic safety improvement, as opposed to its role in traffic safety research.

The traffic safety problem was originally a national health problem, initiated by the societal concern with the consequences of modern motorized traffic as shown by the accident statistics. This data, together with the background of safety as a health problem, led to the epidemiological approach: the safety problem was some kind of social sickness, spreading like a disease. The main concern was to find the agent and to cure society from the disease. This background makes it clear that traffic safety was not a scientific problem in the first place, but a problem for practitioners.
The historical background of road safety is also the reason why so much of the safety research is based on national accident statistics. These statistics are not collected for research purposes, but to monitor the process of traffic development and its safety consequences. On this basis the safety problem in general was raised and many specific problems identified.
The scientific expertise was needed to justify actions and to decrease the uncertainty of decision making. This puts the scientist in an uneasy position. He becomes an advisor instead of a researcher. He hardly gets knowledge of results to check the scientific value of his advise, but at the most only its practical value.

It is not a contradiction to state that, although there has been a lot of progress in the field of traffic safety, there is little progress in traffic safety research. Most of the well-established facts in safety literature have more practical than scientific value. E.g. the statement: "the group of bicyclist between 11 and 14 years is most liable to accidents", although of great practical importance, has hardly any scientific value. It is a call for action: "What are we going to do about it?" It is not a fact that originates from a problem analysis of accidents, or to falsify a hypothesis about their causes, but at most a trigger to stimulate thinking. This is contrary to the ordinary scientific approach.
Science raises from curiosity about phenomena in the real world. Each particular science focuses on a particular aspect of reality, called its object of study. Scientific research starts with systematic and repeated observation of this object. From reflection on these observations it develops a theory, to explain why the observations are as they are and to predict what will be observed in new situations.
Traffic safety continuously asks for social attention, although at the individual level, practitioners and researchers are rarely confronted with accidents. Contrary to regular

scientific practice, traffic safety scientists will only rarely and surely not systematically observe their object of research, the accident, but almost exclusively investigate the documentation on accidents. This documentation is also not based on direct observation of the object itself but on data that has often been collected considerably long after the accident took place. In this respect, traffic safety research is more similar to the science of history than to the natural sciences.
From this lack of direct observation of accidents, a number of methodological problems arise, leading to continuous discussions about the interpretation of findings that cannot be tested directly. For a fruitful discussion of these methodological problems it is very informative to look at a real accident on video. It then turns out that most of the relevant information used to explain the accident will be missing in the accident record. In-depth studies also cannot recollect all the data that is necessary in order to test hypotheses about the occurrence of the accident.

For a particular car-car accident, that was recorded on video at an urban intersection in the Netherlands, between a car coming from a minor road, colliding with a car on the major road, the following questions could be asked:
Why did the driver of the car coming from the minor road, suddenly accelerate after coming almost to a stop and hit the side of the car from the left at the main road?
Why was the approaching car not noticed? Was it because the driver was preoccupied with the two cars coming from the right and the gap before them that offered him the possibility to cross? Did he look left before, but was his view possibly blocked by the green van parked at the corner? Certainly the traffic situation was not complicated. At the moment of the accident there were no bicyclists or pedestrians present to distract his attention at the regularly overcrowded intersection.
All the elements mentioned in this explanatory reasoning will not be registered in the documentary file and cannot be recollected afterwards by in-depth investigation or otherwise. The parked green van disappeared within five minutes, the two other cars that may have been important left without a trace.

It is hardly possible to observe traffic behaviour under the most relevant condition of an accident occurring, because accidents are very rare events, given the large number of trips.
Given the new video equipment and the recent developments in automatic incident and accident detection, it becomes more and more realistic to collect such data at not too high costs.
Additional to this type of data that is most essential for a good understanding of the risk increasing factors in traffic, it also important to look at normal traffic behaviour as a reference base.

The question about the possibilities and limitations of accident analysis is not lightly answered. We cannot speak unambiguously about accident analysis. Accident analysis covers a whole range of activities, each originating from a different background and based on different sources of information: national data banks, additional information from other sources, specially collected accident data, behavioural background data etc.
To answer the question about the possibilities and limitations, we first have to look at the cycle of activities in the area of traffic safety. Some of these activities are mainly concerned with the safety management of the traffic system, some others are primarily research activities.

The following steps should be distinguished:
- detection of new or remaining safety problems;
- description of the problem and its main characteristics;
- the analysis of the problem, its causes and suggestions for improvement;
- selection and implementation of safety measures;
- evaluation of measures taken.

Although this cycle can be carried out by the same person or group of persons, the problem has a different (political/managerial or scientific) background at each stage. We will describe the phases in which accident analysis is used. It is important to make this distinction. Many fruitless discussions about the method of analysis result from ignoring this distinction.

Politicians, or road managers are not primarily interested in individual accidents. From their perspective accidents are often treated equally, because the total outcome is much more important than the whole chain of events leading to each individual accident. Therefore, each accident counts as one and they add up all together to a final safety result. Researchers are much more interested in the chain of events leading to an individual accident. They want to get detailed information about each accident, to detect its causes and the relevant conditions. The politician wants only those details that direct his actions. At the highest level this is the decrease in the total number of accidents. Accidents are no object of study for him, but units to manage in total. The main source of information is the national database and its statistical treatment. For him, accident analysis is looking at (sub-groups of) accident numbers and their statistical fluctuations.
This is the main stream of accident analysis as applied in the area of traffic safety. Therefore, we will first describe these aspects of accidents.

2. The nature of accidents and their statistical characteristics.

The basic notion is that accidents, whatever there cause, appear according to a chance process. Two simple assumptions are usually made to describe this process for (traffic) accidents:

- the probability of an accident to occur is independent from the occurrence of previous accidents;
- the occurrence of accidents is homogeneous in time.

If these two assumptions hold, then accidents are Poisson distributed.
The first assumption does not meet much criticism. Accidents are rare events and therefore not easily influenced by previous accidents. In some cases where there is a direct causal chain (e.g. , when a number of cars run into each other) the series of accidents may be regarded as one complicated accident with many cars involved.The assumption does not apply to casualties. Casualties are often related to the same accident and therefore the independency assumption does not hold.

The second assumption seems less obvious at first sight. The occurrence of accidents through time or on different locations are not equally likely. However, the assumption need not hold over long time periods. It is a rather theoretical assumption in its nature. If it holds for short periods of time, then it also holds for long periods, because the sum of Poisson distributed variables, even if their Poisson rates are different, is also Poisson distributed. The Poisson rate for the sum of these periods is then equal to the sum of the Poisson rates for these parts.
The assumption that really counts for a comparison of (composite) situations, is whether two outcomes from an aggregation of situations in time and/or space, have a comparable mix of basic situations. E.g., the comparison of the number of accidents on one particular day of the year, as compared to another day (the next day, or the same day of the next week etc.). If the conditions are assumed to be the same (same duration, same mix of traffic and situations, same weather conditions etc.) then the resulting numbers of accidents are the outcomes of the same Poisson process. This assumption can be tested by estimating the rate parameter on the basis of the two observed values (the estimate being the average of the two values). Probability theory can be used to compute the likelihood of the equality assumption, given the two observations and their mean.

This statistical procedure is rather powerful. The Poisson assumption is investigated many times and turns out to be supported by a vast body of empirical evidence.
It has been applied in numerous situations to find out whether differences in observed numbers of accidents suggest real differences in safety. The main purpose of this

procedure is to detect differences in safety. This may be a difference over time, or between different places or between different conditions. Such differences may guide the process of improvement. Because the main concern is to reduce the number of accidents, such an analysis may lead to the most promising areas for treatment.
A necessary condition for the application of such a test is, that the numbers of accidents to be compared are large enough to show existing differences. In many local cases an application is not possible. Accident black-spot analysis is often hindered by this limitation, e.g., if such a test is applied to find out whether the number of accidents at a particular location is higher than average.

The procedure described can also be used if the accidents are classified according to a number of characteristics to find promising safety targets. Not only with aggregation, but also with disaggregation the Poisson assumption holds, and the accident numbers can be tested against each other on the basis of the Poisson assumptions. Such a test is rather cumbersome, because for each particular case, i.e. for each different Poisson parameter, the probabilities for all possible outcomes must be computed to apply the test.
In practice, this is not necessary when the numbers are large. Then the Poisson distribution can be approximated by a Normal distribution, with mean and variance equal to the Poisson parameter. Once the mean value and the variance of a Normal distribution are given, all tests can be rephrased in terms of the standard Normal distribution with zero mean and variance one. No computations are necessary any more, but test statistics can be drawn from tables.
In practice the Poisson test is hardly ever carried out. Almost always the Normal approximation is used for testing. For small numbers of observations, the exact Poisson test is sometimes applicable if the Normal approximation is not. Since computers have taken over the computations, the labour involved in applying such tests is not a serious limitation any more.

There is another reason why Poisson tests are seldomly applied. If a number of Poisson variables with different Poisson parameters, are compared, another characteristic of Poisson variables can be used. As such, each of the Poisson processes under investigation results in a particular outcome. For many replications of the process, different values are found, that together follow the Poisson distribution. As said before, the sum of the Poisson outcomes for all the variables together in each replication is also Poisson distributed. The outcomes for this sum for the replications together follow again a Poisson distribution.
If a sum is known, then the outcome for each variable is restricted (for each variable it can never be larger than this sum). In such a case we speak of a conditional distribution: what is the probability of a particular outcome for a (Poisson distributed) variable, given that we know the (Poisson distributed) total?
This conditional distribution turns out to be the well-known multinomial distribution.
It is the distribution that describes the placement of a fixed number of balls (accidents) over a fixed number of boxes (accident conditions), each with its own probability of getting a ball placed. This probability is then equal to the ratio between the Poisson parameter for the condition and for the total.
This multinomial distribution plays an important role in testing, and is e.g. applicable to outcomes of questionnaires. The number of questionnaires is fixed but not the distribution of responses over the response categories.Because of the special relation to the Poisson distribution, tests that are based on this distribution can also be used for accident analysis.The well-known Chi-square test, used in testing accident outcomes, is applied on the assumption of multinomially distributed objects. Multinomial tests are also cumbersome to apply, but in practice, if the numbers are large enough, an approximation is possible again, using the Normal distribution. The Chi-square test is in fact a test based on the joint distribution of Normal variables. In case of small numbers exact tests can be applied, but if these numbers are too small, also exact tests will not do.
The Chi-square test on two-way tables of accident numbers is one of the most applied types of analysis. In this case the additional assumption to be made is that the Poisson probability for a cell is the product of that probability for the row and column to which

this cell corresponds. If this is true for all cells, then the row and column variables are independent and cell-entries do not add extra information. The Chi-square test is therefore based on a multiplicative assumption for row and column counts.
Because of its restricted applicability, it was not popular with researchers, until the seventies. The popularity increased strongly after the extension of the Chi-square test to a log-linear test on multi-way tables.

3. The use of accident statistics for traffic safety policy.

The testing procedure described has its merits for those types of analysis that are based on the assumptions mentioned. The best example of such an application is the monitoring of safety for a country or region over a year, using the total number of accidents (eventually of a particular type, such as fatal accidents), in order to compare this number with the outcome of the year before. If sequences of accidents are given over several years, then trends in the developments can be detected and accident numbers predicted for following years. Once such a trend is established, then the value for the next year or years can be predicted, together with its error bounds. Deviations from a given trend can also be tested afterwards, and new actions planned. There is a long tradition of accident analysis that concentrates on the description of such trends. The most famous one is carried out by Smeed 1949. We will discuss this type of accident analysis in more detail later.

Another area of application is the disaggregation of the total number of accidents according to aspects of interest. The monitoring in general is not restricted to the total number of accidents, but comparisons are made between groups of accidents. The dominant technique for this kind of accident analysis is contingency table analysis. The application of a Chi-square analysis to contingency tables is already mentioned.
Such comparisons, if based on absolute numbers are generally restricted in their use. It is not interesting to know that more accidents happen in daytime than at night, because most people travel during daytime. One wants to know whether a trip at night is more dangerous than the same trip during daytime. To make a sensible comparison, one should compare traffic risk at day and night; therefore, the accident numbers must be weighed for the amount of exposure to such risks.

A main break through in contingency table analysis took place at the end of the sixties and the beginning of the seventies. Then it was realized that the multiplicative model, used to analyze two-way tables, could be treated as a linear model of the log-counts.
Statistical properties of parameters, which are linear combinations of observed random variables, are easily defined in linear models. The nicest generalization is found in Nelder and Wedderburn (1972), who made a distinction between (1) the (linear) model description of the data, (2) the link-function that relates the dependent variable to the model description and (3) the error function that takes care of the stochastic variation in the model. Different choices lead to different models, all united in the context of general linear models.
There are a number of standard textbooks available on log-linear analysis of contingency tables. Their application to road safety is treated in Fleischer 1981.

There are four main developments in recent contingency table analysis:

1. The application of the Chi-square test for interaction is generalized to higher order classifications. Foldvary and Lane (1974), in measuring the effect of compulsory wearing of seat belts, were among the first who applied the partitioning of the total Chi-square in values for the higher order interactions of four-way tables.
2. Tests are not restricted to overall effects, but Chi-square values can be decomposed regarding sub-hypotheses within the model. Also in the two-way table, the total Chi-square can be decomposed into interaction effects of part tables. The advantage of 1. and 2. over previous situations is, that large numbers of Chi-square tests on many interrelated (sub)tables and corresponding Chi-squares were replaced by one analysis with an exact partioning of one Chi-square.

3. More attention is put to parameter estimation. E.g., the partitioning of the Chi-square made it possible to test for linear or quadratic restraints on the row-parameters or for discontinuities in trends.
4. The unit of analysis is generalised from counts to weighted counts. This is especially advantageous for road safety analyses, where corrections for period of time, number of road users, number of locations or number of vehicle kilometres is often necessary.

The last option is not found in many statistical packages. Andersen 1977 gives an example for road safety analysis in a two-way table. A computer programme WPM, developed for this type of analysis of multi-way tables, is available at SWOV (see: De Leeuw and Oppe 1976).

The accident analysis at this level is not explanatory. It tries to detect safety problems that need special attention.
The basic information needed consists of accident numbers, to describe the total amount of unsafety, and exposure data to calculate risks and to find situations or (groups of) road users with a high level of risk.
Smeeds analysis was concerned with these two aspects of the problem. His approach was descriptive: he was looking for regularities in accident numbers and corrected these numbers for exposure, using population and car park figures. And although Smeed himself did not claim to have found more than an empirical relation, there was a strong tendency to interpret it as a model for predictions.
From the beginning onwards his model got a lot of criticism, because it was purely descriptive and did not give an explanation for the relations and trends that were found. It was argued that such an explanation is necessary to justify a model even at this highest level of analysis. His model failed to describe the decrease in accident numbers after the second half of the seventies. This fact justified the criticism and made his model also lose its practical value.
Oppe [1991] and related publications show that at this highest level of aggregation it is possible to state a model that describes and predicts developments in traffic safety. It claims not to be merely descriptive, but to have a simple theoretical basis, only using the two fundamental concepts of traffic safety: exposure and risk. The outcomes for the Netherlands are given in figure 1.

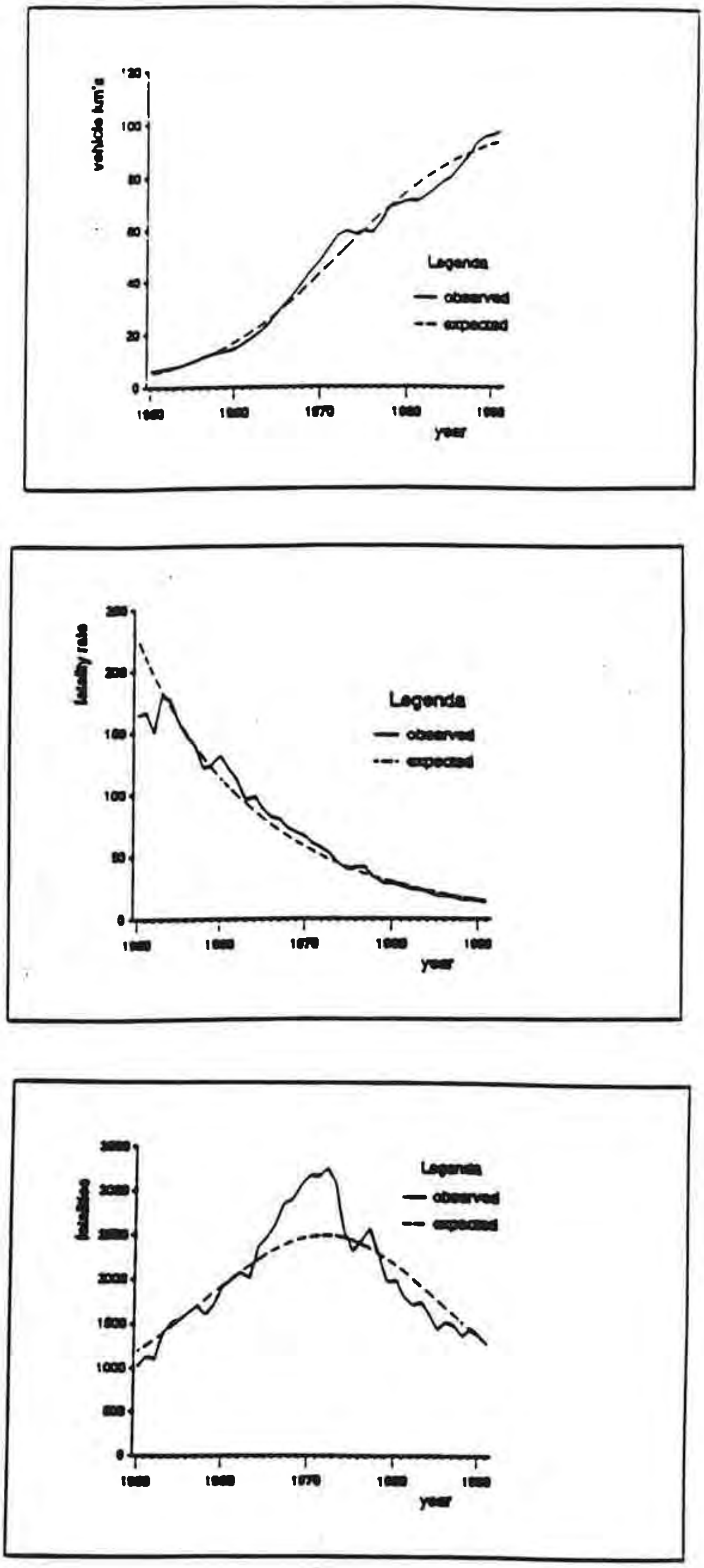

Figure 1. Observed and expected vehicle kilometres (1a), fatality rates (1b) and fatalities (1c) for the Netherlands from 1950-1991.

The model is able to cope with the increase in accidents before, as well as with the decrease after the mid-seventies. Its fundamental assumption is, that the development of risk at the highest level is exponential, with a negative (learning rate) parameter. The explanation given is that the improvement of safety is a societal process of learning, comparable to learning processes of individuals, that are also described by exponential functions. It is the end product of a large number of collective learning events. In the beginning there is a lot to be learned, but the number of learning events decreases with time. Given a constant learning capacity, the learning result is an exponential decay function for the number of learning events and the corresponding safety improvement. A large amount of evidence for exponential learning, as well as the theoretical basis for it, is found in the psychological literature.

The model has been applied at SWOV to describe disaggregated data as well. Exposure and risk developments were modeled for groups of road users, divided by age and traffic mode. Detailed accident and exposure data, collected over a ten year period, combined with the long term trends for the total and information about observed and predicted population growth per age category, were used to make predictions. These predictions were then compared to target values for each group as aimed at in the national safety programme for the years 2000 and 2010.
Figure 2. shows the results for four age groups of bicyclists. The observed accidents, together with the model predictions and their error bounds are given, together with the target values. It looks as if the target will be easily met for the younger road users, but not for the older ones (Oppe 1993).

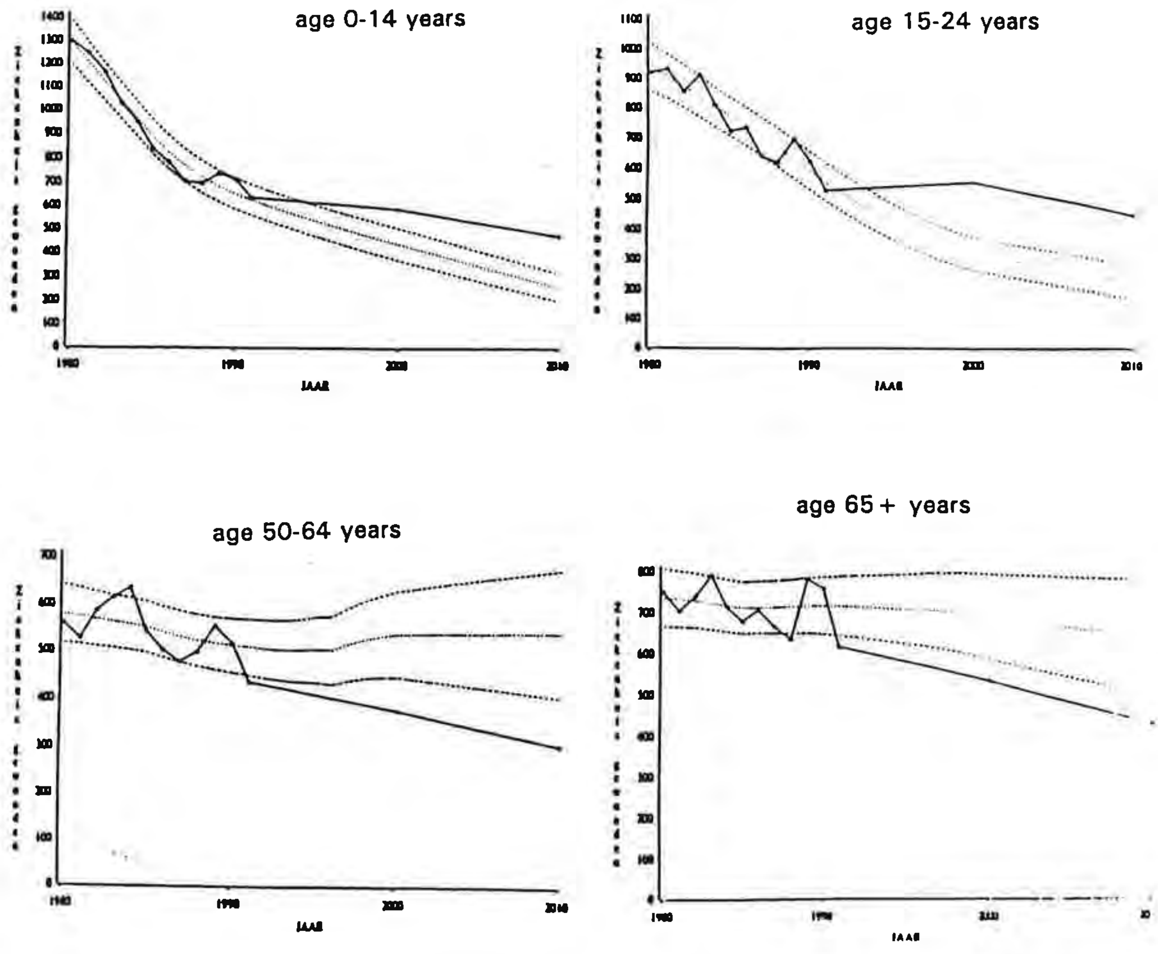

Figure 2. Observed and predicted numbers of hospitalized victims for young bicyclists (2a and 2b) and older bicyclist (2c and 2d) in the Netherlands, together with target values for 2000 and 2010.

The examples show that an accident analysis is very dependent on the aims one has and on the structure of the problem. The accident figures at the highest level hardly reflect any specific influences. From figure 1c, in which the number of accidents is described using the amount of motor vehicle kilometres as a measure of exposure, and the two parameters of the exponential curve for risk, it is seen how little of the variance in accident numbers remains to be explained by other factors. The total figures hardly reflect anything else but the total effort of society as described by the exponential risk reduction over time. The disaggregated figures show much more variation, that need not all be stochastic noise.
Apart from these more descriptive analyses. Several attempts have been made to explain the development of traffic safety at this highest level, using all kinds of variables other than the amount of traffic. Many of these variables (e.g., economic factors such as fuel consumption, fuel prices, amount of unemployment etc.) are again related to exposure or traffic volume. Others are supposed to cover particular risk related factors. An overview of some of these attempts is given in the special edition of Accident Analysis and Prevention, 1991, No 2. In one of these studies, Partyka reports that she initially found a rather good description on the basis of this type of explanatory variables, but that the model failed to describe later series of data. Gaudry 1984 claims to have found a satisfactory model description for the accidents in Québec, on the basis of a large number of explanatory variables. Statistically speaking, his approach is sound. The model is nicely structured and statistically well based. Its weakness seems to be the large number of variables and thus parameters involved.
In spite of this and other claims, it is my opinion that this type of explanation is not suited for this aggregated level of analysis. The disadvantage of explanatory models as used by Partyka and Gaudry is, that they are based on a description of relations between variables, without an explicit theoretical foundation. If relatively many variables are used, a fairly good description may result that seems to explain the fluctuations, but still results in bad predictions.

Generally speaking predictions of the total number of accidents, based on data up to, or from the late seventies onwards, will not show large deviations. As in the case of Smeeds model, a nice test for these models is to make a description of traffic safety up to the beginning of the seventies, and to use the model parameters together with the explanatory variables to predict the number of accidents after that period, up to the nineties.
My expectation is, that unless those variables are used which together predict the exponential decay of risk (e.g. the special safety effects of all measures taken), no model will explain the fall of the accident figures from the second half of the seventies onwards.

My general conclusion is, that accident analysis at the highest level of aggregation can be used to describe and even model traffic safety developments, but can hardly be used to explain these developments in causal terms.

Similar attempts have been made to show that particular safety measures were effective, e.g. by applying a kind of time-series analysis called intervention analysis. Again, figure 1c. shows how difficult it will be to detect such effects at a macroscopic level. The explanation based on exposure and the total risk reduction leaves not much left to be explained by additional factors. Only over rather short periods of time such effects may be isolated from the effects of all other newly taken safety measures. The possibilities for showing such effects are larger for more specific accident types. The effect of the safety belt law is a good example. Its effect is supposed to be found for car occupants and not for other road users, although some researchers claim side-effects for these groups too, because the risk taking behaviour of car drivers may increase if their own risk is reduced. Monthly data collected over a short period before and after the initiation of the law may then prove a direct effect. Figure 3. shows such a result for the U.K., based on monthly data (see Harvey and Durban 1986). Application to the Dutch situation, using he same procedure failed, because the safety belt law effect was confounded with a number of other safety measures taken at the highest level, such as an alcohol law and a general speed law.

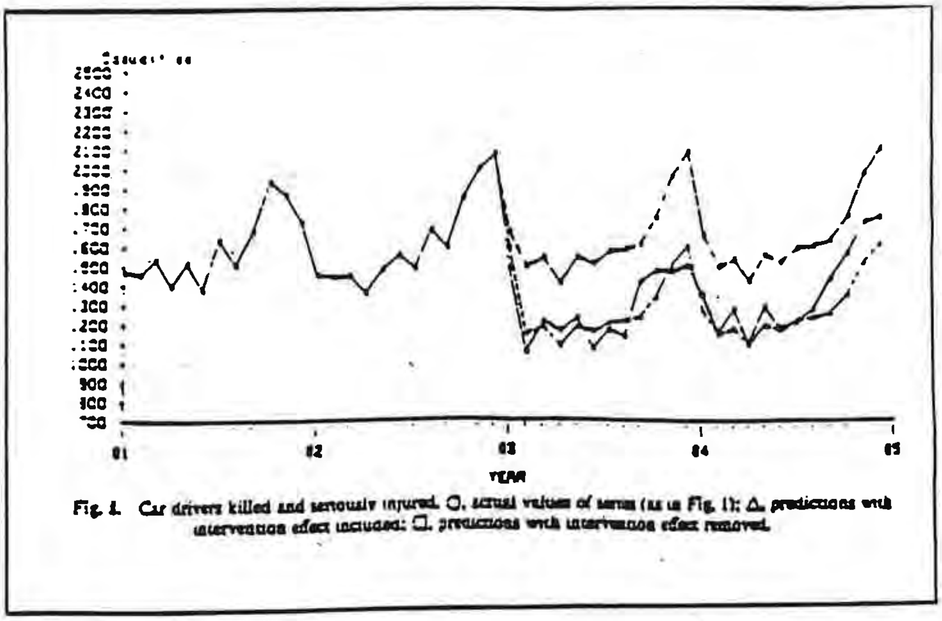

Figure 3. Example of a time-series analysis to detect a safety belt intervention effect, according to Harvey and Durban 1985.

4. Accident analysis for research purposes.

Traffic safety research is concerned with the occurrence of accidents and their consequences. Therefore, one might say that the object of research is the accident. The researchers interest however is less focused at this final outcome itself, but much more at the process that results (or does not result) in accidents. Therefore, it is better to regard the critical event in traffic as his object of study. One of the major problems in the study of the traffic process that results in accidents is, that the actual occurrence is hardly ever observed by the researcher.
Investigating a traffic accident, he will try to reconstruct the event from indirect sources such as the information given by the road users involved, or by eye-witnesses, about the circumstances, the characteristics of the vehicles, the road and the drivers.
As such this is not unique in science, there are more examples of an indirect study of the object of research.
However, a second difficulty is, that the object of research cannot be evoked. Systematic research by means of controlled experiments is only possible for aspects of the problem, not for the problem itself.
The combination of indirect observation and lack of systematic control make it very difficult for the investigator to detect which factors, under what circumstances cause an accident. Although the researcher is primarily interested in the process leading to accidents, he has almost exclusively information about the consequences, the product of it, the accident.
Furthermore, the context of accidents is complicated. Generally speaking, the following aspects can be distinguished:

- Given the state of the traffic system, traffic volume and composition, the manoeuvres of the road users, their speeds, the weather conditions, the condition of the road, the vehicles, the road users and their interactions, accidents can or cannot be prevented.
- Given an accident, also depending on a large number of factors, such as the speed and mass of vehicles, the collision angle, the protection of road users and their vulnerability, the location of impact etc., injuries are more or less severe or the material damage is more or less substantial.

Although these aspects cannot be studied independently, from a theoretical point of view it has advantages to distinguish the number of situations in traffic that are potentially dangerous, from the probability of having an accident given such a potentially dangerous situation and also from the resulting outcome, given a particular accident.

This conceptual framework is the general basis for the formulation of risk regarding the decisions of individual road users as well as the decisions of controllers at higher levels. In the mathematical formulation of risk we need an explicit description of our probability space, consisting of the elementary events (the situations) that may result in accidents, the probability for each type of event to end up in an accident, and finally the particular outcome, the loss, given that type of accident.

A different approach is to look at combinations of accident characteristics, to find critical factors. This type of analysis may be carried out at the total group of accidents or at sub-groups. The accident itself may be the unit of research, but also a road, a road location, a road design (e.g. a roundabout) etc.
This type of analysis is often called analysis of relational data, because the various factors that are involved are not independent from each other. Volume, speed, road width etc. are considerably correlated. Analysis techniques should take these correlations into account.
Sometimes the data are collected in multiway contingency tables and analyzed with the previously mentioned log-linear model for contingency tables. The model structure of these models however, assumes independent factors, as in the case of an analysis of variance. In laboratory experiments the researcher is able to design his study in such a way (e.g. by using an orthogonal design) that interrelations between explanatory factors do not exist. In field experiments and for accident data that are classified afterwards instead of forwards, such an analysis may be misleading (see Oppe 1992 and the examples in section 5).
Techniques such as multiple linear analysis correct for such intercorrelations, but the disadvantage is, that they are meant for measurements and do not apply to counts. A better choice for accident counts is a log-linear model, but then a regression type of model instead of the model for contingency table analysis. GLIM does have both possibilities.
The regression type of log-linear analysis is used by TRRL (Maycock and Hall 1984), to find combinations of risk factors for various types of roads.
There are other techniques developed at the Leiden State University, that are specially suited for this type of exploratory research (Gifi 1990). A comparison between these techniques and GLIM, applied to the TRRL-data is also described by Oppe 1992. The techniques can be found in the recent versions of the statistical package SAS-Stat, under the headings of PRINQUAL and TRANSREG. These types of analysis can be used for exploratory analysis, to find potential problems. For a further (causal) analysis of such problems, more information is necessary.

As said before, accident records do not cover much of this necessary information. Therefore, researchers have tried to get additional information about accidents, in order to study these more in-depth. In other areas of transport (air/rail/water) in-depth accident investigations are much more standard. Many attempts have been made to borrow in-depth techniques from these areas. However, there are a number of reasons why this transfer is not straight forward. Accidents in road traffic are much more frequent, the outcomes are often less serious and get less public attention. Therefore, the cost/benefit rate per accident is much higher. Furthermore, the accidents are of a different nature. In the air, on railways and at the water more time is available for critical decisions to be made (predominantly) by professionals. Procedures for all kinds of conditions are specified and often monitored so that they can be traced afterwards. This makes the decisions taken more rational and easier checked retrospectively. Especially in air traffic, but also on rail or at sea, technical failures are often the cause of an accident and much effort is put in changing the responsibility of the humans involved from the tactical level of actual manoeuvring to the strategic level of monitoring the process.

In road traffic the situation is completely different. The driver has to carry out most tasks himself at the tactical as well as strategic level. His decisions have to be made in a very short time, often in rather complicated situations. The decision rate is on average much higher, less supported by special equipment or controlled by procedures and almost completely not monitored.

Recent developments in road traffic, particularly those in the area of traffic and transport telematics as in PROMETHEUS and DRIVE, are concerned with changes of the drivers task and the driving environment. The implementation of such changes request a detailed insight into this task, to avoid unforeseen accident risks. At the moment, there is a strong tendency to experiment and to find acceptable solutions by trial and error. The evaluation of these systems is thought to be carried out by before and after studies, based on accident numbers. The possibilities for applying such evaluation studies are limited.The use of accident analysis for these purposes in general is very limited. The type of accident analysis that may become useful, in combination with additional behavioural studies, is the video-based type of analysis mentioned in the introduction, but only for systems that are implemented on a sufficiently large scale.

Although the in-depth accident study as carried out in other transport modes is difficult to use for road traffic, many attempts have been made to carry out in-depth accident studies in that area as well. These studies turned out to be rather costly. Most studies focus on the outcomes of accidents, either to improve medical care or vehicle design. Sometimes special teams are trained to carry out such studies on-the-spot, as soon as possible after the accident. Others are primarily based on extra information from participants and witnesses, collected through questionnaires. Research at INRETS, carried out by Fleury, Malaterre and others, focused primarily on the pre-crash aspects of the accidents and less on the outcomes.
In all these studies the aim is to reconstruct the accident retrospectively. As described in the example at the beginning, it will be very difficult to detect the relevant cues, especially the information about the last five or ten seconds. Reports from participants and witnesses turned out to be not very reliable. The most promising examples are studies, such as those carried out by INRETS, focusing on particular types of accidents, testing well defined hypotheses.
Because of the unreliability of the information collected afterwards, reconstruction of accidents and their causes is limited. Such analyses cannot be carried out without additional information about what drivers do in comparable situations, not resulting in accidents. Behavioural studies will give this additional information. The main disadvantage of this approach is, that the risk itself cannot be observed, but must be measured indirectly, on the basis of theoretical assumptions about risk. The missing link between both methods is the observation of the accident. Careful study of the actual accident process may tell us which factors in which situations are responsible for the loss of control. It may also tell us what information is necessary to reconstruct an accident.

This type of combined accident and behavioural research is in my opinion the most promising tool for safety analysis. Without this type of information it is hardly possible to test behavioural assumptions as well as conclusions drawn from (in-depth) accident studies.

A rather popular type of accident research is accident black-spot analysis. It is indeed one of the most promising areas of traffic safety improvement, because it is directed to a very important aspect of safety: the architecture of the traffic environment. Accident black-spot analysis is also the best example to show the limitations of accident analysis. This regards detection and selection, problem analysis and evaluation.

The idea is to select and improve those locations (road sections or intersections) in a certain area or class of roads that are the most dangerous.
The total number of accidents in one or more years is often chosen as the safety criterion. However, these numbers are mostly rather low and therefore they give no

reliable estimates of danger. E.g., for a location with nine accidents on average per year, it is not very unlikely to have yearly accident figures that range from three to fifteen. An ordering of the locations on the basis of such small numbers is rather unstable, and locations will be selected that are not particularly dangerous, while much more dangerous locations are left out. This need not be a serious problem if the procedure is carried out at a yearly basis, because then the dangerous locations will show up in the end anyway.
Increasing the number of accidents by extending the observation period to three or five years may be a solution, but then the assumption is that nothing is changed over that period and that the past number of accidents still is a valid estimator for the number of expected accidents at the moment of analysis. Also increasing the number of accidents by using all accidents, including material damage only accidents, may have drawbacks, because the degree of registration for this type of accidents is very low and also selective. If the set of locations is homogeneous and/or the accident type is restricted, this need not be much of a problem.
Sometimes the problem is solved by using conflict observation techniques, to find out whether a location is dangerous or not. This procedure, if carried out by trained observers, has a number of advantages: the observation period can be kept rather short and still representative; additional countings for exposure can be carried out for cars as well as pedestrians and bicyclists and preparatory accident analysis with regard to infrastructure and behaviour can be carried out by this systematic observation of ordinary traffic flow. Critics of this approach point to the fact that conflicts are no accidents and that it should be proved first that they can replace them. This argument as such is correct, and much effort is put in showing this, but these critics often forget to be equally critical with regard to the above mentioned problems concerning recorded accidents.

A second problem is, that these absolute numbers are not the most appropriate criterion, because they do not measure the risk for passing such a location. To measure risk, a correction for exposure (vehicle kilometres driven or encounters between road users) is necessary. This type of information is often missing. This is one of the most important reasons for choosing the absolute number of accidents as a criterion. It decreases the effectiveness of treatment further, because many locations with high numbers of accidents will be highly occupied (inter)sections probably already with a high quality design. Further improvements will be costly and therefore less cost/effective. A reasonable criterion seems to be the percentage of risk reduction per unit of money, times the absolute number of expected accidents.

The most difficult part always is the accident analysis, in order to select remedial measures. Accident data are far too restricted for these purposes. There is little or no hope to find regular patterns in the accidents. Each selection will be mixed with other selections and soon result in one, two, three examples per selected combination, e.g. for the most basic selection according to conflict type, age group, weather condition, time of day.
As said before, the available information from the accident records is also limited. A mixed procedure, where locations for potential treatment are selected on the basis of accident records and investigated by additional conflict and behavioural analysis seems the most efficient.

The last problem to be met, is the evaluation of safety measures. Apart from the fact that accident numbers are too small to find reasonable effects of measures per location, there is the statistical problem of the regression-to-mean. If all locations were equally dangerous, then the actual accident numbers for a particular period would still fluctuate by mere chance. An ordering according to the outcomes, followed by a classification in classes for low, medium and high accident numbers, will show an average increase, no increase and decrease in the next period respectively. Because the classification was based on the differences that were caused by chance only, the expected outcomes are the same for all locations within the three groups in this second period. The group of selected locations will therefore on average show a decrease in accident numbers, even when no actions are taken at all. For examples of this effect in actual situations, see Hauer 1986. There are procedures to correct for this effect (see e.g. Maher 1990). It is also possible to test for homogeneity within a group of locations. If the variance of the accident numbers is larger than the mean, this is an indication that the Poisson parameters differ from each other. The negative binomial distribution describes the accident distribution better in this case.

An alternative approach, based on the analysis of the characteristics of all the locations together, that circumvent the small numbers problem as well as the regression-to mean problem is given in Oppe 1982.
A before and after study on the basis of behavioural observations or conflict techniques both carried out after selection, need no correction for the regression-to-mean effect either. Such an evaluation in terms of behaviour has also the advantage that the intermediate variables which the safety measures are supposed to change can be checked for their effectiveness. E.g., if speed reduction measures after implementation do not show any effect on the observed speed, then an evaluation of the safety effect by means of accident reductions is superfluous.

5. Evaluation studies.

The last area of accident analysis that will be treated is evaluation research. Problem detection and problem analysis, as covered in 3. and 4. may be carried out rather independently. As we saw in the last example, this is not the case with evaluation. Here the two approaches meet. Evaluation is carried out to prove effectiveness of safety management, but also to test the underlying assumptions on which the applied measures are based. The safety manager is primarily interested in the safety outcome, as measured by accidents. The researcher in the intervening variables the changes of which are assumed to produce this outcome. We gave already some examples in which especially this process evaluation is important. A detailed treatment of this issue is without the scope of this paper. An excellent overview is found in the proceedings of "Evaluation 1985".
A complete review of the possibilities and limitations of accident analysis for product evaluation will also lead us too far. Haight 1986 and Hauer 1986 give detailed treatments of methods to be used. A recent overview of the most important issues for small scale evaluation projects is given in Oppe c.s. 1993.
Two examples of possible pitfalls will be treated here, because they are rather specific for accident analysis, relate to techniques that are widely used and to limitations mentioned before.

The most simple example of an evaluation is the test of the hypothesis of no-effect (no change, no difference). Simple a test of this kind may be, both conceptually and statistically, its simplicity is its main pitfall. We will illustrate the necessity of a sound theory and experimental design as fundamental conditions, by means of a theoretical example.
Table 1 represents the imaginary outcome of an investigation regarding the effect of safety belts. In many studies we find the results reported in a number of two-way tables. Inspecting this table, it is obvious that there is a highly significant interaction between the use of safety belts (A1) and the probability of having an injury (B2). We can even estimate the effectiveness of safety belt use and compute error bounds for this effect.

	A1: belts	A2: no belts
B1: no injury	91	20
B2: injury	14	51

Table 1. Relation between the use of safety belts (A) and seriousness of accidents (B); theoretical example.

However, if table 1 turns out to be the aggregated result of the two sub-tables in table 2 according to rural or urban location (C1 and C2 respectively), then we are confronted with a serious problem. The conclusion drawn from table 1 does not count for either of the two sub-tables. The safety belt effect on accidents turns out to be an artifact of the relations between the location and the use of safety belts and of location and injury. Of course this is a theoretical example (we are not seriously stating that safety belts are ineffective), but it illustrates how wrong obvious conclusions may be.

	C1: rural		C2: urban	
	A1: belts	A2: no belts	A1: belts	A2: no belts
B1: no injury	90	10	1	10
B2: injury	9	1	5	50

Table 2. Disaggregation of table 1 according to variable C; the interaction between A and B disappears.

The conclusion should not be that we have to investigate three-way tables instead of two-way tables, but to analyze the situation and to understand its (possible) structure, before we state or test our hypotheses. The confirmation should be based on a sound theoretical framework. If we expect interactions with other variables to be of influence, then we either have to adapt our study design or else our analysis, in order to take these variables into account.

The next example concerns design problems. Imagine that table 3 results from an investigation of accidents in relation to characteristics of the location, showing the effect of the relation between the type of road (T) and the type of street lighting (L) on safety. Again, there is an obvious effect, suggesting a strong safety interaction between the type of road and the type of lighting. The road types seem to have safety problems under special lighting conditions.

	T1	T2	T3
L1	20	5	3
L2	2	15	1
L3	3	7	25

Table 3. Number of accidents for road types (T) and types of lighting (L).

However, if the road administrator has a rather strict policy regarding the installation of types of lighting depending on the type of road (preferring the combinations T1-L1, T2-L2, T3-L3), then the safety effect is an artifact of this policy and does not say anything about the safety effect of combining these conditions. If all types of lighting were equally spread over all types of roads, the effect could disappear completely. This problem, in its extreme form known as the problem of structural zero's, is a serious problem in contingency table analysis. Technically speaking, it can be solved by means of a correction for exposure, but this makes a modification necessary for the analytical technique as described in the beginning of section 3. This problem also clarifies the advantages of GLIM and TRANSREG analyses over contingency table analysis for this type of data. We will no go into those details, but we only want to state that a theoretical framework is necessary for applying significance tests to evaluate effects.
It is the main concern of exploratory data analysis to investigate the structure of the problem. It often helps to investigate the structure of relations between a large number of variables, possibly connected with the safety problem under investigation.
In laboratory experiments a lot of effort is put in the design of the study, in order to control the experimental and control situation. In traffic and traffic safety research this is

hardly ever possible. However, although we cannot control the situation, this should not mean that we have to ignore the possible effects. In many, highly dedicated log-linear analyses this design problem is seriously overlooked.

6. Summary conclusions:

Accident statistics, especially collected at a national level are particularly useful for the description, monitoring and prognosis of accident developments, the detection of positive and negative safety developments, the definition of safety targets and the (product) evaluation of long term and large scale safety measures.

The application of accident analysis is strongly limited for problem analysis, prospective and retrospective safety analysis on newly developed traffic systems or safety measures, as well as for (process) evaluation of special short term and small scale safety measures.

There is an urgent need for the analysis of accidents in real time, in combination with background behavioural research. Automatic incident detection, combined with video recording of accidents may soon result in financially acceptable research. This type of research may eventually lead to a better understanding of the concept of risk in traffic and to well-established theories.

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TRAFFIC CONFLICT TECHNIQUES AND OTHER FORMS OF BEHAVIOURAL ANALYSIS: APPLICATION TO SAFETY DIAGNOSES

I. INTRODUCTION

The purpose of this paper is to examine the tools available for a road safety diagnosis (or the evaluation of the road safety situation at a given point of time), aimed at supporting preventive action either at the national or at the local level, and to show how these methodological tools can confort each other, both from a theoretical and a practical viewpoint. Although the use of alternate or complemental approaches to those traditionally based on accidents is the main focus, accident analysis has to be considered as a reference and an integral part of any safety diagnosis with an operational outcome.

The paper is based on scientific findings from road safety research as well as on practical experience, gathered in field studies carried out at the national and the local levels in European and in less motorized countries. As a framework, it admits the principle of an integrated approach to road safety management, which was first proposed by OECD in 1984 and has been further developed by INRETS since.

The point of view offered here is that of a road safety engineer who has repeatedly found through field experience and research that hard sciences need the counterpart of a human scientist approach in order to contribute to realistic road safety policies and an in-depth understanding of the problems at stake.

II. A FRAMEWORK: THE INTEGRATED APPROACH TO ROAD SAFETY

In most European countries, very visible improvements of the road safety situation were obtained in the 70's and the early 80's, mainly as the consequences of broad regulatory measures taken at the national level, with the addition of more localized measures such as blackspot treatment or pedestrian schemes in urban areas. But then, the trend stabilized: it appeared that new approaches to road safety management and the design of preventive measures were required in order to further reduce accident figures, and that these could only be based on more comprehensive knowledge of the mecanisms generating unsafety.

In opposition to the generally ruling method of "trial-and-error", in which the various areas of road safety work (infrastructure improvements, regulatory measures, education, etc.) were kept separate and the new safety measures were implemented more or less as they came to the mind of specialists in one area or another, a more rational way of producing national road safety programmes was recommended (OECD, 1984), based on the fact that road accidents result from multifactorial processes and that preventive measures addressing the road, traffic, vehicles, or road-users cannot really be considered as independant from each other.

In-depth road safety studies carried out in some less motorized countries with a fast growing accident problem, such as Côte d'Ivoire, Niger, the Philippines or some parts of Eastern Europe, showed that urgent solutions had to be found in situations where road, training and educational infrastructures were still quite inadequate, and moreover, the ressources available for road safety measures were very limited. Such situations were also found to require a global approach, that built the different forms of safety measures into an action programme, so as to avoid irrelevant measures, redondancies and lack of consistency (Muhlrad, 1987).

In the late 80's, urban road safety studies and policy-making, particularly in European countries, took a similar orientation, partly because localized infrastructure operations (blackspot treatment, route improvement, pedestrian precincts, etc.) or local publicity campaigns, although bringing some progress, were of limited scope, and partly because it was found that safety measures were more acceptable to the road-users (and more easily financed also) when included in wider policies aiming at facilitating mobility or access, improving public transport and facilities for non-motorized road-users, or increasing local living amenities. The "comprehensive" approach in this case takes into account, not only all the possible aspects of road safety action at the city level, but also those other urban problems that may be treated jointly with accident prevention.

Whatever the country or the city considered, the main goals of a comprehensive approach to road safety management can be detailed as follows:

a) to get some control on the development of transport and traffic systems in order to avoid creating malfunctions that could later produce accidents;
b) to prepare remedial action in connection with actual accident problems, identified through objective studies;
c) to select or design safety measures only to influence some of those particular elements of the transport system which have been found to contribute to the main accident problems, in order to ensure the relevance of the measures by logical construction;
d) to coordinate planning and implementation of complemental safety measures with a view to increasing their joint effects;
e) when possible, to coordinate design and implementation of safety measures and other measures that may include or support them;
f) to avoid as much as possible redundancies and/or contradictions in road safety programmes, or between safety and other programmes related to transport and development;
g) to make the best use of past experience in other cities, countries or regions of the world, after checking its relevance and possible adaptation to the conditions in the country (or the city);
h) to contribute to produce relevant knowledge by following up the effects of the measures and policies implemented in the country (or the city);
i) to set up an adequate institutional organisation able to manage road safety according to the above requirements.

The comprehensive approach advocated has been termed "integrated safety management", as, at some points of the study and decision-making process, safety measures of different kinds are considered together and compared, and trades-off discussed; in addition, safety measures may in some cases be integrated into wider management policies.

Clearly, goals b) and c), which induce "corrective" safety policies, imply that an objective and detailed diagnosis of the safety situation should be performed, so as to identify the best targets for remedial action (accident types to eliminate, categories of road-users to protect, hazardous locations or areas to treat, etc.), and to analyse the processes that have led to such accident problems. Goal a), one for "preventive" policies, requires extensive knowledge as to what configurations of the transport system are the most likely to produce accidents, a knowledge that can only be acquired through comparing diagnoses of real situations such as those necessary for corrective policies. Goals g) and h) suppose that evaluation studies are systematically carried out following implementation of road safety policies (or elements of them), and a thorough diagnosis of the initial situation is a necessary starting point.

Finally, goal e), relating mostly to urban policies, associates road safety and other fields, and the initial diagnosis as well as the final evaluation are bound to be based, not only on safety indicators, but also on the relevant variables describing the associated fields (Bigot et al., 1990, Faure, 1991).

The components of a detailed diagnosis aimed at supporting integrated safety management are discussed in this paper. Presentations of other requirements and specificities of the integrated approach can be found elsewhere (Muhlrad, 1991, 1993).

III. THE COMPONENTS OF A COMPREHENSIVE ROAD SAFETY DIAGNOSIS

In order to adequately support integrated safety policies, a safety diagnosis needs, not only to put into light the main accident problems and the processes that have directly generated them, but also to bring forth complementary information for use in the selection or design of relevant safety measures. Of particular interest are the identification of some determining features of behaviour observed in accidents or pre-accident situations, that may provide leads towards modifying such behaviour, a better knowledge of the characteristics of road-users, that would indicate how to address them and get through to them, and the study of the psychological context of unsafety and remedial action which has a bearing on the acceptability of different types of measures.

Such a comprehensive diagnosis obviously cannot rely solely on accident studies, but requires wider approaches, including observations and analyses based on the methodologies of human sciences. Some of these are briefly described here, as examples of what can be done.

One should be aware that a safety diagnosis carried out in a particular situation does not have to include all the elements suggested here: a selection needs to be made according to the problem at hand and the goals fixed for action. Accident analyses thus play a fundamental role in outlining the main characteristics of the safety problem and defining the scope of additional investigations.

It must also be noted that most of the author's experience in comprehensive diagnoses has taken place in developing countries, where the data and ressources available were not the best: the approach can therefore be considered as reasonably realistic.

III. 1 Accident analysis

For practical purposes, accidents and their consequences are usually considered as *the* indicator of a road safety level, either existing or to be reached. Clearly, for the practitioner, accidents which were not reported to appointed agencies or were not recorded never existed. For the researcher contributing to field work, accident history indicates the lower limit of unsafety and is not the sole predictor of future risk; a prerequisite to any safety diagnosis is therefore to examine the quality and comprehensiveness of the accident data available, looking for various sources of data to compare, in order to assess how far the apparent (or measured) safety situation may be from real facts. Given reasonable satisfaction on this point, past accidents are studied as the outcome of malfunctions of the road and transport system, in order to get a lead to these malfunctions and subsequently design corrective measures.

Recent scientific approaches have converged on a multi-factorial concept of accidents, which are considered as the product of interactions between several factors related to the personality and behaviour of the road-users involved, the design of roads and road-side environment, as well as the design and maintenance of vehicles. In such a system approach, any accident that occurs has been the effect of a combination of uncorrected human and technical failures, identifyable after the event, provided the latter has been thoroughly documented and appropriate analysis methods are used.

Although, for justice purposes, traffic police and law courts are usually only interested in finding out *one* road-user responsible for the damage, and therefore in highlighting *one* human error, it is knowledge of the full complex causation process which is useful for accident prevention as it may lead to a number of directions for action from which to choose. It is therefore essential to analyse past accidents in details, in order to identify as many as possible of those failures intervening as accident factors and their mutual relationships.

From a practical viewpoint, not all failures identifyable in an accident generating process can be acted upon, as some are beyond human reach (weather conditions for example), and others do not yet respond to any known measure (drug consumption for example). In a diagnosis performed with a view to practical accident prevention, such accident factors will therefore be discarded, and only the controllable failures in the various components of the mobility sytem (roads and their environment, vehicles and traffic, road-users) that have played a part in the accident generating process will be retained. If the analysis is reliable, the elimination or neutralization through appropriate measures of any of the factors contributing to an accident should be sufficient to ensure that similar accidents cannot happen in the future (Ferrandez et al, 1986, 1991).

Following these lines, a safety diagnosis, whether aimed at supporting national road safety policies, local programmes, or infrastructure measures more limited in scope (such as blackspot treatment for instance), necessarily includes two steps of accident analysis (Muhlrad, 1987):

a) problem identification: assessment of the size of the overall safety problem in terms of numbers of accidents and victims (and possibly a rough cost of these for the community), identification of the main targets for action in terms of frequent types of accidents, categories of road-users mostly at risk, hazardous locations, hazardous driving situations, etc.; problem identification relies on statistical analyses of accidents and their consequences, using the existing national or local files when available and reliable, or representative samples of data wich can be checked for accuracy and completeness.

b) problem analysis: identification of malfunctions in the road and transport system in terms of the most frequent factors contributing to the accidents in the target groups already identified; problem analysis cannot in general be performed only through statistics, although good quality data and thorough epidemiological methods may indicate some likely factors; most often, an in-depth analysis of a sample of accident cases will be required; data is obtained from detailed investigation files such as those provided in most countries by the police or by law courts, sometimes by insurance companies, at least with regards to the most serious accidents; accident cases are selected for study so as to obtain acceptable representativity of the main target groups.

Findings from such accident analyses can only be valid as far as the objective data on which they are based is itself valid. In many countries, under-reporting of accidents is a problem at the national level, which of course sets a limit to what can be obtained from officially recorded data. Also, when working at the city level or on an even smaller scale, numbers of accidents considered unacceptable to the community may be too small in terms of statistics and of input for in-depth studies for the findings to be significant.

It has been observed however that good quality accident investigation files as used for problem analysis were found even in countries with no adequate national statistics. One should not jump too fast to conclusions regarding the availability of data!

III.2 Field observations related to accidents

In-depth analysis aims at identifying various factors involved in accident-generating mecanisms, that appropriate remedial measures may hopefully eliminate. However, the data on which it is based is often contradictory or not sufficiently detailed in some areas (in particular, the description of local environmental or road features) to ascertain such factors in a definite way: thorough analysis will therefore yield hypotheses as to each accident mecanism, sometimes with alternate possibilities; these hypotheses have to be checked, and the unrealistic ones eliminated. A number of complementary methods can be used to this purpose.

A first step in reaching a better understanding of accident factors is to perform site observations on accident locations, following a checklist worked out according to the questions raised in the data analysis. Most of these are related to elements of the road and its environment, and to particular patterns of behaviour they may induce: arrival speeds of vehicles at a junction, environmental perception of the drivers on the stretch of road preceding the accident spot, visibility problems, night visibility, conspicuity or consistency of particular facilities (including signing), traffic light phasing and red-light violations, etc. Observations are precisely defined and kept to a minimum, especially if the number of locations to visit is high; obviously, the more detailed the data on accidents, the stronger the hypotheses will be and the shorter the list of observations! Measurements such as speed checks or traffic counts can also be performed for background information.

Such approach has been used systematically for local safety work such as blackspot treatment, or area improvement in cities (Ferrandez et al, 1979). Although it is not so well adapted to check hypotheses relative to non-site related accident targets or to national safety policies, the method has been partly extended, for instance to assess the effect on safety of road standards or typical infrastructure amenities.

III.2 Traffic conflict data

So far, it has been assumed that available accident data was sufficient at least to formulate realistic hypotheses as to some accident factors amenable to treatment. This is not always the case however:

a) At the national level, accident statistics are still very unreliable in a large proportion of countries of the world; even in the more industrialized countries where safety information systems have been developing over a long period of time, data is still often found unsatisfactory and a thorough safety diagnosis requires complements obtained through ad'hoc surveys (for instance, Nilsson G., 1989).

b) Detailed data on accident cases is not always available, either because the Police or Justice do not systematically produce investigation reports for each injury accident recorded for a number of practical reasons (shortage of manpower, no point in drafting the details of an accident unlikely to go to Court, pressure exerted by some of the people involved in accidents, etc.), or because the case-files that exist are not classified and are therefore difficult to get access to.

c) At the local level, a safety diagnosis, especially when site-oriented, is supported by a relatively small number of accidents; even when data is good and complete, some additional information is often needed to confirm the first hypotheses from accident analysis or even to help formulate them.

Traffic Conflict Techniques or TCTs have thus been developped in a number of European and North American countries to the particular purpose of adding relevant information to existing accident data, or replacing missing accident data as may be the case, for diagnosis and evaluation studies. TCTs are based on the detection and count of "near-accidents" or "critical incidents" occurring in real traffic situations. Once recorded, conflict data is analysed in the same way as accident data in order to identify factors likely to generate future collisions.

It is to be noted that, in areas of safety work where accidents are serious but scarce, such as air travel, nuclear industry, etc., studies carried out to support preventive action are naturally based on the analysis of incidents, under the hypotheses that the factors contributing to these incidents are bound to be involved in potential accident processes: the validity of the approach is taken for granted. In road safety however, field actors have long denied the relevance of near-accidents, an attitude generated by the (hasty) assimilation of accident statistics to the actual safety situation. A lot of research was therefore required, both to develop accurate methodologies and to demonstrate their worth.

Research on the concept of traffic conflict started in the U.S.A. in the late 60's and was taken up in England and Sweden in the early 70's, followed by Austria, Canada, Finland, France, Germany, Hungary, Israel, the Netherlands and Norway. International cooperation was set up in 1977 to compare and harmonize TCTs elaborated by different teams (Amundsen and Hyden, 1977) and ICTCT was unformally created in 1979 as a coordinating body of researchers (Older and Shippey, 1979).

A standard definition of a Traffic Conflict was agreed upon, by which "a conflict consists in an interaction between two road-users (or between one road-user and the road environment) that would shortly lead to a collision unless one at least of the road-users involved performed an evasive action".

On the basis of this theoretical definition, operational descriptions of conflicts were worked out by the different research teams to enable field observers to detect, count and describe conflicts in real traffic situations. Obviously, operational descriptions had to precise two key elements: the recognition at a given point of time of a collision course between two road-users (or between one road-user and an obstacle), and the performance of a critical evasive action by one at least of the road-users involved; the latter was differentiated from "normal" road-user behaviour, either on objective bases by using a measured threshold (for instance a TTC or time-to-collision under a fixed limit), or on "subjective" bases by training observers to use their own traffic experience to assess the manoeuvres observed (or on a combination of these two approaches). Comparisons between the various TCTs showed that some subjective assessment was in fact involved in most of them (Grayson, ed., 1984).

TCTs generally included, in addition to the operational description of conflicts, a severity scale, detailed procedures for the observation and recording of conflicts, detection and observation tools such as cameras or computers (for techniques at least partly based on objective measurements), a standard procedure for training observers, methods and corresponding softwares to treat the data recorded, and finally a set of tests of the consistency of observations and reliability of the data obtained which set limits for the valid use of the technique.

The TCTs developed by the various research teams somewhat differed in each of these elements: it was therefore necessary to compare the findings obtained in similar conditions in order to finally decide whether traffic conflicts were useful as an operational concept. Three Calibration Studies were thus organized sucessively, in Rouen, France (1979), in Malmö, Sweden (1983), and in Trautenfels, Austria (1985), in order to compare in details the conflicts observed by a number of techniques (five in Rouen, ten in Malmö and Trautenfels) on common locations, and to examine future applications (Older and Shippey, 1979, Grayson et al, 1884, Risser and Tamme, 1985). In addition, a validation of conflict data against accident data was performed with the American and Swedish TCTs (Glauz and Bauer, 1985, Gaarder, 1985), following a methodology evolved in Toronto University (Hauer, 1972, Gaarder, 1985). Calibration studies showed that there was more agreement between the different techniques than anticipated and that safety diagnoses carried out from each set of data brought up similar conclusions. Validation studies showed that conflicts were a better predictor of future unsafety than accidents themselves where these were in small numbers, particularly as regards pedestrian accidents.

Following the research, manuals for observers' training and guidelines for traffic conflict studies were published in several countries, in particular Great Britain, Sweden, the USA, Germany, and France. Several road administrations have either recommended the use of their national TCT at a decentralized level (in the USA, for instance) or actually used it in their own national services to assess safety on roads where accidents are widely scattered (as in Sweden or Finland).

Some reluctance to a systematic use of TCTs has however been noted in different countries (including France) where the techniques using field observers are seen as too man-power consuming. The argument is only valid, of course, when authorities eventually consider they can do without a detailed diagnosis or without evaluation. In view of this rather predictable development, several research teams, in particular in the Netherlands (Van der Horst and Riemersma, 1981) and in Sweden have started developing semi-automatic techniques based on computer analysis of video-films.

Meanwhile, TCTs have been widely used by researchers in site-oriented diagnostic studies (problems at urban or rural junctions, safety in residential areas, pedestrian safety, etc.) as well as in evaluation studies (new junction facilities, speed reducing measures, etc.) (OECD, 1982, Biecheler et al, 1985). Other research developments were the adaptation and use of the original conflict technique for use on board a vehicle in real traffic situation, either to get information on the driver's behaviour, for instance in assessment of needs or effects or training procedures (Risser and Schützenhöfer, 1984), or to assess the level of safety on long stretches of the road network. An example of the latter is described in the Philippines case study.

III.3 Behavioural observations

From a general point of view, behavioural observations in real traffic stituations are a basic tool for research on human factors. Speed behaviour is for instance an object of current in-depth investigations, and the impact that such research should have on safety policies including speed reduction measures is obvious (Barjonet et Saad, 1986, Saad et al, 1990). But as our present purpose is not basic research but rather diagnosis to support action, we will here narrow the field to practical observation studies.

In order to design efficient remedial measures, it is necessary to get accurate information on the contributing factors identified in the accident analysis and on their interactions. Because the road-users are at the core of the road system, the human factors are particularly at stake.

However, when working with safety decision-makers, who are mainly engineers or economists, it is sometimes difficult to get them to enlist a psychologist to perform parts of the diagnosis which are not based on accident data or accepted surrogates such as conflicts. Although the "Human Factor" is universally declared by decision-makers to be the main failure in the road-and-traffic system that needs controlling, there is a strong tendancy, usually encouraged by donors in the less industrialized countries, to get "hard sciences" specialists to design measures addressing road-user behaviour! A lot of effort has therefore been devoted, particularly by researchers, to prove that appropriate behavioural information can be obtained at relatively low cost and great advantage as a support for safety policies.

The observation of human behaviour in real traffic situations is a useful means of investigation as it provides greater knowledge of effective road-user behaviour as well as means to identify and describe some of its determining features. Such observation affords a better understanding of how a traffic system operates and thus contributes to the global safety diagnosis. It represents a vital complement to in-depth accident analysis as a support for action design, and, where appropriate, may even compensate for a shortage of available information on accident generating processes.

Behavioural observation studies for diagnosis purposes are designed according to the particular situation tackled. Behavioural items to observe are determined primarily by the findings of the accident analysis, but may include some items whose importance for road safety are well known, even if these do not explicitely appear in the first step of the diagnosis for lack of appropriate data. In this respect, the observation of drivers' behaviour with respect to traffic regulations is of particular importance, in order to ascertain whether drivers actually comply and understand the purpose of the regulations (Saad, 1986, 1990).

For each study of this kind, a specific study plan has to be drawn: relevant sites are selected, an observation chart is drafted as well as a recording procedure, and a schedule is worked out. A team of investigators is selected and trained to the use of the chart. Observations are usually complemented with objective measurements, used as a reference background (speed measurements, traffic counts, etc.).

It is to be noted that, while the professional qualifications of investigators need not to be very high, so long as they accurately follow instructions and keep their attention up during the whole observation campaign, the results obtained can be treated and interpreted only by a psychologist familiar with road investigations.

Some examples of behavioural observation studies will be found in the Philippines case study.

III.4 ***Surveys of road-users' characteristics***

Road safety policies developed at the national level include some "structural measures", so called because they contribute to shaping the basic infrastructure (in the general sense of the word: road, but also educational infrastructure) of the traffic and transport system. Structural measures may not have immediate effects on the accident situation, but are meant to influence road-users' behaviour and to participate in reversing the accident trend (or in further reducing accidents) in the long term. As such, they should be built, not only on a diagnosis of the present accident situation, but also on a systematic examination of the relevant parts of the system (road standards and the road network, the educational system, driver training programmes and procedures, etc.).

Of particular importance are again measures aimed at influencing road-users' behaviour, in particular those related to drivers' information and training. Implementation of such measures must be based on adequate knowledge of the characteristics of the population they address. Knowledge of this kind facilitates especially the targeting of information and training campaigns, both in terms of their contents as of the media to be used.

Although information on road-user characteristics is not provided by observations but by surveys, it does contribute to the understanding of particular items of behaviour and is such a direct complement to behavioural analysis for the design of safety measures that we felt necessary to include at least an example in this paper.

Surveys are designed to collect data according to the needs put into light by other parts of the diagnosis, including accident analyses and 'infrastructure" investigations. In a study carried out in Niger, for example (Lassarre et al, 1992, Saad, 1990), it was found useful to assess the type of training undergone by various categories of drivers and their educational level. A survey was thus performed in the capital, Niamey, through questionnaires focussing on seven main points: age and occupation of driver, educational level, type of license, data and place of obtainment, type of vehicle driven, type of training undergone prior to getting the license, possible upgrading since the license. The survey involved a psychologist and three agents of the Ministry of Transport as investigators. The distribution of drivers interviewed according to the vehicle used was controlled.

The survey brought into light the very heterogeneous nature of both educational levels and the channels followed by drivers to obtain their license; in order to cater for such heterogenity, the measures planned had to be diversified, in particular through the use of specific media for safety campaigns targeted at different groups of road-users and the adaptation of training procedures in the light of the educational levels of those at whom they were aimed. The question was raised of the standard of knowledge acquired and its consistency, and the consequences of such state of affairs on the way the traffic system operates and its reliability. Obviously, more detailed investigations following similar methods to those applied in the short survey were been required to obtain a reasonable assesment of these consequences, but the simple study carried out was sufficient to raise the decision-makers' awareness of the problem and, hopefully, avoid over-simplification of the action taken.

Surveys similar to that of Niger may be conducted easily enough on the basis of simple questionnaires which can be adapted to each case and local context. The effort involved remains reasonable and data treatment is fast, provided a micro-computer is available to enter data from the questionnaires.

IV. THE PHILIPPINES CASE STUDY: A COMPREHENSIVE SAFETY DIAGNOSIS BASED ON ACCIDENT AND CONFLICT DATA AND BEHAVIOURAL OBSERVATIONS

In 1985-86, a research team from INRETS carried out an extensive road safety study in the Philippines, financed by the World Bank. Ten months were available to draw a nationwide diagnosis of the accident situation and to design an action programme for the following five years.

When the study started, no accident data statistics were available. Moreover, there was not a single reference file available to indicate the magnitude of the safety problem or its main characteristics. The time-span allocated for the study was obviously too short to design and implement from scratch a comprehensive accident data collection system. It was immediately obvious that other approaches would be needed, and a panoply of them was used.

IV.1. Accident investigations

An exploration of all the possible data sources was first carried out. It was found that:

a) the main hospitals registered all entries, mentionning "road accidents" as one of the possible causes of trauma; a casualty file could be built on this basis, indicating a minimum annual number of accident victims, but the file would not be complete, as a large part of casualties would not be attended to in the hospitals; moreover, the fatalities occurring on the accident spot or during transfer would not be recorded;

b) the provincial Courts of Justice held detailed accident investigation reports for all cases coming to trial (i.e. all cases which were not settled directly out of court by the road-users involved); it was thus possible to draw a sample of accident cases from the files of some of the courts, and to analyse them in order to identify the main causal factors, but the sample representativity with respect to all injury accidents could not be checked;

c) the road police was starting to design an accident data collection procedure for rural roads; over a short period, it was possible to produce a simple accident form and micro-computer processing system, to train a group of police officers, and to implement the system over a limited geographical area; statistical results covering a period of three to four months would then be available at the end of the study.

The three types of accident studies were undertaken on a selected sample of two test-regions representing most the road and traffic conditions to be found in the country. Out of these, the statistical part was by far the weakest. None of the studies could be considered as representative of the overall safety situation and the findings could only be considered as first indications of what was going on. More investigations would be necessary to support these (Muhlrad, 1987).

On the basis of the accident records collected during the first four months of test of the new statistical procedure in the test-regions, the annual number of road fatalities in the Philippines was estimated to be over 4,800. When checking with other information from medical sources, the figure was thought conservative. It was nevertheless much higher than what was expected by Philippino authorities.

Although there were differences between the patterns observed in the two test-regions, some common accident problems were indicated, both from statistical data and from in-depth analyses of Court cases:

a) pedestrians were involved in about a quarter of all accidents, and accounted for a third to a half of fatalities; a third of the victims were children up to ten years old; low attention paid by drivers to pedestrians (especially by professional drivers who had to carry out several tasks simultaneously) could be at the origin of a quarter of pedestrian accidents; Court investigation files also indicated that drivers did not make much effort to avoid an impending collision with a pedestrian, but whether this was due to effective behaviour or to inadequate information on the emergency actions performed was not clear;

b) commercial vehicles (buses and trucks) were involved in a fifth of accidents in one of the test-regions and in a third of accidents in the other one; among these, single-vehicle accidents consecutive to a loss of control were particularly lethal, due both to the number of passengers transported by each vehicle, and to the absence (or inadequacy) of shoulder;

c) mopeds and light vehicles (bicycles and tricycles) were involved in a quarter to a third of all accidents, and probably more in urban and suburban areas;

d) overtaking manoeuvres played a part in about 15 % of urban accidents and over 25 % of accidents on highways, generating, according to traffic and infrastructure conditions, either head-on or rear-end or insertion collisions; on rural roads, overtaking accidents often indicated a parking problem, related to the absence of shoulder or lay-by;

e) priority problems at junctions played a part in a third of urban accidents, which may have been due to the drivers being unaware of the regulations, or the priorities not being clearly indicated and the road-users disagreeing in their interpretation of them.

Overall, the findings were not quite what was expected from the general feelings or opinions currently expressed by the road-users and the media: whereas jeepneys (or local minibuses) were usually considered as the major hazard, they did not appear as particular safety targets from accident studies; also, the risk to pedestrians and non-motorized traffic seemed to be generally underestimated by the population.

IV.2. Traffic conflict survey

In order to check and possibly confort the tentative findings of the accident analyses, it was thought that conflict observations, carried out in a systematical way, would be useful.

The French Conflict Technique was considered for the task, but it applies to spot-locations such as urban or rural junctions, pedestrian crossings, etc. and could not fully account for problems such as dangerous overtaking manoeuvres; moreover, there was no basis on which to choose relevant observation points (Muhlrad, 1988). The technique was thus adapted, with the aim to provide a description of behavioural and other factors playing a part in near-accident causation all along the road network.

The modified conflict technique, or SBOT (Systematic Behavioural Observation Technique) has been described at length in a previous ICTCT paper (Muhlrad, 1989). To summarize, the SBOT differed from most TCTs used in Europe or North America on two main points:

a) conflicts were counted as well as lighter interactions less narrowly connected to accident risk; the main reason for this adaptation was that we could not get the time or means necessary for a proper calibration study fixing a minimum threshold for observations; this had the side-advantage however of providing more information on the traffic conditions encountered by drivers;

b) conflicts and interactions were counted by observers, not from fixed locations at the road-side, but from a moving vehicle on a sample of test-routes; the conflicts observed were those in which the driver of the test vehicle had to perform an evasive action; the perturbation at the origin of the situation was noted.

Counting conflicts from a moving vehicle made it possible to get some information for the diagnosis without having to choose arbitrary locations for observation; the drawback was that the SBOT was less powerful than the original TCT to identify the influence on safety of particular road features: most of what could be gained from it was indications of behaviour.

Three teams of three Philippino observers were trained to use the new technique, then put to work. Again, roads were sampled in the two test-regions.

Over 6000 conflicts or pre-accident situations were registered in the following three months. Data was analysed through computer programmes, and results were compared to what was found from accident studies.

Findings from the SBOT observations confirmed that overtaking manoeuvres were at the root of the largest proportion of pre-accident situations involving two vehicles; head-on conflicts were the most frequent type observed in such situations. On rural roads, the parking problem suggested by accident data also appeared from conflict data as frequently at the origin of the dangerous overtaking manoeuvres.

The most frequent sources of perturbations were found to be, not jeepneys as expected from public opinion, but private cars and buses as shown by accident studies. Again, the main "offending" manoeuvre was overtaking, associated to head-on conflicts.

There were indications that tricycles, used for passenger transport, may also have generated more than their share of perturbations, but these were only observed in urban areas. This would confirm the involvement of such light vehicles in accidents and suggest that behaviour of tricycle drivers may be one key to the problem.

Conflict analyses did not bring any information on hazards to pedestrians: virtually no pedestrian conflicts were recorded by the observers. It was assumed that this was due to a combination of driver behaviour (a driver seldom attempts to avoid a pedestrian) and bias of the observation technique (a conflict or an interaction was recorded only if the driver of the test vehicle had to perform an evasive manoeuvre, not if the "perturbing" pedestrian had to jump aside!); this would be in accordance with the previous assumption made from in-depth analyses of Court cases.

Similarly, conflict analyses did not provide any additional knowledge as to priority rules at junctions, due to the fact that the test vehicles went through intersections with the flow of traffic, while sedentary observations would have been requested to seize the phenomenon. Other forms of behavioural observations could partly fill this gap.

IV.3. *Behavioural observations*

Two campaigns of observations were staged, one directly related to the overtaking problem already suggested both by accident and conflict analyses, the other aiming at additional knowledge of the drivers' compliance with road signs and regulations, and focussing on intersections with priorities marked by a stop sign.

In addition to observations, traffic counts were taken for each category of vehicle and a survey was carried out on the drivers' awareness of road signs (Saad and Sevilla, 1986).

IV.3.1 *Observance of the no-overtaking markings*

Observations were conducted at four sites where longitudinal road markings prohibited overtaking: one site was located in an urban area, one in a suburban area and two on rural highways (one before an intersection and one before a bend). A table was drawn up in order to collate data on the types of overtaking and overtaken vehicles, the motives for overtaking (vehicle stopped on the carriageway, preceding vehicle slowing down or slower), and the appearance of traffic on the opposite lane at the time when the overtaking vehicle begun its manoeuvre.

Results were expressed as a percentage of drivers committing violations out of the global traffic passing the observed site. They indicated a relatively significant proportion of violations of regulations (17 %) in spite of the potential danger indicated by the road markings. Bus drivers tended to overtake more frequently than other road-users (28 %), followed by drivers of private cars (21 %) and truck drivers (18 %). It was observed that bus drivers accounted for the highest violation rates on all sites, while jeepney (or minibus) and truck drivers committed violations more frequently in urban or suburban areas than on rural roads (where traffic speeds were higher).

The violation rate was higher (22 %) at the site located in the urban area. This was linked to the frequency of stopping manoeuvres on the carriageway or of slowing down manoeuvres (particularly by public transport vehicles). The three other sites studied yielded comparatively similar results (violation rate ranging from 15 to 17 %) although non-compliance with the regulations was particularly dangerous at one of them located before a bend with reduced visibility on a rural highway.

Most violations were observed in the absence of on-coming traffic in the opposite lane (70 %). These violations were nonetheless dangerous inasmuch as they could have affected the safety of other road-users (pedestrians in the urban area, for instance) and on account of the hazards which the road-markings were supposed to identify (bends without visibility, proximity of an intersection).

The types of behaviour observed were partly related to the heterogeneous nature of the traffic involved, which led to significant variations in driving speeds, and partly to the stopping of public transport vehicles on the carriageway, especially in urban and suburban areas. They also illustrated the importance given by drivers to maintaining their speed regardless of traffic regulations. More generally, they raised the problem of drivers' perception of danger and risk-taking (Saad, 1988).

The survey of drivers' awareness of traffic signs, which was conducted in parallel to the observation study in the same geographical area, involved 140 drivers (55 drivers of light vehicles, 30 of buses, 30 of trucks, and 60 of jeepneys). The main findings were that very few drivers were unaware of the meaning of road signs and markings (5 %), but most of them admitted to breaking regulations in certain instances (e.g. in the absence of any on-coming traffic, for overtaking much slower vehicles, or when there was little risk of being caught by the police).

IV.3.2 Behaviour at junctions with a stop-sign

Observations were performed at six intersections, including three cross-junctions and three T-junctions. An observation table was drawn up in order to collate data on the type of vehicle (jeepney, motorcycle, moped, bus, truck, or light vehicle), the behaviour displayed at the stop-sign (full stop, near stop, no stop), and the appearance of traffic on the highway by the time the observed vehicle arrived at the junction.

The main results, based on the observation of 1,290 vehicles, showed that the majority of drivers (64 %) did not strictly observe the regulations at the junctions. The most frequent offenders were bus-drivers (88 %) and motorcyclists (73 %).

Drivers' behaviour largely depended on visible traffic on the highway: in the presence of traffic, most drivers came to a full-stop (64 %), whereas this was the case for only 8 % of drivers in the absence of traffic. The result was valid for all categories of road-users, but it must be said that bus drivers seemed to be less influenced by the presence of traffic than other drivers (it would seem that they tended to assert their right-of-way at junctions).

Generally speaking, the stop sign did not seem to be associated, in the minds of drivers, with a systematic unequivocal type of behaviour. In fact, they seemed to behave more in terms of their own evaluation of the situation encountered and of what could be called functional determining factors related particularly to traffic, rather than in terms of regulatory determining factors as represented by the road sign system.

The survey of drivers' awareness of traffic signs referred to earlier indicated that, although most of the drivers were aware of what the Stop sign meant (92 %), 32 % of them stated that they usually merely slowed down in the absence of any visible traffic on the highway. This result suggested that awareness of regulations would not be the only factor for explaining observed behaviour: the attitudes of road-users towards formal regulations probably played quite an important part.

IV.3.3 Conclusions

The two behavioural studies carried out in the Philippines brought into relief the significant scale of non-observance of traffic regulations on the part of the various categories of road-users (although this tendancy is more pronounced among certain categories such as bus drivers). The survey conducted in the same geographical area indicated that non-observance would not be due to a lack of awareness of the meaning of road-signs and markings, but rather to the priority which drivers gave to informal rules at the expense of formal rules as laid down in the highway code. Improving compliance with traffic regulations was therefore a vital objective to be reached and constituted a priority theme for information and training campaigns for road users.

IV.4. Additional investigations

To complete our knowledge, it was thought useful to examine the traffic regulations themselves and their consistency. A short investigation showed that there were in fact several sets of highway code actually in effect dating from before, during and after McCarthy's time, and that two of them at least were behind existing road markings. Thus, central lane marking indicating a ban on overtaking could be yellow or white and include one or two solid lines. Such a situation is certainly not conducive to the driver preferring formal rules to his own informal ones, especially when coming from an area where overtaking is banned by two parallel solid lines and coming onto a road where only one line is used.

It was also observed that, in urban areas, road signs or markings did not always match the local priority regulations; an example of this is the city of Cebu where a traffic plan had been enacted, but no signing was put in to indicate one-way streets and priorities; in such case, road-users familiar with the city usually agree on the same rules (formal or not) while outsiders are at a loss.

Prior to improving drivers' compliance with safety regulations, it was therefore found essential to update the highway code and put road signing and marking in accordance with the rules, either general or local.

IV.5. Compound findings

Although the Philippine road safety study started in a difficult situation where accident data and other relevant information were concerned, the association of several methods enabled us to draw a reasonable diagnosis. We felt confident in recommending a number of measures including:

a) up-dating the highway code;
b) performing a more comprehensive inventory of the highway network in order to improve and homogenize markings and signing;
c) adapting the road design where necessary to take care of growing traffic (in particular through adding, widening or better maintaining road shoulders);
c) developing signing and markings in the larger urban areas where traffic plans have already been required;
d) organizing safety campaigns, targeted to the purpose of regulations and the need to comply, and addressing particularly private car and bus drivers;
e) improve driver training, with particular attention to information taking to prepare overtaking, to compliance to priority rules, and to risk and rights of the pedestrians.

The whole road safety study lasted only one year, which was made possible by the availability of a large team of Philippino professionals to perform observations and surveys. The use of conflict techniques based on live-observations is in general time-consuming; one could wonder, for instance, whether SBOT findings, which relied on three months work for nine investigators, were worth the effort; to which we could answer that, in a situation where no valid information was at first available but where it was nevertheless unthinkable to propose safety measures without any objective background, any amounts of data recouping each other were a welcome improvement.

The only possible alternative would have been to reconstruct the accident data recording systems at the national level, an operation that could have lasted at least three or four years, including agreeing on a system for data collection and treatment at the institutional level, training the road and the urban police, and implementing the system in real size, before any kind of (hopefully) reliable data could be available; even this could not have ensured that all injury-producing accidents be declared by the citizens to the relevant authorities!

It has to be noted that in most of the countries of the world where road accidents are now becoming a problem (and a fast growing one), there are yet no valid accident data systems. Such an approach adopted in the Philippines, although it has been declared by some decision-makers too ambitious and research oriented, is in fact the only possibility in many cases to formulate short and medium term safety policies based on objective facts and addressing the real problems. Reducing the amount of analysis and observation work needed would mean acting blindfolded, which warrants little hope for efficiency.

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WHAT IS SUSTAINABLE TRAFFIC? ARE SAFETY, MOBILITY AND LIFE QUALITY COMPETING WITH EACH OTHER?

Report - working group A

Introduction

In this working group two papers were presented. In one of them (Glaser, AUVA - Vienna) methods were discussed on how to remind the drivers that their behaviour is of social relevance (e.g., for vulnerable road users). The second presentation (Pajunen, VTT - Espoo) gave some comparisons between the risks connected to different types of traffic modes, including a differentiation of the risk one undergoes oneself and the risk one constitutes for other road users.

Some reflections about subjective risk and mobility

The discussion of subjective risk came up, as well. E.g., bus drivers and bus passengers are quite safe, according to results of accident analyses; at the same time, again according to results of accident analyses, busses do not produce so much risk for other road users, when risk is quantified with the help of accident numbers and accident ratios.

However, in the discussion, the problem was taken up that "objective" safety (defined as "no accidents") can also be influenced positively by the fact that other road users keep out of way or stay at home. The hypothesis was expressed that local-transport busses are involved in very special interactions: Other road users, especially pedestrians, accept longer waiting times, renounce in their right of way, or avoid certain roads and intersections, just in order not to get involved in a more narrow - and more dangerous - interaction with busses. The interaction bus-pedestrian is maybe not a really strong case, but we wanted to take it as an illustration for the general problem that is connected to subjective safety aspects: There is a strong potential, there, that feelings of not being safe in certain traffic circumstances - that definitely reflect negative impacts on life quality - influence the modal split. Bluntly speaking, it is not at all unprobable that objective safety often improves because certain road user(s) (groups) renounce in certain rights and/or reduce their mobility. (It is very difficult, however, to tell what impacts it has on traffic safety that many potential pedestrians use the car, instead of, e.g., walking).

Conflicting values

The discussion in the frame of this work was based on the concepts reflected in tables 1 and 2 (below), that were presented by the chairman and accepted by the group. The concepts are based on the assumptions that

a) dealing with values happens on different levels (see table 1: a four-level scheme was accepted by the working group),
b) and that on all levels different types of conflicts can arise (see table 2: within the person, and between persons, groups and society).

Table 1 reflects the idea - and so did the discussion in the workshop - that it is more probable that people easily agree on a higher level of the discussion (everybody agrees on the relevance of the values themselves - at least, nobody says that they should not be considered). Operationalisation, implementation and evaluation are increasingly more difficult.

Table 1: Levels of discussion of values

Values agreed upon
Equal rights
protection and integrity of human life
freedom (of choice, of decision)
environmental protection, etc. etc.
Operationalisation of values
How are these values reflected and defined more in detail?
Implementation
What do you have to do? How do you have to behave in order to achieve these values?
Evaluation
Is a value achieved?

Table 2 beneath gives a very simplyfied overview over different types of conflicts within and between persons and groups with respect to values. Many of the examples given further below may imply several of the conflict types mentioned in table 2 at the same time.

Table 2: Some selected types of conflicts with respect to values

Conflicts between values
Intrapersonal conflicts
Conflicts between individuals (interpersonal conflicts)
Conflicts between groups (cohorts) in society
Conflicts between individual (or group) and societal interests

The scheme displayed in table 2 can certainly be extended (both from a systematic point of view, and from a more analytic perspective). However, in order to understand the work done in our working group it is perfectly enough to stick to the conflict constellations that were mentioned in the working group's discussion.

Some examples and possible solutions

In the discussion several examples for conflicts with respect to values, their operationalisation, their implementation and the evaluation of situations (e.g., before and/or after countermeasures) were given. Table 3 (below) reflects these eamples in a more systematic way.

Mainly the following *conflicts between cells (capital letters) in table 3* were discussed extensively by the working group:

a) Conflicts between E and P.
b) Conflicts between F and P.
c) Conflicts between I and P.
d) Conflicts between J and P.
e) Conflicts between K and P.
f) Conflicts between L and P.

Below, those aspects of these conflicts that were discussed in the group and some recommended, or suggested, solutions will be displayed.

Table 3: "Safety and equal rights" or "safety or equal rights"?

	Safety		Equal rights	
	Bus(+driver +passenger)	Pedestrians	Bus(+driver +passenger)	Pedestrians
Values	A) ok	B) ok	C) ok	D) ok
Definition/ Operationalisation	*E) no accidents*	*F) no accidents*	G)agreeable mobility	H)agreeable mobility
Implementation (as things have developed	*I) A la status quo*	*J) A la status quo*	*K) A la status quo*	*L) A la status quo*
Evaluation (has v.been achieved?)	M) yes	N) yes	O) yes	*P) no*

a) and b) Conflicts between E/F and P

One could provide for more equal rights - with respect to mobility - by accepting more accidents between pedestrians and busses. Of course, this is absurd. The only other way to solve the problem via a redefinition of safety both for busses and pedestrians is, to include subjective safety: Let us say, we are not satisfied by busses who give pedestrians the feeling that they are unsafe. Both groups (bus drivers+passengers and pedestrians) should feel, e.g., comfortably safe. What kind of driving by bus drivers would that imply? The question is, to what degree bus drivers feel comfortable already with the driving style they display today, and if maybe a more considerate driving style causes them discomfort? This question will be discussed more extensively under e) and f).

c) and d) Conflicts between I/J and P

Changes in road design and in the organisation and regulation of traffic might be able to solve the contradiction we have displayed in table 3. One comes immediately to think of separation of different traffic modes, on one hand, and of lower bus speeds on the other.

The possibilities for separation of different traffic modes are very limited, however, as there is only limited space. Moreover, we know from experience, that separation often causes even bigger problems for pedestrians than we are discussing here:

Bridges, tunnels, streets there pedestrians are with physical means kept from crossing, etc., are well known "safety-"measures for pedestrians.

Lower speeds of busses would definitely do subjective safety of pedestrians good and make walking more comfortable. (But please remember that busses are only our pedagogical example, here; if one takes "motorised traffic" instead of "busses", the relevance of this discussion will become more transparent). Lower speeds of busses would not, at the same time, deteriorate the safety situation of both bus drivers + passengers and vulnerable road users; and one could dare to add: even if exposure of pedestrians increases as a consequence of improved comfort and ease.

However, lower speeds of busses have been discussed even more, in the working group, as displayed below:

e) Conflicts between K and P

All members of the working group agreed that drivers of busses in public transport obviously feel the press to drive fast - so lower speeds would definitely contradict what drivers probably define as unacceptable with respect to travel times. However, some arguments were presented that could change this perspective a little bit:

It cannot be excluded that bus drivers feel press from the passengers' side to drive fast - where "high speed" is equal to "short travel time". On the other hand, some members of the working group know of literature that shows that the absolute speeds themselves are not so important: It is much more important that travelling is not disturbed by long stops and by frequent changes in rhythm. The journey should go smoothly, the passenger should feel that things move on all the time. Higher speeds in urban areas imply most probably more necessities for more or less abrupt changes in speed. Even swerving might become more frequent. All that could actually be felt as the contrary to a smooth travelling by the passangers.

Another argument was that, after all, bus drivers are "only" car drivers. The suspicion was raised, thus, that for them with respect to speed it would be the same as for "all" other car drivers: Rather high speeds are preferred to what drivers feel as being low speeds - probably on the contrary to what vulnerable road users often think of vehicle speeds.

f) Conflicts between L and P

A more cynical part of the discussion is reflected by the question: Can we achieve smooth, comfortable, and safe mobility for pedestrians, at all? Or shall we decide that it is not necessary to achieve smooth, comfortable, and safe mobility for pedestrians, and that other achievements are much more important (e.g., fast moving surface transport)?

However, *this will be an either-or question only if it is not possible to combine values we have been discussing*. If it can be shown that high speeds for busses in local transport are not a necessity for the passengers, then why should we not argue for a compromise including lower speeds of buses (and remember, that "busses" stands for more than just busses), if lower bus speeds make life easier for pedestrians, at the same time?

Maybe, today we cause a lot of economic damage by infrastruc-tures that disturb the mobility of pedestrians (and ***busses one is afraid of are part of such a disturbance****), because fewer people than would be possible otherwise walk under the prevailing conditions. They prefer to travel in "a safer way", instead.*

On the other hand, for our cities it would be of great value, in many respects, if as much persons as possible walked (and maybe cycled). It is very probable that car use could be reduced by that; many car drivers do not walk or cycle today because they experience these modes as being unsafe. A reduction of car use would, at the same time, help to reduce the consumption of space, air pollution, noise, stress, and, objectively, unsafety.

With respect to the example we chose for our discussion one can say that safety, mobility, and life quality are not really competing with each other.

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SECURITY AND QUALITY OF LIFE FROM THE POINT OF VIEW OF ACCIDENT PREVENTION

Today traffic is much more a human problem than a technical one. A flood of regulations have an effect on the road user. As long as he does not see the real sense of these regulations, it seems a competition to mobility and quality of life because he feels himself restricted in his personal freedom.

Therefore we can only pass on information in a useful way, if road users become aware of the concrete danger without feeling "annoyed". If we are only satisfied with "security just being a participant", ways will always be found to annul or avoid the measures (support of organisations - test cases).

An example of successful road-safety-work is the campaign "apple-lemmon" which has been sponsored by AUVA and KfV. Within this campaign pupils, in cooperation with the local police, distributed the fruits on certain places along the roads depending on the drivers' behaviour. They gave apples (if the speed limitations were kept) and lemmons (if the speed limitations were exceeded) to the drivers. The effect on those drivers is great.

Similar positive experience can be made at seminars with professional drivers and drivers of emergency vehicles. These people have mostly got a high experience value in road traffic. The reactions of these drivers are very impressive when the "physics of driving" and the "dynamic of accidents" are illustrated clearly in the seminars.

All these activities alone will not be enough to raise security on our roads. They can only be a part of a complex approach. If children, however, draw our attention to our mistakes, and if we react positively, we reach an increase in the life-quality of us all without realizing it.

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COMPETITIVE TARGET IN THE DESIGN OF THE STREETS DUE TO THE NEED OF OLDER ROAD USERS

Because of the demographic development in the Federal Republic of Germany, as well as in other western industrial countries, we must reckon with a high increase of the older population. Results of our own as well as other questionings make clear that the car is of a great importance to maintain mobility and therefore the quality of life for the old. That is why measures which make participation for the old in road traffic more difficult are to be refused. Future efforts should be rather concentrated on the design of the road-system so that, in its demand, it corresponds with the efficiency of the old. This necessity also results from the (low involvement in accidents in general) considerable risk of older passengers in the case of an involvement of an accident to suffer from fatal accidents. A condition for a better organization of the road system is the exact knowledge of those duties older drivers hace difficulties with (e.g. complex junctions). These difficulties are examined by us within the scope of an extensive research project whose most important results should be presented in the report in hand. Furthermore we suggest that with a view of the needs of older road users one has to take future measures for the organisation as well as criteria of mobility and security from the point of view of the poverty of demand into account.

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SAFETY OF TRAFFIC COMPARED TO OTHER HUMAN ACTIVITIES

1 Background

The comparison between traffic and other human activities has been made already four times in our laboratory. The first time covered years 1979-1981, the second time years 1982 - 1984, the third time years 1985 - 1987 and the fourth time years 1988-1990.

2 Comparing safety

The safety of traffic can be compared with other human activities only on the basis of fatalities because the statistics cover almost all fatalities in different areas of human activities.

When studying only the traffic sector also the personal injury accidents (fatalities + personal injuries) could be used. The severity of the accidents is however different in different traffic modes. The comparing of personal injuries is difficult because the definitions of an injury differ so much. Also the coverage of the statistics in different human activities and in different traffic modes varies a lot.

When comparing traffic and other human activities the measure of the risk exposure is the volume of person hours (person exposure). In the studies in the traffic sector also the volume of person kilometres is used.

Different traffic modes were not compared only with the fatalities caused to the own traffic mode but also with the fatalities caused to other traffic modes. This is done to describe all the risks of different traffic modes.

We also estimated the lost living time in the traffic accidents compared to the time used in traffic.

2 Results of the comparison

The number of fatalities / 100 x 10^6 person hours and for the traffic also the number of fatalities / 100 x 10^6 person kilometres are presented in table one. There are also figures that describe the safety of time spent at home and leisure time in the year 1986. In air traffic the safety of scheduled domestic air traffic is presented by the numbers describing international scheduled air traffic. In industry the professional diseases are included in the numbers and the numbers for years 1988 - 1990 are calculated on the basis of new industry classes. The volumes of cars on other highways and local roads were not accessible, thus we were not able to calculate those.

The safety of working during 1985 - 1987 decreased compared with the previous three year period. The safety of industries except constructing remained the same when comparing years 1988 - 1990 with years 1985 - 1987. The decrease of the safety of constructing is partly caused by the increase of professional diseases (especially cancer caused by asbestos) which is probably going to increase also at the beginning of the 90'es.

It can be concluded from the number of fatalities per person hour and kilometre which is the safest traffic mode. Train and bus are still safest and private aviation and gliding the most dangerous traffic modes. Travelling by motor cycle or moped was clearly more dangerous in the three years period 1988 - 1990 than 1985 - 1987. Those two were the most dangerous traffic modes in road traffic.

The safety of travelling by car remained the same when comparing the years 1982 - 1984 with the years 1985 - 1987. When we compared years 1988 - 1990 with the previous three year period the safety of travelling by car had decreased. Also the safety of travelling by van and lorry had decreased during this period. The safety of travelling by bus had increased by some degree. The safety of motor vehicles in total increased a little when comparing years 1985 - 1987 to the previous three year period. But when we compared years 1988 - 1990 with the years 1985 - 1987 the safety of motor vehicle travels decreased clearly.

The effect of the speed of the traffic mode is clearly seen in the following example. The risk per person kilometres for the pedestrians (7.4) is about ten times as high as travelling by car (0.77). When studying the risk per person hours the risk of walking (34) is lower than the risk of travelling by car (40). The faster traffic modes seem to be safer when comparing the risk by kilometres than when comparing it by time.

The risk caused to the own traffic mode is highest for motor cycle, which is light and fast. There is no cover like you have in a car. When the speed is high the accidents usually have severe consequences. The heaviest vehicles cause usually the highest risk for other traffic modes. In road traffic the lorries seem to cause the greatest danger for other traffic modes. In data from the years 1988 - 1990 the risk caused by lorries (4 fatalities/100 million person kilometres or 179 fatalities/100 million person hours) to others has decreased a little compared with the years 1985 - 1987.

Table 1. The numbers of fatalities in different activities and the fatalities per 100 million person kilometres and hours in 1982 - 1984, 1985 - 1987 and 1988 - 1990.

ACTION	Number of fatalities			Number of fatalities /100x10^6 h			Number of fatalities /100x10^6 person km		
	82–84	85–87	88–90	82–84	85–87	88–90	82–84	85–87	88–90
INDUSTRY [1]									
Agriculture and forestry	19	13	19	4	6	6	–	–	–
Industry	73	114	95	2	4	3	–	–	–
Construction	66	61	77	7	7	11	–	–	–
Traffic	46	45	52	6	6	6	–	–	–
Other industry	52	64	60	1	1	1	–	–	–
Total Industry	**256**	**297**	**303**	**2**	**3**	**3**	–	–	–
TRAFFIC Public roads									
Car	598	644	862	46	44	52	0.81	0.77	0.91
Bus	6	7	3	2	2	1	0.04	0.04	0.02
Lorry	20	12	22	14	8	14	0.32	0.18	0.31
Van	26	39	52	27	32	36	0.53	0.64	0.71
Motor cycle	33	44	48	500	770	1,000	10	14	18
Moped	61	50	61	130	130	290	6.5	6.7	15
Total	**744**	**796**	**1,048**	**39**	**37**	**44**	**0.72**	**0.68**	**0.81**
Car									
Main roads (I class)	280	313	420	70	65	76	0.97	0.90	1.06
Main roads (II class)	76	105	119	57	65	62	0.85	0.97	0.92
Other highways	176	155	–	36	29	–	0.72	0.58	–
Local roads	66	71	–	24	26	–	0.58	0.62	–
Streets and private roads	149	175	193	15	16	17	0.41	0.46	0.46
Total	**747**	**819**	**1,046**	**35**	**35**	**40**	**0.68**	**0.67**	**0.77**
Ages 15–64									
Pedestrian	203	208	191	33	37	34	7.7	8.1	7.4
Cyclist	129	105	98	28	28	26	2.7	2.4	2.2
Moped and motor cycle	102	114	126	183	288	317	7.0	9.7	10.7
Total	**434**	**427**	**1,147**	**38**	**43**	**42**	**4.9**	**5.3**	**5.1**
Air traffic									
International scheduled traffic [2]	–	–	–	–	37	–	–	0.06	–
General aviation	19	8	19	4,100	1,400	2,700	20	7	14
Gliding	3	3	3	700	2,800	2,700	45	45	45
Total	**22**	**11**	**22**	**105**	**46**	**71**	**0.19**	**0.08**	**0.13**
Rail traffic									
Rail traffic, passenger	6	0	0	3	0	0	0.06	0	0
TIME SPENT AT HOME AND LEISURE (5–64 years) 1986									
Men at home, awake				–	4	–	–	–	–
Women at home, awake				–	1	–	–	–	–
Men, leisure time, outside home				–	30	–	–	–	–
Women, leisure time, outside home				–	7	–	–	–	–

1) Professional deseases included
2) The average of the international scheduled flight in 1982–86.

It seems to be safer to travel by car along lower class roads (both fatalities/hours and fatalities/kilometres). This is because of smaller speeds on the lower class roads and in average the milder consequences of the accidents. The safety of travelling by car has decreased during the years 1988 - 1990 compared with the previous three year periods.

The accidents of scheduled or charter flights are rare. When comparing by time scheduled flights are as safe as going by foot and by kilometres as safe as travelling by bus or train. The risk of general aviation decreased in 1985 - 1987 compared with the previous three year period. In 1988 - 1990 the safety increased again. The yearly variation has been big.

The risk of dying accidentally in different activities for the persons aged 15 - 64 are is presented in table 2. The risk figures of working can be compared with other activities as they are. The risks of pedestrians and cyclists are estimated with the help of the travelling studies. The safety of time spent at home and leisure time has been estimated with the figures from 1986. Because the knowledge of the exposure is incomplete the risk of fatality of other traffic modes for ages 15 - 64 is presumed to be as high as the average risk for all ages. In reality the risk of elderly people is higher than the risk in average.

Table 2. An estimate of the number of fatalities for persons aged 15 - 64 in different traffic modes in 1982 - 1984, 1985 - 1987 and 1988 - 1990.

ACTION	Fatalities/ 100 million					
	person hours			person kilometres		
	82-84	85-87	88-90	82-84	85-87	88-90
WORKING						
Total	2.5	2.8	2.9	-	-	-
TRAFFIC						
Cars, total	26	26	32	0.54	0.55	0.64
Pedestrians	33	37	34	7.7	8.1	7.4
Bicycles	28	28	26	2.7	2.4	2.2
Motor cycles/mopeds	183	288	317	7.0	9.7	10.7
Road traffic, total	30	31	39	0.89	0.88	1.04
Air traffic, total	105	46	71	0.19	0.09	0.13
Road, air and rail tr., total	29	30	38	0.80	0.79	0.96
TIME SPENT AT HOME AND LEISURE						
At home, awake 1986	-	2.8	-	-	-	-
Leisure time outside home		21	-	-	-	-

In traffic when compared by kilometres especially going by foot and motor cycling are unsafe ways to travel. Also cycling is a little more unsafe thean other road traffic modes. When compared by time motor cycles and mopeds are clearly more unsafe than other traffic modes.

When comparing the figures from 1988 - 1990 with the ones from 1985 - 1987 in traffic the safety of pedestrians and cyclists has increased. The safety of motor cycles and mopeds, cars and air traffic has decreased clearly.

When the lost living time (the ages of the fatalities in traffic accidents substracted from the average age of the population) was compared with the time spent in traffic the most unsafe traffic mode was motor cycling. For every hour spent driving a motor cycle 1 h 37 min of life time was lost.

The safety of work seems to have decreased a little compared both from 1982 - 1984 to 1985 - 1987 and from 1985 - 1987 to 1988 - 1990. In 1988 - 1990 the risk of accidental fatality was about 4 % higher than during the previous three year period. In average time spent working is about as safe as time spent at home awake.

The safety of traffic varies greatly according to the traffic mode. In average travelling was in 1988 - 1990 about 13 times as dangerous as working.

If the difference between sexes is ignored the risk of accidental fatality during the leisure time spent outside home is about 7 times as high as the risk of working time in average.

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ROAD SAFETY AND THE URBAN POOR

The road safety situation in developing countries gives rise to significant concern. The number of reported road accidents has been increasing over the years. For example, in Kenya, reported road accidents increased at a rate of 6.8 per cent per annum throughout the 1980's. This rate of increase is twice as high as the population growth rate and two and a half times higher than the rate of growth of the motor vehicle fleet. The number of fatalities and injuries also increased over the same period at 4.2 and 9.6 per cent per annum respectively. Road safety has become a major health issue since there are now in Kenya more than 2.000 deaths and 20.000 injuries per year. At 65 deaths per 10.000 vehicles, Kenya has one of the largest fatality rates. Clearly the situation gives rise to much anguish and grief to families and friends of victims. In addition enormous economic costs are involved with annual cost of road accidents in Kenya estimated to be in the region of US $ 125 million, equivalent to 2.5 per cent of GDP (1988 prices).

A large proportion of road accidents occur in urban areas. Data from 1972, 1986 and 1987 indicate that around 31% of personal injury accidents and 56% of all accidents occured in the Capital City of Nairobi. 60 to 70% of all accidents in the urban centres involve both the pedestrians and cyclists. A very large number of workers in all urban centres walk to work. In Nairobi, about 60.000 pedestrians enter the central and industrial areas in the mornings. Overall, it is estimated that 45% of daily trips in Nairobi were by the walk mode. The routes taken by the pedestrians are generally unsafe and uncomfortable. They walk in the carriageway of roads exposing themselves to traffic hazards, or use rough tracks cutting across open spaces. There are very few side walks and those that exist are generally in very poor condition.

Transport infrastructure facilities for the urban poor have not been provided and those that are neglected. Lack of cycle tracks in the transport network has discouraged cyclists leaving the poor workers to walk to work. This lack of facilities has resulted in increased traffic accident involving pedestrian and cyclists.

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PERCEPTIONS OF SOCIETY ON MOBILITY AND RELATIVE SAFETY

Human behaviour is a reflection of the needs of individual members of a Society and the environmental factors that dictate survival instincts. Humans by nature seek personal well-being first and later considers the wider society. This instinct has since creation been moulded by the wider society in creating accepted norms, rules and laws which confer specific responsibilities to individual members. There are thus expected norms of behaviour.
A society's degradation can be observed when accepted norms are ignored or flouted without recourse or punishment. Aggressive behaviour becomes the accepted norm and increasing conflicts of interest become frequent. A society under such norms is one in turmoil and lacks harmony and national goals or aspirations. A society's level of education and awareness is a major determinant.
A simile can be drawn on the road traffic situation. Where as there are specific rules on the usage of roads, the level at which are respected is a reflection of the perception of norms of that society. In addition, the perception of responsibilities and obligations during usage is determined by the level of education and awareness of the users. Road user behaviour is a combination of factors most of which are environmental related. Mobility is created when a purpose is defined. Hence, trips are made to fulfill certain objectives.
The variety in trips and purposes comprise traffic interactions and if order and harmony prevails, there is little conflict. When order and harmony lacks, self interest come to the fore and shows itself in the form of aggression on the road, lack of respect for traffic regulations and other users and the result is conflicts of interests and accompanying accidents. As they say, accidents do not just happen, they are caused!

Human characterists that are shaped by environment include:
a) Individual perception of his/her responsibilities to society
b) Perception of reward from society arising from his/her contribution.

Driver for example will show civility and respect for traffic laws when they consider the society to put emphasis on order and respect for norms and reward him/her appropriately. However, the same driver could be aggressive and careless with his habits when the society loosens, is not responsive to personal welfare and encourages or is reluctant to punish, disobedience.
Similarly, a poorly rewarded driver feels demoralised and is tempted to show disaffection or aggression to balance the deficiency. Such is the aggression of drivers/conductors to over-speed in order to make good for the low rewards.
Environmental exposure also contribute significantly in moulding of attitudes and behaviour patterns. Pedestrians will be more careful on the use of roads when they have been given some exposure. Drivers will learn to be more considerate with continual interaction with other road users. Passengers will learn to be patient and refuse to be crowded in buses.
Safety is determined when all factors affecting individual members of a society and their relative contribution to social well-being are defined.

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THEORIES ON HUMAN BEHAVIOUR AND INTERACTION IN TRAFFIC

Report - working group B

E.J. CARBONELL VAYA, R. BANULS EGEDA & J.J. MIGUEL TOBAL - Anxiety and traffic safety. University of Valencia and University of Madrid, Spain.
O. CARSTEN - Safety is not necessary pleasant and pleasantness is not necessary safe. Institute for transport studies, University of Leeds, Great Britain
R. Van der HORST - Time-To-Collision and car-Following behaviour. TNO, Institute for human factors, The Netherlands
L. MONTORO, E.J. CARBONELL VAYA & P. TEJERO- Alcohol and traffic accidents. Unit of research on traffic safety, University of Valencia, Spain.

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Road users play an essential role in regulating road traffic system. It therefore follows that the study of their behaviour and the underlying psychological mechanisms is fundamental in any research aimed at increasing system reliability.

Research into road user behaviour logically falls within the theoretical framework of Human Sciences. It is aimed at developing our knowledge of this behaviour and its main determinants, both internal (specific to the individual) and external (linked to the physical and social environmental characteritics in which the individual develops his activity).

This research is diversified in terms of the theoritical frames of reference (perceptive, motivational, cognitive theories) and the investigative techniques it uses (observation, experimentation, simulation, surveys). This diversification in research reflects, to some extent, the complex causality networks revealed by accident analysis, which in turn brings into question the different dimensions of human behaviour and their interactions.

In road safety research, knowlegde acquired in these various fields of investigation helps to identify and put into effect the measures likely to modify user behaviour with a view to increased safety (information campaign, education and training, road infrastructure or driving aids design).

Depending upon the field of action proposed, this knowledge is formalised and compared to knowledge acquired by other sciences involved in road safety research (Engineering, Artificial Intelligence, Traffic Engineering, Epidémiology, ...).

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Work presented in session B represents some of the various fields of investigation developed in road safety research.

Before presenting this work, it should be emphasised that, in the other sessions held at this conference, considerable attention was given to the different theories on human behaviour and their application in this field. A number of the papers presented make explicit reference to such theoretical frameworks, whether this referred to analysing human error, risk-taking or yet again identifying behavioural determinants in certain specific situations (tramway crossing or intersection crossing for instance).

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Research presented par R. VAN DER HORST dealt with the analysis of driver information processing in traffic situation and the type of assistance that may help him in this processing. It was focused on the analysis of a specific driving situation, i.e. car-following, the aim being to identify the type of information likely to improve driver performance in this type of situation.

This falls within the optic flow theory frame of reference. One of the idea put forwards was that the direct use of time-related measures may be used as a basis for decision-making in traffic situations.

To investigate this point in greater detail, two research projects have been implemented using complementary investigation techniques: observing driver practices in actual driving situations on a stretch of motorway (using an inductive loop detector) and studying behaviour in a simulted situation (TNO driving simulator, a fixed-base interactive driving simulator).

Several behaviour indicators (speed, following distance, time headway and Time-To-Collision) were considered and compared in different sight distance conditions (normal and impaired).

The discussion dealt essentially with comparing results in an actual situation with those in a simulated situation, on the differential effect of sight distance on the various behavioural indicators selected and finally on the type of information most likely to be used by drivers to adjust their driving.

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Research by L. MONTERO et al., presented by E.J. CARBONELL a co-author of this paper, concerned another level of behavioural analysis, namely the driver's intention to enter in a driving situation which is known, from a safety expert point of view, to be risky, i.e. Drinking-Driving situations. This is focused on a specific population, for which the problems would appear to be particularly critical, young people.

The aim of this research is to identify the psychological factors associated with risky behaviour in young people, to form a basis on which to increase the effectiveness of traffic accident prevention programs. It entailed analysing the motivational, cognitive and attitudinal factors that may explain this behaviour. A model of human behaviour is used as a framework to investigate these problems, based on the Theory of Planned Behaviour, derived from the Theory of Reasoned Action (taking into account an additional factor, Perceived Behavioural Control).

It was conducted using a questionnaire-based survey, structured in particular around the presentation of various scenarios where this type of behavioural intention could arise.

The discussion dealt with the fact that, contrary to initial expectations, the "Perceived Behavioural Control" factor appear to be a non-significant determinant of intention with regard to the behaviour being studied. One of the reasons put forward during the discussion was that this result could be due to the fact that the "control factors" were not correctly selected. Finally, the question of switching from behavioural intention to actual behaviour was also raised.

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Research by E.J. CARBONELL et al., presented par E.J. CARBONELL refers to the development of an investigative method dealing with driver anxiety with regard to different driving situations, based on self-report - Inventory of Anxious Situations in Traffic (ISAT). The development of this inventory is based on an interactive behavioural model (emphasising the interaction between personal and situational factors) and on a review of present-day literature dealing with this subject.

Forty situations likely to produce anxiety were selected and classified into four types of situations : situations that imply evaluation, situations that imply an impossibility of achieving an aim, situations of real danger and situations that include non specific stressors.

The validity, reliability and internal consistency of the definitive inventory (which retains 32 of the 40 situations under consideration), were examined. This should provide an instrument with which to study the analysis of anxiety problems with regard to driving in greater depth.

Discussion focused essentially on the scope of the documentary investigation on which this research is based, on the type of indicators the most appropriate to study the variable in question, their measurement (direct or indirect) and, finally, on the links between these various indicators.

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The paper presented by O. CARSTEN, referred to the question of impact and the effectiveness of the different safety measures in relation to road user behavioural adaptation and/or unexpected uses of some road installations (that are somewhat different from the uses either expected or intended when these were designed).

It questions, in particular, the apparent gap that occurs when considering two problematics, calming the traffic environment and risk compensation.

Using several examples, the author examined the different types of problems that could be encountered:

- an unexpected use of traffic-calmed environment (eg: streets that have been traffic calmed being used for other activities such as motorcycle racing or skateboarding)

- a use that does not conform to traffic-calmed environment (eg: an attempt to drive through clamed environment as fast as possible to maximise one's thrill),
- or yet again, the transition from a traffic calmed environment to a non calmed environment (eg: an attempt to compensate for the delay after driving along calmed roads)

This presentation therefore forms part of the theoretical and methodological debate within the road safety research community with regard to these problems: driver adaptation, driver optimal level of arousal, risk homeostasis, accident migration. Discussions such as these lead us to question both the type of environmental changes that occur when implementing safety measures and the psychological mechanisms underlying driver adaptation to these environmental changes.

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As we have seen, the different papers presented in this working group illustrate the diversity of theoretical anchorages in research into road user behaviour, levels of analysis, the investigate techniques used and finally, the types of problems dealt with.

Study in this field revolves around the choice of models likely to clarify the road user behaviour in traffic, the consequences of this behaviour with regard to safety, and the choice of behavioural indicators which serve to reveal the psychological mechanisms underlying this behaviour.

The links between these different research orientations remain to be more defined. Although considerable knowledge has, in fact, already been acquired in each specific field, it still seems difficult to position this different knowledge dealing with the representations that road users make of themselves, of the technical and social system in which they operate (of its functioning and safety); the functional roles of these representations with regard to actual road user practices and information-processing in road situations; and, finally, the effects of situational variables on behaviour modulation. It is probable that future research work will be focused on defining more closely this links.

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THEORIES ON HUMAN BEHAVIOUR AND INTERACTION IN TRAFFIC

This paper will describe and summarize recent work by the Driver Behaviour Research Group in Manchester, UK. Our initial work developed a threefold typology of aberrant behaviours on the road - violations, errors and lapses. Lapses are unintentional mistakes whose consequences are embarrassing but not serious (e.g. attempting to drive away in third gear). They are more likely to be reported by female drivers. Errors are failures to monitor the environment which have potentially dangerous consequences (e.g. failing to notice a cyclist on your inside; misjudging on overtaking gap). Violations are intentional breaches of legal norms (e.g. exceeding a speed limit; running red lights) or social norms (e.g. showing hostility and high mileage drivers). They are reported more often by young drivers, male drivers and high mileage drivers. Young, male and high mileage drivers are over-represented in traffic accident statistics. Violations, but not errors or lapses, are related to accident history, even when demography and "exposure" are statistically controlled for. This holds true for both active accidents ("I hit ...") and passive accidents ("I was hit by ..."). While the immediate cause of any particular accident is generally one or more drivers making an unintentional error, drivers who intentionally commit higher levels of violations are more likely to be accident-involved.

Working form, and developing, a current social psychological theory base (Ajzen's Theory of Planned Behavior) we have conducted a number of studies showing that drivers'intentions to commit particular violations are influenced by the components of the theory: attitude towards the behaviour (the product of behavioral beliefs and outcome evaluations), subjective norm (the product of normative beliefs and motivation to comply with significant others), perceived control over the behaviour, moral norm and anticipated regret. Examples of the beliefs, attitudes and motivations which distinguish those drivers who do and do not intend to commit particular violations will be given.

Over the last decade attitudes and social norms have been targeted and turned around in respect of, for example, drink-driving and smoking. In our current resarch we are developing persuasive communications to be targeted at high violators, with a view to contributing to the reduction of road traffic accidents by changing drivers# attitudes in order to change their behaviour.

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TIME-TO-COLLISION AND COLLISION AVOIDANCE SYSTEMS

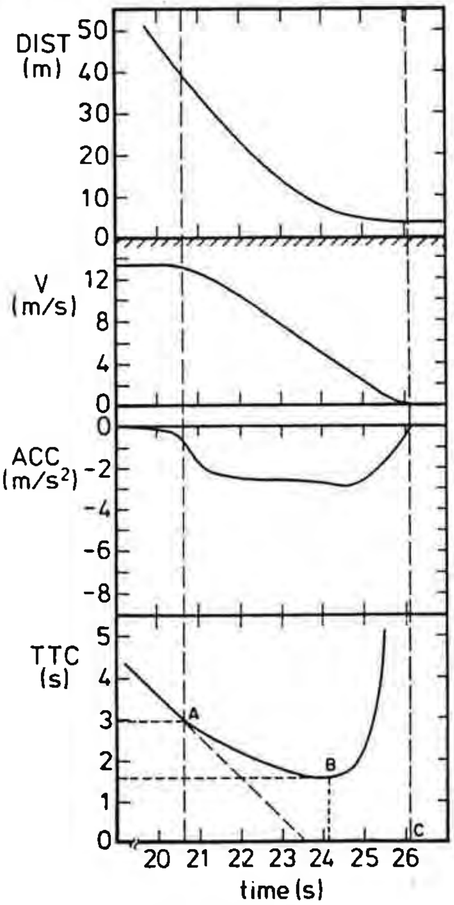
ABSTRACT

In research on Traffic Conflicts Techniques, Time-To-Collision (TTC) has proven to be an effective measure for rating the severity of traffic conflicts and for discriminating critical from normal behaviour. The results of several studies point to the direct use of TTC as a cue for decision-making in traffic. The current development of driver support systems based on the application of modern technologies makes it necessary to have detailed knowledge on how drivers operate, and at what level and when a system should warn the driver or take action. An important issue in developing Collision Avoidance Systems (CASs) is to define a proper warning strategy, that warns the driver only when the driver is really at danger and immediate action is required. Misses should be avoided, but too many false alarms may easily cause the system to become a nuisance to the driver.

The present paper deals with the use of the TTC measure to define an adequate criterion for activating a driver support system such as CAS in order to reduce the number of rear-end collisions on a motorway. Reduced visibility conditions (e.g. due to fog) frequently cause multi-vehicle crashes with very severe consequences. The results of a field experiment where subjects approaching a stationary object were instructed to start braking at the latest moment, reveal that both the decision to start braking and the control of braking may well be based on TTC information available from the optic flow field. First tests with Collision Avoidance Systems (CAS) indicate that warning strategies based on a TTC-criterion are preferred by the drivers and seem to be most in line with what drivers expect to get from a CAS. These tests only refer to a fixed 4 s TTC-criterion. Recently, some studies on driver behaviour in fog enable a more precise definition of CAS-critical situations and relevant criterion values for TTC. Based on the analysis of driver behaviour in adverse visibility conditions, it is concluded that it is worthwhile to investigate a TTC criterion in the range of 4.5 to 5 s for activating a CAS. Especially in the visibility range between 40 and 120 m free-driving speeds are too high, and therefore, special attention should be given to this distance range when developing a CAS.

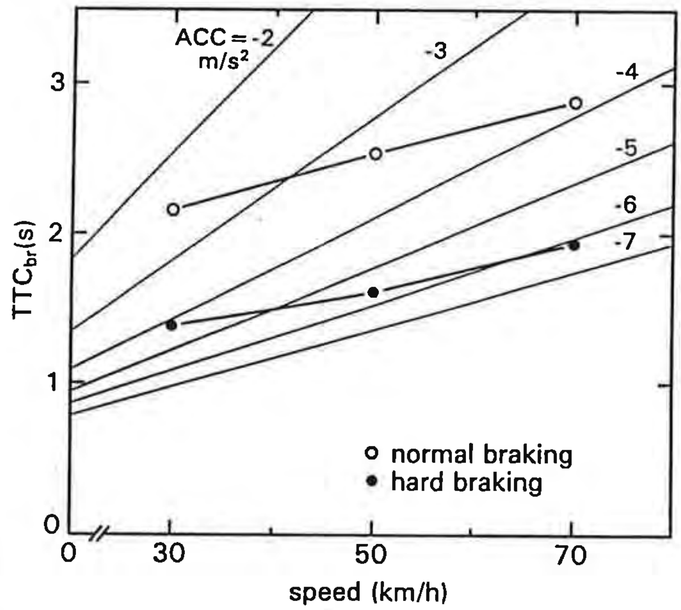
1 INTRODUCTION

Systematic observations of road user behaviour in various traffic situations combined with knowledge of human information processing capabilities and limitations, offer good perspectives in understanding the causes of safety problems. In particular, the study of conflict behaviour is a natural candidate for that purpose; the processes that result in near-accidents or traffic conflicts have much in common with the processes preceding actual collisions (Hydén, 1987), except for that the final outcome is different. The frequency of occurrence of near-accidents is relatively high, and they offer a rich information source on causal relationships. The process preceding conflicts can be systematically observed, which is essential for analysing, diagnosing, and solving traffic safety problems. The analysis of road user behaviour in critical encounters may not only offer a better understanding of the processes that ultimately result in accidents, but, perhaps even more important and efficient in the long run, also provide us with knowledge on road users' abilities of turning a critical situation into a controllable one. An important issue is how to distinguish critical from normal behaviour. The results of several studies point to the direct use of time-related measures as a cue for decision-making in traffic. In research on Traffic Conflicts Techniques, Time-To-Collision (TTC) has proven to be an effective measure for rating the severity of conflicts. Hayward (1972) defined TTC as: "The time required for two vehicles to collide if they continue at their present speed and on the same path". TTC at the onset of braking, TTC_{br}, represents the available manoeuvring space at the moment the evasive action starts. The minimum TTC as reached during the approach of two vehicles on a collision course (TTC_{min}) is taken as an indicator for the severity of an encounter. In principle, the lower the TTC_{min}, the higher the risk of a collision has been. To illustrate TTC, Fig. 1 shows what happens when a car approaches a stationary object. TTC_{min} indicates how imminent an actual collision has been. Details of the calculation of TTC can be found in Van der Horst (1990).

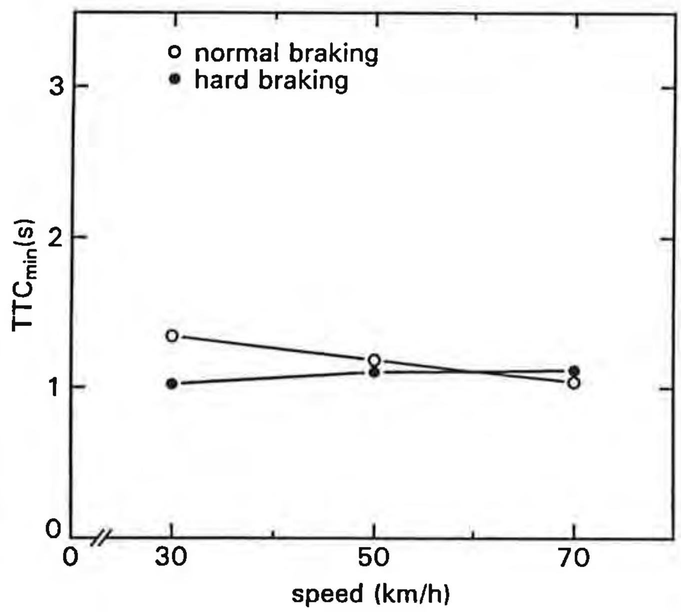


In general, only encounters with a minimum TTC less than 1.5 s are considered critical and trained observers appear to operate rather consistently in applying this threshold value (Grayson (ed.), 1984; van der Horst, 1984; Kraay & van der Horst, 1985; Hydén, 1987; van der Horst, 1990). When analyzing all encounters occurring at an intersection, encounters, in general, hardly display a TTC_{min} less than 1.5 s.

In a study on drivers' strategies of braking, it was found that both the decision to start braking and the control of the braking process itself may well be based on TTC information as directly available from the optic flow field (van der Horst, 1991). In a field experiment, subjects approaching a stationary object (simulated rear end of a small passenger car) with a given speed, were instructed to start braking at the latest moment they thought they could stop in front of the object. Fig. 2 reveals that TTC_{br} increases with speed, but less than could be expected on the basis of a constant deceleration model as represented by the fan of lines. The effect of braking instruction (start normal braking at the latest moment you think you can stop safely vs. hard braking at the latest moment you think you are able to stop in front of the object) indicates that subjects are able to apply the given instruction well, independent of approach speed.



The minimum TTC as reached during the approach appears to be independent of approach speed and normal or hard braking instruction and reaches a value of about 1.1 s, on an average (Fig. 3).

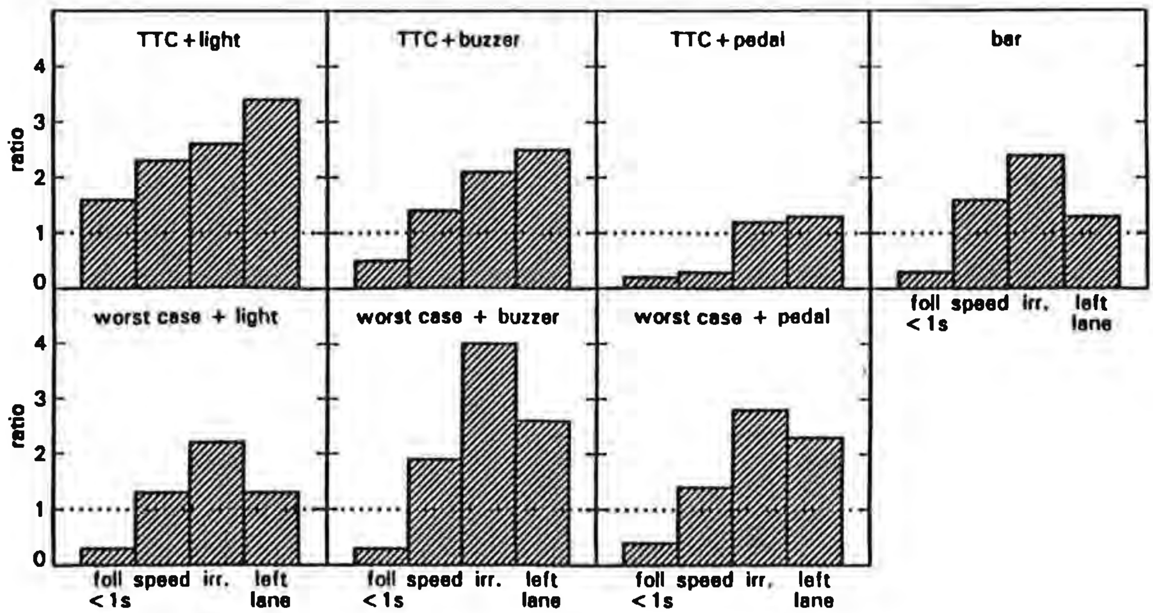


Since in this study the subjects were instructed to start braking at the latest moment they thought they could stop just in front of the object, the TTC_{br} values from Fig. 2 have to be regarded as absolutely minimal for activating a Collision Avoidance System. Together with an 1.5 s reaction time (with the time needed for moving the foot from the gas to the brake pedal included), an average TTC_{br} of 2.5 s would result in a TTC-criterion of 4 s.

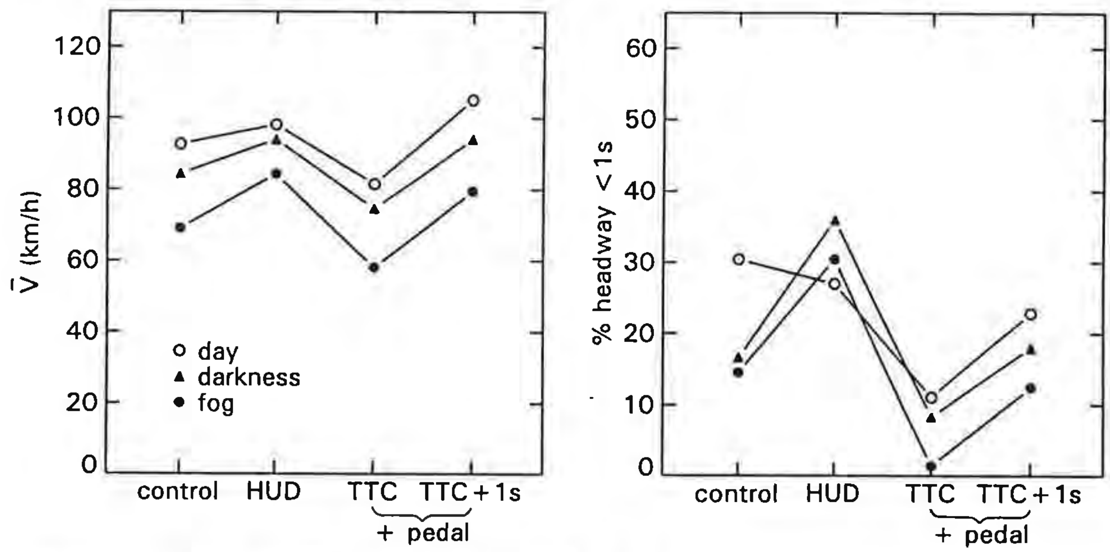
In the next chapter the first evaluation tests of applying this criterion value for activing a CAS will be briefly discussed. Since adverse visibility conditions such as fog enable a more precise description of critical approach situations and provide information on what criterion value for TTC should be used, some recent studies on driver behaviour in adverse visibility conditions have been critically reviewed. This paper concludes with a discussion on the consequences for defining an efficient CAS.

2 TTC IN COLLISION AVOIDANCE SYSTEMS

Within the DRIVE project GIDS (Generic Intelligent Driver Support) Janssen and Nilsson (1990) compared seven Collision Avoidance Systems (CASs) in an experiment in the TNO driving simulator. They combined two different CAS criteria with three possible system warning actions, viz. via a buzzer, a red warning light on the dashboard, or an active gas pedal. The two CAS criteria consisted of a 'worst-case'-criterion (at each moment the lead vehicle can brake with maximum deceleration) or a TTC-criterion of 4 s. In case the following vehicle drives at an higher speed than the lead vehicle, TTC is defined as the distance to the lead vehicle divided by the relative speed. The seventh CAS consisted of a continuous displaying of the momentaneous braking distance by a horizontal red line on the windscreen via a HUD (Head Up Display). Each subject made two runs, one without and one with a CAS, on an undivided rural road with lead vehicles driving at varying speeds. In Fig. 4 the effects of the different CASs on four performance measures are presented as a ratio relative to a control group. Ratios > 1 have to be regarded as a negative safety effect. Most systems give a reduction of the proportion of short headways, but this frequently resulted in contra-productive effects on the other behavioural measures. The combination of the 4 s TTC-criterion and the active gas pedal does not produce contra-productive effects and has been selected for the CAS in the prototype GIDS system.



In a study within the DRIVE-II project ARIADNE (Application of a Real-time Intelligent Aid for Driving and Navigation Enhancement), V2004, Janssen and Thomas (1993) compared three CASs in the TNO driving simulator for car-following situations under adverse visibility conditions (normal daytime, darkness and fog). These systems included the HUD as tested by Janssen and Nilsson (1990), the selected 4 s TTC-criterion with an active gas pedal, and a combined 4 s TTC and an 1 s headway criterion (whichever came first) with an active gas pedal. The results reveal that, again, the combination of a 4 s TTC-criterion and an active gas pedal reduces the proportion of small headways most without an increase in speed (Fig. 5), both in daytime and under reduced visibility.



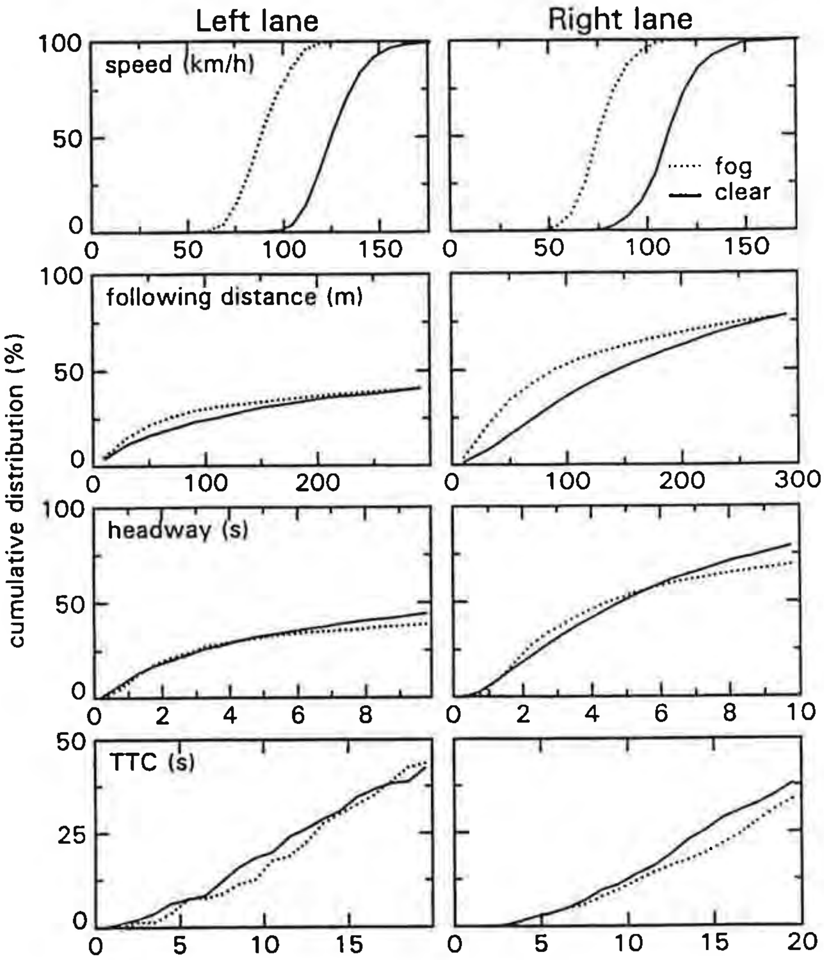
In conclusion, the CAS with a 4 s TTC-criterion and an active gas pedal that produces a counter-force as a direct warning to the driver gives the best results and seems most in line with what drivers expect to get from a CAS. So far, only one TTC criterion value for activating the CAS has been applied. The question arises whether the 4 s TTC-criterion is to be regarded as the optimal setting or whether other values may apply too. To explore these questions in more detail, in the following chapter the results from two recent studies on driving behaviour in adverse visibility conditions will be critically reviewed, as these conditions especially provide situations that are relevant for applying a CAS in preventing rear-end collisions on a motorway.

3 DRIVER BEHAVIOUR IN GOOD AND POOR VISIBILITY CONDITIONS

Within the DRIVE-II project ROSES (Road Safety Enhancement System) V2045, two studies on driver behaviour in adverse visibility conditions have been conducted. Section 3.1 briefly reports on an analysis of inductive loop detector data combined with continuous visibility measurements in real traffic, whereas Section 3.2 summarizes a simulator experiment on driver behaviour in fog in both daytime and nighttime conditions (van der Horst et al., 1993; Hogema & van der Horst, 1993a; 1993b).

3.1 Inductive loop data

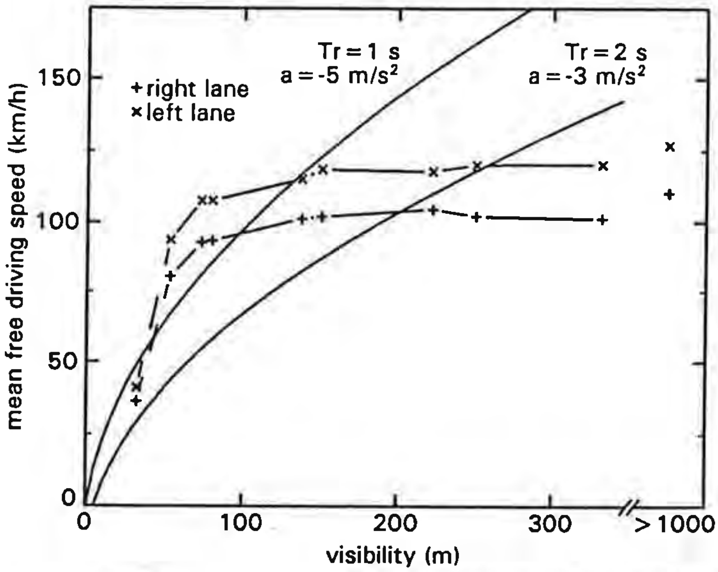
For over a year inductive loop detector data have been collected on the A59 two-lane motorway near the city of Breda, The Netherlands, together with visibility measurements from a nearby scatter type sensor on a continuous one minute basis. For each individual vehicle, speed, vehicle length, following distance, headway, and Time-To-Collision (TTC) were available. The latter is defined as the following distance divided by the speed difference between following and lead vehicle (only if speed of the following vehicle is larger than the lead vehicle's speed).
As an example, the cumulative distributions of the driver behaviour variables in a period of heavy fog are contrasted with a clear view period with otherwise similar characteristics (day of the week, time of day, traffic volume, etc.), see Fig. 6. During this fog period the visibility was less than 50 m, according to the standard definition for the Meterological Visual Range (MVR), e.g. White & Jeffery (1980).



Various other fog periods give similar results, viz.:

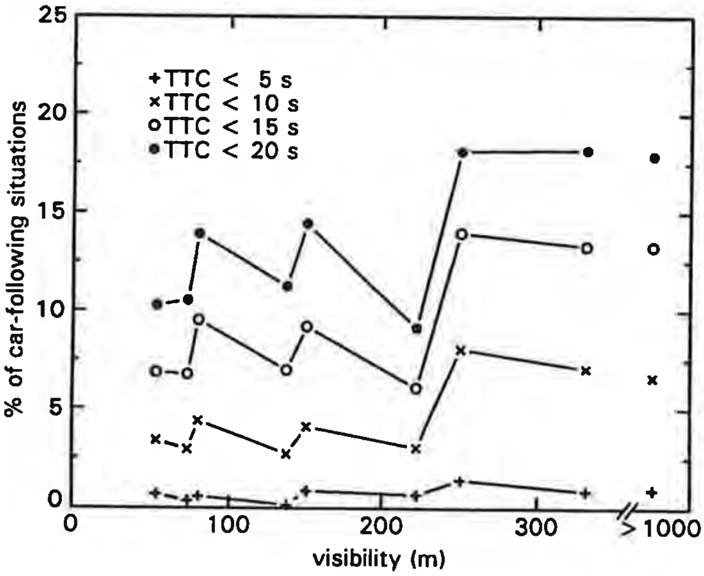
- Speeds are much lower in fog than in clear visibility, but speeds in the left lane remain higher than in the right lane.
- Following distances decrease in fog, especially in the right lane.
- In general, fog has only minor effects on headway distributions.
- TTC values tend to increase in fog. TTCs less than 5 s are rarely observed.

Fig. 7 shows the mean free driving speed as a function of visibility (free driving defined as having a headway > 5 s). Added are two lines that indicate the (maximum) initial speed possible as a function of the required stopping distance, one for a rather extreme case of a short reaction time (1 s) and hard braking (acceleration - 5 m/s² with no safety margin left), whereas the right line corresponds to a more moderate reaction time and deceleration level.



Even in the extreme case, the speeds of the free driving vehicles are too high to avoid a collision when the driver is suddenly confronted with a stationary object (e.g. a stopped vehicle) in a visibility range between 40 and 120 m. Hogema and Van der Horst (1993a) computed other scenarios as well and concluded that drivers at mean speed may be able to slow down in time for lead vehicles that drive with a speed of at least 38 km/h and 53 km/h in the right and left lane, respectively.

In fog conditions, the percentage of following situations with a given TTC value decreases rather suddenly at a visual range of about 230 m (see Fig. 8), i.e. TTC values increase. When visibility decreases further, no additional effect is found. TTCs < 5 s are rarely observed, and consequently, no significant effect could be established. However, the few observations available seem to indicate a lower percentage in that range as well.



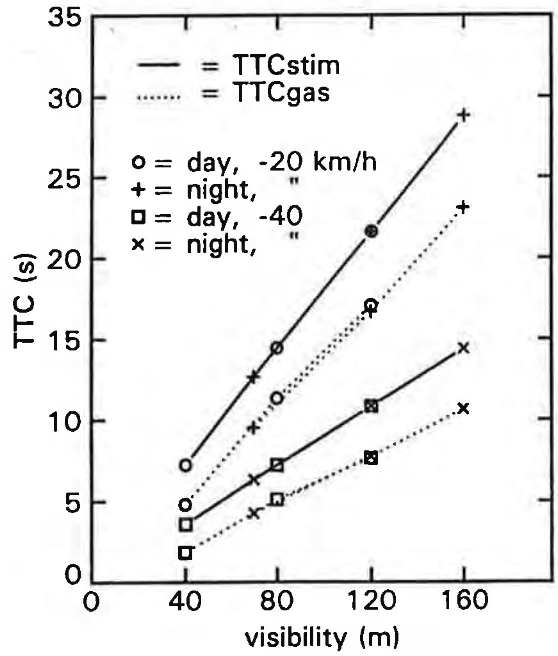
3.2 *Simulator study*

The results of the inductive loop data analysis only refer to the behaviour at one cross-section of the motorway. Although this approach has the advantage that a huge amount of data on road user behaviour in real traffic is available, the dynamics of car-following behaviour can not be studied this way. To study car-following behaviour of drivers over time and to have full control over the experimental conditions, a driving-simulator study has been conducted on car-following behaviour in both good and adverse visibility conditions (day/night, fog).

Visibility distances used were 40, 80, 120 and 600 m, according to the standard MVR visibility definition, e.g. White & Jeffery (1980). Since at night, the rear lights of a vehicle are visible over a larger distance than the contour or the road outline following the definition of MVR, the rear lights of the lead vehicle were made visible over a larger distance according to the results of Heiss (1976). In each run, subjects were partly free driving (i.e. no lead cars) and partly in car-following situations with varying speeds. To prevent overtaking, the left lane of the freeway was closed by means of diagonally striped workzone panels.

The *free driving* speeds as found in the simulator experiment reveal a good resemblance with real-world data in good and very poor visibility. In moderate visibility, speeds in the simulator appear to be somewhat lower. Driver's high expectancy of a lead vehicle in the simulator and the absence of overtaking possibilities due to the working zone situation may well explain this difference.

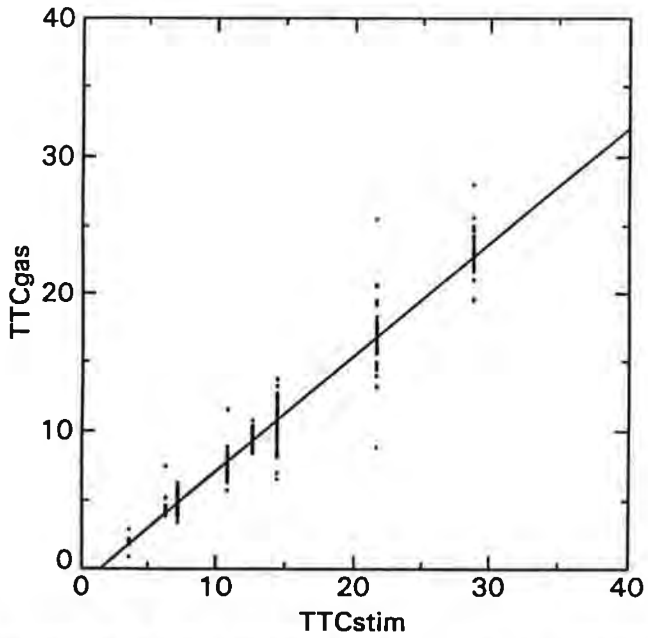
The relevant cue in *approaching* a lead vehicle may be TTC: in the simulator the lead vehicles would become visible at the determined visibility distance, whereas the speed difference was set at either 20 or 40 km/h. From these visibility distances and speed differences the corresponding TTC values can be calculated, represented by TTC_{stim}. In the night conditions, TTC_{stim} values were larger since, with an equal speed difference, the visibility distance (of the rear lights) was larger. Fig. 9 gives a comparison of TTC_{stim} and TTC_{gas}, being the TTC at the moment the subject fully releases the gas pedal for the first time after the lead car has become visible.



The finding that the TTC_{gas} curves in the night condition coincide with the daytime curves if the different visibility distances for vehicle contours and rear lights are taken into account, indicates that at night subjects already react to the lead vehicle before its contour becomes visible. Their first reaction is based on the extra visibility range provided by the rear lights. Apparently, TTC_{gas} is mainly determined by whatever becomes visible first.

The relationship between TTC_{gas} and TTC_{stim} can be described well by a linear regression line ($r = 0.97$, $p < 0.0001$) of the following form (Fig. 10):

$$TTC_{gas} = -1.15 + 0.83 * TTC_{stim} \qquad (1)$$



Similar results were obtained for TTC_{min}, the minimum TTC value as reached during the whole approach phase (Hogema & van der Horst, 1993b). Eq. (2) gives the linear relationship between TTC_{min} and TTC_{stim} ($r=0.92$, $p<0.0001$).

$$TTC_{min} = -2.58 + 0.80 * TTC_{stim} \qquad (2)$$

TTC_{min} and TTC_{gas} also linearly relate ($r = 0.93$, $p < 0.0001$):

$$TTC_{min} = -1.43 + 0.96 * TTC_{gas} \qquad (3)$$

4 *DISCUSSION AND CONCLUSIONS*

Several studies on Traffic Conflicts Techniques have shown that Time-To-Collision (TTC) is an effective measure for rating the severity of conflicts. In general, only encounters with a minimum TTC less than 1.5 s are considered critical and trained observers appear to operate rather consistently in applying this threshold value in real traffic. Whereas TTC_{min} indicates how imminent a collision actually has been during the approach process, TTC at the onset of braking (TTC_{br}) represents the available manoeuvring space at the moment the evasive action starts. The results of a field experiment where subjects approaching a stationary object with a given speed where instructed to start braking at the latest moment they thought they could stop just in front of the object (van der Horst, 1990; 1991), revealed that both the decision to start braking and the control of braking may well be based on TTC information as directly available to the driver from the optic flow field. This TTC information is an important cue for the driver in detecting potentially dangerous situations. The study by Van der Horst (1990) provided values for both TTC parameters that have to be regarded as minimum values that should be avoided in normal traffic conditions. Together with an 1.5 s reaction time (including the time needed for moving the foot from the gas to the brake pedal), an average TTC_{br} of 2.5 s would result in a TTC-criterion of at least 4 s for activating a Collision Avoidance System (CAS). Tests with different CASs reveal that a CAS with this 4 s TTC-criterion, in combination with a system action to the driver via an active gas pedal, reduces the percentage of small headways considerably without having contra-productive effects on other behavioural measures (Janssen & Nilsson, 1990; Janssen & Thomas, 1993). Apparently, a criterion based on TTC seems most in line with what drivers expect to get from a CAS. So far, only one criterion value has been tested and the question arises whether it would be worthwhile to try other TTC-criterion values as well.

Recently, some studies on driver behaviour in fog, both in real traffic and in a driving simulator (van der Horst et al, 1993; Hogema & van der Horst, 1993a; 1993b), provided a more precise description of critical approach situations. Given a slower lead vehicle that becomes visible at the visibility distance, TTC values are well defined. Since drivers have adapted their speed (at least partly) to the visibility conditions, driving situations in fog may enable information on what criterion values for TTC should be used. Based on an analysis of inductive loop data at an individual vehicle level in various visibility conditions, Hogema and Van der Horst (1993a) conclude that in fog driving speeds are considerably reduced, but that, especially in the visibility range between 40 and 120 m, free-driving speeds are too high to allow for a successful stop for a stationary object. Drivers' speed choice seems more in line with expecting only (slower) moving vehicles ahead. In fog, TTC values tend to increase whereas following distances decrease. Since in the case of car-following TTC equals the following distance divided by the speed difference, this clearly indicates that speed differences between successive vehicles are reduced in fog. Apparently, drivers pay more attention to the car-following task. In addition to this study in actual traffic, Hogema and Van der Horst (1993b) also conducted a driving-simulator study on car-following behaviour in both good and adverse visibility conditions (day/night, fog) with a visibility range between 40 and 600 m. A given visibility distance together with a 20 or 40 km/h slower driving lead vehicle, results in a well-defined TTC value at the moment a lead vehicle becomes visible (TTC_{stim}). So, in this way given TTC values can be presented to a subject in a realistic setting. When comparing TTC_{stim} with TTC at the moment the gas pedal is fully released (TTC_{gas}), it appears that TTC_{gas} can be described well by a linear function of TTC_{stim} (see Eq. (1)). The same yields for TTCmin as reached during the approach phase (see Eq. (2)). The finding that TTC_{min} increases with TTC_{stim} implies that drivers include an additional safety margin when they have the opportunity to do so. When they are asked to apply a minimal margin (Van der Horst, 1990), a more or less constant TTC_{min} of 1.1 s results.

For determining a proper criterion setting for a CAS, it would be of interest to combine these relationships with earlier findings with respect to critical TTC_{min} values, e.g. the 1.1 s value as found in the study on TTC and driver's decision-making in braking, and the 1.5 s to distinguish critical from normal behaviour in Traffic Conflicts studies (van der Horst, 1990). By applying Eq. (2), these critical TTC_{min} values would result in a TTC criterion for activating a CAS of about 4.5 and 5 s, respectively.

Based on the results of the first tests with CASs, it is concluded that for defining an appropriate criterion for activating a CAS, the TTC approach is a promising one. The results of the studies on driving behaviour in adverse visibility conditions reveal that, apart from a 4 s TTC criterion, it is worthwhile to investigate a TTC criterion in the range of 4.5 to 5 s as well. For driving in fog as an important application area of CASs, special attention should be given to the distance range between 40 to 120 m.

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FIGURE CAPTIONS

Fig. 1 Time histories of braking by a car approaching a stationary object; DIST = distance to object, V = velocity, ACC = acceleration, and TTC = Time-To-Collision based on constancy of speed and heading angle. Point A indicates TTC_{br} and point B TTC_{min}.

Fig. 2 TTC_{br} as a function of approach speed and braking instruction (van der Horst, 1990).

Fig. 3 TTC_{min} as a function of approach speed and braking instruction (van der Horst, 1990).

Fig. 4 Behavioural effects of 7 Collision Avoidance Systems (Janssen & Nilsson, 1990) on a) the percentage of headways < 1 s (foll. < 1s); b) average speed (speed); c) speed irregularities (irr.); d) the percentage of time the vehicle is in the opposite lane (left lane).

Fig. 5 Effects of three Collision Avoidance Systems on mean speed (left panel) and on the proportion of headways < 1 s (right panel) (Janssen & Thomas, 1993).

Fig. 6 Cumulative distributions of speed, net following distance, headway, and TTC in fog (Meteorological Visual Range 50 - 60 m) and clear view conditions for the right and left lane on the A59 motorway.

Fig. 7 Mean free driving speed as a function of visibility on the A59 motorway (general speed limit of 120 km/h), and initial speed possible as a function of the required stopping distance.

Fig. 8 Percentages of all following vehicles with TTC below the given values as a function of visibility.

Fig. 9 TTC_{gas} as compared to TTC_{stim} as a function of visibility, light condition, and relative speed.

Fig. 10 TTC_{gas} as a function of TTC_{stim}, according to Eq. (1).

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SAFETY IS NOT NECESSARILY PLEASANT AND PLEASANTNESS IS NOT NECESSARILY SAFE

This paper questions the view that the safety and pleasantness of the traffic environment are closely related. The argument is made on a number of grounds, some of them theoretical and some empirical.

The first theoretical argument is made on the basis of the need for alertness and therefore arousal on the part of road users, if they are to negotiate the traffic system safely. This means that a system that is completely "calmed", will tend to result in a loss of vigilance on the part of road users, and therefore in increased risk of unforeseen events and hence accidents.

A further argument is made on the basis of behavioural adaption - indeed the first point could also be construed as being a form of behavioural adaption. The reasoning here is that road users in a calmed environment will seek to increase their level of risk. It is somewhat surprising, perhaps, that the discussion of calming the traffic environment and the discussion of behavioural adaption (or risk compensation) seem to proceed on parallel lines, without any specific links between the two being made. Behavioural adaption to traffic calming can take two forms:

1. An attempt to drive through the calmed environment as fast as possible or in such a way as to maximise one's thrills.
2. An attempt to compensate for the delay caused by the calmed roads by driving faster on non-calmed roads.

There is some evidence that both these effects are taking place. As regards effect (1), there are reports of streets that have been traffic-calmed being used for such activities as motorcycle racing or skateboarding (humps are particularly attractive to skateboarders). In normal circumstances, such activities may not negate the benefits of traffic calming, but in certain situations it is possible for things to get out of control, as recent UK experience with joyriding indicates.

Effect (2) would tend to produce a form of accident migration. Traffic engineers have for some time noted that where there is temporary congestion in a network, such as that cause by major road works, there can be an effect of drivers seeking to compensate for lost time by driving faster once they are past the bottleneck. This can cause a rash of accidents. On a national level, recent UK experience indicates a declining trend in urban accidents, but a rising trend in rural accidents, particularly those on two-lane arterial roads. One hypothesis to explain this phenomenon is that once out of the congested and calmed urban environment into the relatively uncongested rural environment, drivers take advantage of the comparative freedom of the situation and engage in driving too fast and in risky overtaking. The effect is rather like that of a cork popping out of a champagne bottle.

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ALCOHOL AND TRAFFIC ACCIDENTS

SUMMARY

There is ample evidence that young people are not only at high risk of traffic accidents in general, but also at high risk for alcohol-related traffic accidents. Thereby, identification of the factors that could explain drinking-driving behavior in young people has become a necessary previous stage to increase the effectiveness of traffic accident prevention programs focused on this specific population.

Research examining motivational, cognitive and attitudinal factors that influence risky behaviors such as that one has revealed as a successful approach to that goal. Thus, the study following reported mainly concerns a recent application of a social psychological model to this problem which could be a very useful framework in this research field: the Theory of Planned Behavior (Ajzen, 1.985; Ajzen, 1.987; Ajzen, 1.988; Ajzen, 1.991). The results provide first evidence in support of the explanatory and predictive value of this model.

1. INTRODUCTION

During the last years, traffic safety has become an important goal in national and local public Spanish policies, corresponding to the seriousness of economical, social and healthy consequences of accidents in Spanish roads. Trends in traffic accident rates in Spain have been progressively increasing on the last decades, paralell to the increasing in the number of registered motor vehicles and the number of drivers, and at the present time, Spanish traffic accident rates are unfortunately greater than those which correspond to most of the European countries (Megía, 1993). Thus, in 1991 there were more than 170000 injuries and more than 9000 deaths as a result of accidents in Spanish roads -taking as a criterion that defunction is occurred as a result of a traffic accident in a maximum of thirty days from it-.

The extent of the costs that traffic accidents implie depends largely on the fact that the traffic accident problem is specially dramatic among younger age groups. As research frequently has evidenced, even when exposure to roads has been controlled, young drivers are at greater risk of accident involvement than older drivers, and specially young male drivers. In effect, as in other industrialized countries, one from two deaths in traffic accidents on the last years in Spain was a person who was between 15 to 27 years old, and a 1992 report by the *Dirección General de Tráfico* -the national gouvernment agency that attends road transportation problems- noted that responsibility for all of the fatal traffic accidents that occurred during 1990 in Spain can be attributed to drivers less than 25 years old in 1 from 3 of those accidents, and to drivers less than 30 in half of them. Furthermore, the number of persons who were between 25 to 34 years old and died in traffic accidents increased in 167 per cent between 1983 to 1990, while average increase was only 49 per cent, and as a result, traffic accidents constitute at the present time the single greatest cause of death for young Spanish adults, and also a leading cause of injury to them (Dirección General de Tráfico, 1992).

Since it is generally accepted that road user behavior is a crucial factor in traffic safety, researchers have been examining various psychological and behavioral factors that can be related to that higher traffic accident risk. In addition to inexperience, some age characteristics and attitudes could be important in the accident risk of young drivers. But, on the other hand, epidemiological research shows that alcohol consumption is also a significant factor in accident causation among an important proportion of traffic accidents involving young drivers. In effect, alcohol has been recognized as a factor leading to increase crash risk from the earliest days of motorization, and recent laboratory experiments have been able to demonstrate that crash and injury risk in general population is greater when alcohol is present. But the role of alcohol appears to be specially important in those accidents involving young drivers. That is, young adults would not be only at high risk of accidents in general, but also at high risk for alcohol-related traffic accidents. Even low concentrations of alcohol in blood appear to be significantly related to collision involvement among teenagers, while this is not true for all other age groups -with the exception of the oldest drivers- (Zylman, 1975; Cameron, 1982).

Studies focusing on adolescents and young people in Spain have found that from 15 to 30 % have alcoholic drink daily, but these data raise from 50 % to 80 % when they refer specifically to weekends (Tejero & Civera, in press). A major problem is that a significant proportion of them, specially young males, drinks in a very hard way preferentially on one or more weekend days. Such a this behavior has resulted in an increased number of alcohol-related traffic accidents involving young drivers in weekends, and subsequently, in an increased number of injuries and fatalities among young people (Piera et al., 1990; Zabala & López, 1993). In this context, identification of the psychological and behavioral factors associated with these risky behaviors in young people is a necessary previous stage to increase the effectiveness of traffic accident prevention programs (Carbonell, 1992; Carbonell, Bañuls & Tejero, in press). Of course, studies of demographic and personality predictors of these behaviors can identify relevant target groups (Donovan, Marlatt & Salzberg, 1983). But when it concerns to their explanations in view of the optimization of contents and procediments of intervention estrategies, a more succesful approach is the examination of the more immediate motivational, cognitive, and attitudinal factors that affect the execution of these behaviors (Turrisi et al., 1988; Parker & cols., 1992). A model on human behavior that could be a very useful framework to investigate these problems is the *Theory of Planned Behavior* (Ajzen, 1985; Ajzen, 1987; Ajzen, 1988; Ajzen, 1991a; Ajzen, 1991b).

2. *APPLYING THE THEORY OF PLANNED BEHAVIOR TO EXPLAIN RISKY DRIVING BEHAVIORS*

The Theory of Planned Behavior has been proposed as a social psychological theory that provides a general framework to explain human behavior. Actually, it derives from the Theory of Reasoned Action, which has been used successfully to predict behaviours in a wide variety of research fields

(Fishbein & Ajzen, 1.975; Ajzen y Fishbein, 1980), as well as from its extension to the prediction of behavioral goals (Ajzen, 1985; Ajzen & Madden, 1986). Although research on the Theory of Planned Behavior is still less numerous, it has revealed that when the behavior under consideration is a behavior over which people tend to have a problematic control, such as smoking, problematical drinking, or losing corporal weight, predictions of intentions as well as predictions of behavioral achievements from the extended model improve in comparison with those derived from the original formulation (Ajzen, 1.991a).

As a central assumption, the Theory of Planned Behavior considers that *intentions* to perform a given behavior captures the motivational factor that influences it directly, as indications of how hard people are willing to try, or how much of an effort they are planning to exert, in order to perform the behavior (Ajzen, 1991b). Thus, when a person has been having alcoholic drinks and needs to travel to a given destination, he or she will probably try to drive if this one is his or her previous intention in such a situation, while if his or her intention is not to drive in such a situation, he or she will probably not try to drive. But, in addition to individual's intention to execute or not execute a determinate behavior, this model also proposes that the named *perceived behavioral control* is other significant immediate antecedent of actual behavior, and this is the essential difference from the original model -the Theory of Reasoned Action-, which did not include this factor. For instance, although a person has a moderately strong intention to not drive after having some alcoholic drinks, it could be that the extent in which his/her intention influences on his/her behavior in such a situation decreases in relation to the extent in which his/her perceptions about certain factors that could control his/her behavior influence on actual behavior. It could be that that person is in a hurry for a meeting that he or she perceives as a really important meeting, while there is not other kind of transportation to arrive at this previously planned destination and he or she is not able to find someone who is sober and accepts to take him/hers to their destination in his/her vehicle. Or merely it could be that he or she do not think really that is under legal limit, because is not be able to infer approximately his/her blood alcohol concentration from the amount and type of alcoholic drinks that he or she has been having. According to this model, if the relative weight of the overall influence of all of these named *control factors* -such a lack of alternative transportations or knowledge about the relationship between alcohol consumption and blood alcohol concentration- on the driving behavior is clearly higher than the relative influence of the personal intention on the same behavior, in such a circumstances this person will probably drive. Thereby, the degree of success in behavioral predictions will depend not only on individual's intention, but also on other nonmotivational factors, including time, money, skills, knowledge, social cooperation, that is, the required opportunities and resources to perform the behavior (Ajzen, 1985). The perceived ease or difficulty of performing the behavior, reflecting past experience as well as anticipated impediments such as these above mentioned, was then introduced as a determinant factor in the Theory of Planned Behavior. Therefore, according to Ajzen's model, intentions, together with perceptions of behavioral control, would account for considerable variance in actual behavior (Ajzen, 1991b).

In turn, the theory postulates three conceptually independent determinants of intention: the *attitude towards the behavior* or the degree to which the person has a favorable or unfavorable evaluation of the behavior in question, the *subjective norm* or the perceived social pressure to perform or not to perform the behavior, and, again, the degree of *perceived behavioral control*, that has already been defined above and it is the only one that could influence directly both intention and behavior. Thus, in general, the more unfavorable the personal attitude towards driving after drinking alcoholic beverages, and the more unfavorable the subjective norm with respect to this behavior, and the greater the perceived control over this behavior, the stronger should be the individual's intention to avoid to drive in such a situation; and inversely, the more favorable the personal attitude and the subjective norm towards driving in these kind of situations, and the smaller the perceived control over this behavior, the stronger should be the individual's intention to drive in such a situation. At a more specific level, attitudes, subjective norms, and perceived behavioral control are shown to be related to approapiate sets of *salient behavioral, normative, and control beliefs about the behavior* (Ajzen, 1.991b), that is, personal beliefs specifically referred, respectively, to the perceived characteristics of the behavior -for example, "drinking and driving is funny", "drinking and driving increase traffic accident risk", "drinking and driving is not dangerous if you are a good driver", etc.-, to the opinions of those people or institutions that are significant for him or her with respect to this particular behavior -parents, friends, the police, etc.-, or to the factors that, as it was previously argued, the person perceives as obstacles or facilitators with respect to that behavior -availability of alternative transportations, nightime conditions, intensity of alcoholic symptoms, etc.-. All of these three types of beliefs, in combination -respectively- with their subjective evaluation, the degree of motivation to comply with those people or institutions, and the perceived power of each control factors over the behavior, are the most basic behavioral determinants according to the Theory of Planned Behavior (Ajzen, 1991b).

Although Ajzen proposes that, in general, all of these factors are sufficient to account for intentions and behavioral actions, he also recognizes two questions: first, they are not always all necesary, and second, it could be that additional variables improve behavioral predictions (Ajzen, 1991a). The first question has the most interest for the main objective of this work. Such statement implies that results may indicate that we do not have to include all of the measures corresponding to these theoretical variables to get the best behavioral prediction; it may be found that attitude towards a behavior do not significantly influence on intention to perform this particular behavior, or, in the opposite side, it may be found that it is the perceived control over this behavior the element that do not improve the prediction of the intention to perform it, or even do not improve the prediction of the behavior. In any case, according to Ajzen's arguments, the relative importance of each of these elements in the prediction of intentions -that is, the relative weight of attitude towards the behavior, subjective norm and perceived behavioral control- or in the behavioral predictions -that is, the relative weight of intention and perceived behavioral control-, depends on which is the particular behavior and which is the population where all of those variables are measured. A simple instance of this has been previously referred partially: it could be that a proportion of people who sometimes drive under the legal blood alcohol limit have actually the opposite intention, but, while this factor is unrelevant to determinate their behavior, the actual determinant is that they are not able to infer the approximate blood alcohol concentration that results from their previous alcohol consumption. In this simplified case, drinking driving behavior could be adequatly and sufficiently explained only from perceived control over it.

The study following reported was an opportune occasion to assess the potential explanatory of the Theory of Planned Behavior with respect to two particular risky road behaviors in young Spanish people: drinking driving behavior, and riding in a drunk driver's vehicle. If our results would support the predictive utility of the theory, including all or some of the theoretical variables, it will be progressed not only to have a good explanation to these risky road behaviors in young people, but also to differentiate between risky drivers and safe drivers, as well as between risky riders and safe riders, in terms of the most specific determinants of these behaviors -e.g. in terms of their behavioral, normative and control beliefs-. In effect, if we could isolate in which particular aspects the determinants of intention to drink and drive in risky drivers differ from the determinants of intention to not drink and drive in safe drivers, as well as in which particular aspects the determinants of intention to ride in a drunk driver's vehicle in risky riders differ from the determinants of intention to not ride in such a vehicle in safe drivers, we will get a very interesting information to optimize intervention strategies, and the Theory of Planned Behavior will become a useful framework to design future interventions to reduce the prevalence and human costs of alcohol-related accidents in young people.

METHODS

The study mainly consisted in a survey which was performed as part of a community intervention to reduce the prevalence of traffic accidents among young people. As it is mentioned above, this survey intended to identify those motivational, cognitive and attitudinal factors involved in several risky behaviors in young drivers, according to the *Theory of Planned Behavior*. A representative random sample of 1500 subjects from 14 years old to 29 years old residing in the Comunidad Valenciana were interviewed (the size of sample's univers was estimated in 954151 persons). Subjects were sampled from each of the three provinces which compose the Comunidad Valenciana, on the basis of each respective population size. Of these, 53.4 % were females and 46.6 % were males. With respect to age, 23.1 % were less than 18 years old, 35.6 % were between 18 to 22 years old, and 41.3 % were more than 22 years old.

The interviews were administrated as in-home interviews by trained inteviewers, requiring approximately 30-45 minutes for each subject to complete. We decided to use two different versions of the interview: one for subjects who addmit to drive habitually when they go 'to do something and drink with their friends', that is, for 'drivers in drinking contexts'; and another one for subjects who denie drive habitually when they go 'to do something and drink with their friends', that is, for 'passengers in drinking contexts'. The interview for 'drivers in drinking contexts' consisted in two different kinds of questions. The first items assessed background data and a number of behaviours, concerning driving habits, driver record, drinking behavior, and illegal drug consumption. The rest of the items was built to measure all of the theoretical constructs postulated by the Theory of Planned Behavior. The interview for 'passengers in drinking contexts' also consisted in such two kinds of questions, adequating their contents to refer to rider behavior and excepting those referred to driving behavior in the case that a subject does not have a license.

In addition, based on a study by Parker & cols. (1.992), the interview included a verbal description of an hypothetical drinking-driving scenario, which was written in the second person singular to encourage the respondent to imagine him- or herself in the situation described. The description used in interview for 'drivers' was as follows:*"Imagine that you have been having a good time and having some alcoholic drinks with your friends. As in others times, you have driven your vehicle -car or motorbike- there, and you have planned to move with it. You have had some alcoholic drinks (beer, spirits, or any other kind). Because of that, when you leave you feel some sensations due to alcohol: you feel a little dizzy, your vision has become a little blurred,* *you have some difficulties to control your movements..."* ; while the description used in interview for 'passengers' read thus: *"Imagine that you have been having a good time and having some alcoholic drinks with your friends. The person C, who drives the vehicle -car or motorbike- where you had planned to ride, has had some alcoholic drinks (beer, spirits, or any other kind). Because of that, when you leave you perceive that C shows some symptoms due to alcohol: he or she appears to be a little dizzy, he or she says that his or her vision has become a little blurred, he or she has some difficulties to control your movements...'* In both of these cases, the aim was to evoke in respondents a homogeneous mental picture: the driver has been having some alcoholic drinks; the driver feels some psychophysiological symptons due to alcohol, which are symptoms similar to those displayed by individuals weighing between 52 to 86 kg with approximate Blood Alcohol Levels between 0.5 to 0.8 mg. per litre, according to the New York State Driver's Manual (Turrisi et al., 1.988); the subject (driver or passenger) goes away, and his/her initial intention was, respectively, to drive his/her vehicle or to ride with the drunk's driver. The expectation was that these mental picture would aid to elicit respondents' beliefs, attitudes and intentions with respect to the correspondent behavior, and, in addition, to explicit the context and the particular action that defined the behavior in question. The interviewer had to read out the description to the subject and give him/her the one written to hold as the interview was administrated.

A pilot study involving 50 subjects was previously carried out in order to identify salient behavioural beliefs, salient control beliefs and salient referents with respect to the drinking-driving situations in these population, following Ajzen's research procediments. Persons approached were asked to imagine that hypothetical situation and then asked if they could think of any reasons why they might be driving/riding or why they might refrain themselves from doing so (behavioral beliefs), whether they could think of anyone who would approve or disapprove of their driving/riding in that way (referents), and which factors they think could prevent them from driving/riding and which factors they think could to impel them to drive/ride (control beliefs). Furthermore, we developed four discussion groups formed by no more than ten persons randomly selected who were from 14 to 29 years old. Results of the pilot study and discussion groups were considered to redact the items corresponding to Ajzen's theoretical constructs. Thus, thirteen behavioural beliefs, eight salient referents and nine control beliefs became the basic patterns to develop the corresponding measures in the two versions of the interview (see Figure 1).

Figure 1. Salient beliefs, referents and perceived control factors in 'drivers'

BEHAVIORAL BELIEFS	REFERENTS	CONTROL FACTORS
• Driving my vehicle takes less time than catching a bus, a metro or a train • Driving my vehicle is cheaper than taking a taxi • Driving in that way is funny, you can have a good time • Driving my vehicle is easier and more comfortable • If you are a good driver, driving in that way won't be risky • Driving in that way makes that I do other traffic violations • Driving in that way increases risk accidents • Driving in that way makes that I drive more imprudently • Driving in that way implies that I loss vehicle's control • Driving in that way makes me nervous • Driving in that way increases risk of causing injuries and fatalities • Driving in that way makes that I drive faster • It's very likely I have a fine if I drive in that way	• Mother • Father • Brothers and/or sisters • Friends in general • Certain friends • Police • Family • Partner	• If friends have not an alternative transportation • If there is not somebody who is able to drive • If it is night time or there is nobody on the street • I do not know how much alcohol affects to me • If nobody try to persuade to me to avoid driving • If I am in hurry • Taxi is very expensive • If I has had too much alcohol • If there is few police agents

In order to avoid possible inconsistencies in results due to measurement of the variables postulated by the Ajzen's model at a different level of specificity (Ajzen, 1988), we referred all of them -and consequently, all of the items- to the situations that have already been described.

RESULTS

The total number of respondents included 30.8 percent of 'drivers in drinking contexts', and 69.2 percent of 'passengers in drinking contexts'. Overall, the mean values for belief-based measures of attitude, subjective norm, and perceived behavioral control, as well as for the intention, indicated in both of the cases that respondents tended to be favorable to avoid the execution of, respectively, drinking driving behavior and riding in a drunk driver's vehicle, as it can be seen in Figure 2. Interpretation of these mean values must take into account that the higher and more positive the value is, the more *pro* is attitude, subjective norm, perceived behavioral control and intention with respect to the risky behavior.

Figure 2. Mean values of belief-based measures of Ajzen's theoretical constructs

	'Drivers'	'Passengers'
Attitude (Range = 13 , 637)	110.7	91.6
Subjective norm (Range = -168 , 168)	-84.4	-81.9
Perceived behavioral control (Range = 9 , 441)	204.3	195.7
Intention (Range = 1 , 7)	2.9	2.4

Thus, respondents who addmited to display habitually a rol of 'drivers in drinking contexts' tended to have an unfavorable evaluation of driving in a situation such as the one described; also tended to have a negative perceived social pressure to perform the behavior; and a moderate perceived behavioral control over it, indicating that they felt that they would moderately easily avoid drinking and driving in such a situation. Congruently to these results, the mean value of intention also indicated that, as a group, 'drivers' tended to have the intention to avoid driving in this type of situations, althoug we can't either say that it's a certainly opposite intention. On the other hand, the mean values for attitude, subjective norm, perceived behavioral control, and intention from 'passengers in drinking contexts', indicated again that respondents tended to be favorable to avoid the execution of the risky behavior. Even respondents who declared to habitually display the role of 'passengers in drinking contexts' tended to have a more unfavorable evaluation of riding in a drunk driver's vehicle than attitude to drinking and driving was in "drivers in drinking contexts'; respondents also tended to feel that significant referents would not approve of their riding in a drunk driver's vehicle, indicating a relatively high perceived social pressure to not perform the behavior; however, both passengers' perceived behavioral control over this behavior and intention appeared to be lower than those referred to 'drivers in drinking contexts', although they also tended to feel that it would be relatively ease to avoid riding in such a situation, and that their general intention to ride in a drunk driver's vehicle was moderately low.

Figures 3 and 4 show mean values corresponding to attitude, subjective norm and perceived control and intention with respect to both behaviors, crossing with age, sex, academic level, laboral activity, and type of vehicle (car or motorbike). Significant differences resulting in analyses of variance using those four psychological measures as dependent variables has been marked. As it can be seen, results from 'drivers in drinking contexts' indicated that there were significant differences in attitude due to sex and type of vehicle (car or motorbike), also significant differences in subjective norm due to sex, no any significant differences in perceived behavioral control, and significant differences in intention due to sex; while results from 'passangers in drinking contexts' indicated that there were significant differences in attitude due to sex, also significant differences in subjective norm due to sex, academic level, laboral activity, and type of vehicle, as well as significant differences both in perceived behavioral control and in intention due to age, and again, due to sex.

Figure 3. Mean values of the belief-based measures crossing by sociodemographical variables, type of vehicle and risk criteria, in 'drivers'

	Attitude	*Subjective norm*	*Perceived control*	*Intention*
• Under 18	128.0	-77.8	208.3	3.0
• 18-24	111.9	-87.0	208.4	2.8
• Over 24	106.4	-82.5	199.2	2.9
• Females	98.3 *	-89.8 *	210.4 *	2.3 *
• Males	116.1 *	-82.0 *	201.5 *	3.1 *
• Student	115.8	-82.8	203.7	2.9
• Unemployed	112.4	-79.8	208.4	2.9
• Employed	107.2	-87.3	202.8	2.8
• Car	105.1 *	-85.1	201.6	2.8
• Motorbike	135.6 *	-81.5	215.9	3.1
• 'Risky'	119.3 *	-80.3 *	204.4	3.1 *
• 'Safe'	86.5 *	-95.3 *	204.1	2.2 *

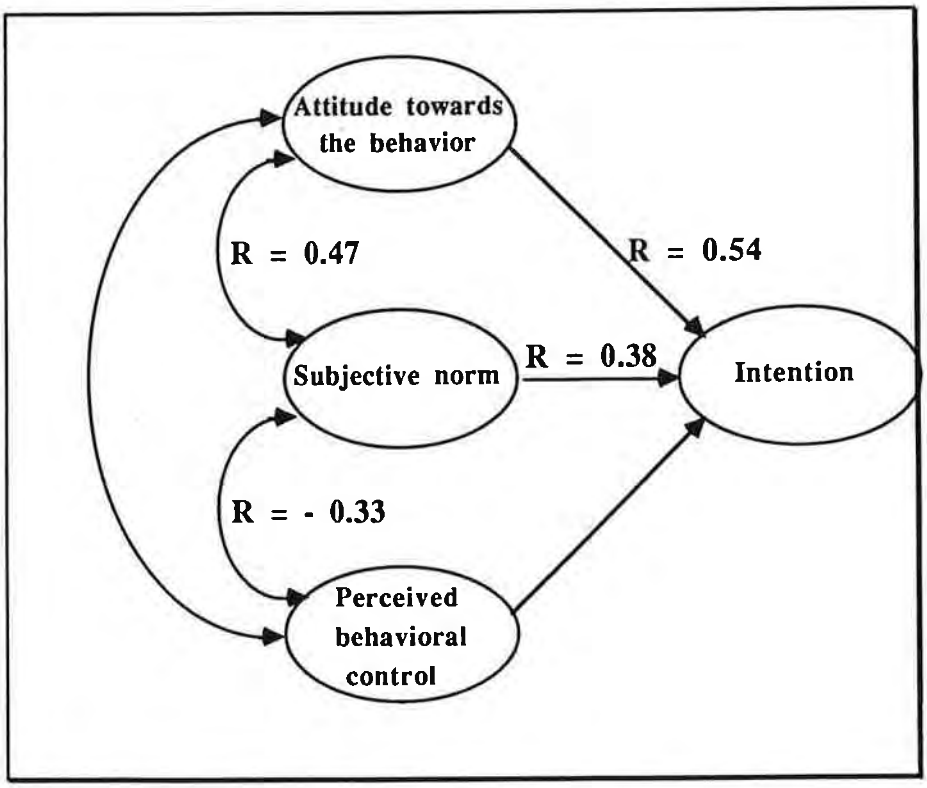
Figure 4. Mean values of the belief-based measures crossing by sociodemographical variables, type of vehicle and risk criteria, in 'passengers'

	Attitude	Subjective norm	Perceived control	Intention
• Under 18	94.2	-87.2	204.1 *	2.2 *
• 18-24	94.3	-80.2	197.9 *	2.6 *
• Over 24	83.1	-78.8	180.9 *	2.1 *
• Females	85.1 *	-85.9 *	199.7 *	2.2 *
• Males	103.2 *	-74.7 *	188.4 *	2.8 *
• Student	95.5	-83.9 *	205.0	2.4
• Unemployed	90.3	-77.2 *	186.1	2.3
• Employed	85.6	-83.5 *	188.2	2.4
• Car	87.3	-80.0 *	184.2	2.5
• Motorbike	97.8	-76.2 *	204.9	2.9
• 'Risky'	97.4 *	-77.9 *	196.8	2.7 *
• 'Safe'	82.6 *	-88.2 *	194.0	1.9 *

In turn, we differentiated two subgroups in each of these mentioned groups, according to a criterion based on individual alcohol and drug consumption patterns, as were measured in the interview: on one hand, 'risky subjects' -subjects who reported that they had drank or that they had had some kind of illegal drugs on the last week prior to the interview- and 'safe subjects' -subjects who denied that they had had alcoholic beverages or some kind of illegal drugs on the same period of time-. Variance analyses indicate that there were certain and important differences in some of the psychological measures between 'risky' and 'safe' subgroups, as is shown in the lower part of Figure 3. It can be seen that 'risky drivers in drinking contexts', that is, subjects who addmited to drive habitually when they go 'to do something and drink with their friends' and reported that they had drank or that they had had some kind of illegal drugs on the last week prior to the interview, have a significant more favorable attitude to driving in a situation such as the one described than 'safe drivers in drinking contexts', that is, subjects who addmited to drive habitually when they go 'to do something and drink with their friends' but denied that they had drank or that they had had some kind of illegal drug in the same period of time. Also, 'risky drivers in drinking contexts' have a significant lower perceived social pressure with respect to driving in such a situation than 'safe drivers in drinking contexts', and as it is expected, risky drivers' intention was significantly higher that safe driver's intention to drive in such a situation. However, we haven't found significant differences between these four subgroups in belief-based measure of perceived behavioral control, although they certainly were found in the directed measure of this variable. On the other hand, results from 'passengers in drinking contexts' were in the same direction: 'risky passengers in drinking contexts', that is, subjects who reported not to drive habitually when they go "to do something and drink with their friends" and also reported that they had drank or that they had had some kind of illegal drug on the last week prior to the interview, have a significant more favorable attitude to ride in a drunk driver's vehicle in a situation such as that one described, a significant lower perceived social pressure with respect to this behavior, and a significant higher intention of performing it, than 'safe passengers in drinking contexts', that is, subjects who also reported not to drive habitually when they go "to do something and drink with their friends" but denied that they had drank or that they had had some kind of illegal drug in the same period of time. Again, perceived behavioral control appeared to be a non significant variable in order to discriminate, according to the criterions above mentioned, between 'risky ' and 'safe' passengers in drinking contexts.

In fact, the first available results of the regression analyses for the prediction on intentions of the first wave data appear to indicate that both respective attitude and subjective norm make significant contributions to the prediction of intention to drive in such as the one described and to the prediction of intention to ride in a drunk driver's vehicle, while the addition of perceived behavioral control do not improve the model's predictive power in neither of these two cases (see Figure 5). That is, contrary to initial expectations, perceived behavioral control appears to be a non significant determinant of any of these two risky intentions.

Figure 5. Significant correlations ($p < .05$) between Ajzen's model variables in 'drivers' group (N = 462)



DISCUSSION

As it was mentioned previously, Ajzen (1991a) has noted that it could be that certain specific applications of their theoretical model to particular behaviors indicate that it is not always necessary to consider all of the variables that this model proposes to explain a given intention and/or their correspondent behavioral execution, but results may demonstrate that we do not have to include some of the measures corresponding to these theoretical variables to get the best intentional and/or behavioral predictions. The intention to drink and drive as well as the intention to ride in a drivers' vehicle, in situations such as the ones described in the hypothetical scenarios, appear to be two instances of this statement. Initial results indicate that both attitude and subjective norm with respect to drinking and driving in such a situation, have a significant influence on the intention to perform this particular behavior, while perceived behavioral control do not improve in any case the prediction of the intention to perform this behavior. On the other hand, both attitude and subjective norm with respect to riding in a drunk drivers' vehicle in such a situation have also a significant influence on the intention to perform it, and again, perceived behavioral control does not improve the prediction of this intention. Contrary to expectations, factors such as time, money, alcohol dosis consumed or availability of an alternative transportation appear not to be perceived as important control factors by respondents, nor in the case of subjects who habitually display the role of driver, nor in the case of subjects who habitually display the role of passenger in this kind of contexts.

In fact, supporting the emphasis that Ajzen states in the practical implications of their model, results corresponding to the differentation of subgroups according to their reported exposure to risk traffic in terms of their alcohol or illegal drug and driving habits have indicated that the application of the Theory of Planned Behavior to drinking and driving behavior is useful in order to differentiate between attitude, subjective norm and intention with respect to this behavior that these subgroups have. In the same way, the application of this model to passengers' behavior is useful in order to differentiate between behavioral attitude, subjective norm and intention that the named 'risky riders in drinking contexts' and 'safe riders in drinking contexts' have. Thus, applying the theory of planned behavior to these two instances of road behavior in young people, it will be possible to isolate which are the particular beliefs and subjective evaluations that lie in risky road behavior in this group of population, and these must be known in order to optimizate effectiveness of traffic safety intervention programs.

On the other hand, the results presented with respect to the prediction of these intentions lend partial support to the Theory of Planned Behavior. Both respective attitude and subjective norm appear to have a significant influence on intention to drive in a situation such as the one described and to ride in a drunk driver's vehicle. A different issue is that the multiple correlations with intentions that are obtained when these regression analyses are performed are not certainly high. However, perceived control over each of these risky behaviors do not appear to have a significant effect on respective intentions to perform them, nor to improve those multiple correlations with intentions appreciably.

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ANXIETY AND TRAFFIC SAFETY

Identification of the psychological factors and behaviours associated with driver behaviour has become an important subject in traffic safety research. In particular, anxiety is one of those variables which has a significant role in driving behaviour as research reveals. First, research shows that a significant number of drivers involved in traffic accidents suffer a high level of anxiety and insufficient level of self-confidence. Second, anxiety is also one of the emotional reactions most frequently related to driving behaviour in literature. Third, anxiety or stress is a factor which is included in most of the theoretical models explaining driver behaviour. However, research on anxiety and on interaction to traffic safety is still insufficient comparatively with other fields. This insufficiency is evidenced by the little number of self-reported instruments according to that assess traffic anxiety.

So, it was that the study reported in this paper has intended to obtain and investigate an instrument to measure anxiety in traffic contexts. Thus, our inventory constitutes a first stage to develop an instrument which allows assessment of the reactivity of the three response systems -cognitive, physiological and motor systems-, using a representative sample of driving situations which are potentially able to generate anxiety, according to the Lang's Tridimensional Anxiety Theory.

In this paper we present the Inventario de Situaciones Ansiógenas en el Tráfico, I.S.A.T., (Anxious traffic situations inventory). This inventory provides a global measure of anxiety as well as scores corresponding to each of the following different situational contexts: 1) situations involving cognitive self-evaluation, and social evaluation; 2) situations involving criticism and aggression; 3) situations involving external obstacles and 4) situations involving evaluation from authorities. We report data with respect to its psychometric properties and its utility to discriminate between different groups of population.

1.- INTRODUCTION

The searching for variables that keep a relationship with the driving becomes the main investigation aim in the traffic safety field. In particular, anxiety is one of those variables which have a significant role in driving behaviour as research reveals. First, research shows that a significant number of drivers involved in traffic accidents suffer a high level of anxiety and insufficient level of self-confidence. Second, anxiety is known as one of the most frequently experienced emotional reactions when driving. Third, anxiety or stress is a presented variable, implicitly or explicitly, in a great deal of the models developed to explain driver's behaviour, eventhough none of them depends on its analysis. These reasons have brought us to consider the need of directing our attention towards this variable, even more if we consider that its study in the fields of Psychology and Traffic Safety shows a considerable delay in comparison to other fields.

2. RESEARCH ABOUT ANXIETY AND TRAFFIC SAFETY

In fact, the terms anxiety or stress only emerge occasionally in the extense literature about Psychology and Traffic Safety and, when this occurs, it is usually related to traffic accidents. In this paper we try to offer a vision as complete as possible of how and in which extent anxiety has been and is studied in this ambit, focusing mainly in the traffic environment as the generator of anxiety on drivers. For the attainment of this purpose we carried out a bibliographic search that would allow us to detect the required documentation for this analysis.

The first stage of this investigation was, therefore, the search of papers that would approach the studies on anxiety and stress in the field of Traffic Safety.

Subsequently we grouped the subjects into two broad types:

- those investigations that study how do stress and anxiety originated out of the driving situation can affect a person's way of driving
- those other investigations directed to investigate how the proper situation of driving generates anxiety on the population exposed to traffic.

Along with this, we can find some articles specifically directed to study the driving phobias and their treatment; anxiety derivated from traffic accidents (postraumatic anxiety), anxiety before the test to obtain the driving licence and the alcohol and drug effects, as a way of handling anxiety, in the self-propelling vehicles driving.

2.1. anxiety originated out of the driving situation

A first analysis of the information obtained shows us that perhaps the most fructiferous investigation line connected to accidentality has been the one that considers the effects of the stressful vital events on the driver and its causative relationship with accidents. Eventhough this is not view we pretend to develop, we find interesting to point out some of the work done over this aspect, because logically, the driver's emotional state is going to influence his way of reacting to the stimulus originated in the traffic environment.

Holmes and Rahe's initial work (1967) on the apparition of stress as consequence of the readjustments to the experienced life changes, propitiate some investigations with the only aim of explaining if life changes on a person and the following adjustment degree could be significantly related to traffic accidents. The refereed investigations approach stress as an event or group of circumstances that supposedly elicit or require a non common answer from a person, and show that the effects of these vital events generally reduce a person's responding capacity towards the exterior world, provoking the apparition of physiological knowledgeable and conductible maladjustments that difficult or obstruct the correct fulfilment of the driving task.

Selzer et al. (1968), showed that social stress -associated to personal or economical conflicts- was significantly greater in a group of drivers that had suffered serious accidents, than in a group of drivers without accidents. A year later, Brenner & Selzer (1969) concluded that the risk of mortal accidents on persons that had experienced a severe social stress, is 5 times superior to the one of those others that not experienced it. Facing these discoveries, Selzer & Vinokur (1974) try to develop an instrument predictive of traffic accidents, from the stress generated by the person's life events, rely on a multidimensional conception of stress. They focus on the estudies of the so-known as vital changes and the subjective answer to the changes, on the experiences of negative stress in the various essential contexts (work, marriage...) and on the physiological and conductible expression of stress. With this implement they corroborate, in 1975, the relationship between vital events, subjective stress and traffic accidents, also finding that the accumulation of those events correlates significantly with tension and with cognitive and behavioural indicators of anxiety, eventhough only in the case of vital events non desired by the person (Vinokur &Selzer, 1975), suggesting this way that the desirability or not of these events by the person is a crucial determinant of the way in which stress is related to accidents.

Similar results are offered by Fernández-Ríos et al. (1987)'s work, who confirm the existence of significant differences between accidented and non accidented drivers, as in the number of disturbing events as in the importance applied to them. The authors conclude that stress proceeding from negative economical events (salary reductions, a loan refusal...) and from negative events related to health (physical illness, injuries, lack of adequate medical assistance...) is the one that allows a better classification between accident and non accident drivers.

Attempting to deepen a little more in this relationship between vital events and traffic accidents, Holt (1979) classified accidented people into two categories attending to their guilt and responsibility or not in the accident finding out that the guilt and responsibility or not in the accident finding out that the guilty people experimented more unpleasant and problematical events than the non guilty, during the year before the accident.

On the other hand, McMurray (1970) observed that in the following days, and even months, to highly stressful events, the possibility of having an accident raised remarkably. A partial support to this investigation has been provided by Sobel & Underhill (1976)'s work who, at the time they examined life and family styles related to driving antecedent, pointed out that family disruption and social stress on males (not women) acts as a predictor of the probability of suffering a traffic accident.

Finally, Finch y Smith (1970) discovered that 80% of sample of people who died in traffic accidents had suffered an important stressful situation upon 24 hours before the accident. However, eventhough the authors confer the accident's cause to the effects of stress, they do not take into account that the automobile is used by certain people as a suicidal instrument (McDonald, 1964; Crancer y Quiring, 1970; Signori y Bowman, 1974; McGuire, 1976), therefore we find premature by the light of the refereed investigation, to be able to establish that relationship in an absolute way.

In general, the importance of the variable stress derivate from essential events to explain and predict traffic accidents is the thesis that underlies this group of investigations that we have just briefly commented. Underline that this has been a working line developed in the 70's and actually rather forgotten, or in any case highly criticised, mainly centred around the scarce scientific severity shown at the time of stress assessment (Thoits, 1983). It is certain that vital events influence in a considerable way people's driving behaviour, favouring the risk of accidents, especially if alcohol or other drugs' ingestion is appealed to solve the conflicting situation (Wagenaar, 1983). When a person is found in an anxious state, adequate facing strategies are not usually at one's disposal so as the disponibility of drugs or a car provides the alternative means to reduce the psychological tension. The use/abuse of specific medicines or alcohol with the purpose of reducing or managing anxiety can, in this way, incline the driver towards accident (Campbell y Singer, 1987). Neverthless, we find it necessary to investigate deaper before being able to confer cause and effect relation, even more if we keep in mind that these works are generally unaware of the interaction between the driver and the traffic surrounding and the way in which this last one affects the persons' driving.

2.2. the traffic situation as a generator of anxiety

The investigations centred around the traffic situation as a generator of anxiety are furthermore limited if possible. Traditionally the anxiety generated by the traffic environment has been approached with the help of the evaluation of the physiological answers of drivers facing traffic incidents (Robertson, 1987; Gulian, 1987). Generally, these investigations focus on specific groups of professional drivers: bus drivers. Urban bus drivers' work is located among the most stressing and unhealthy modern occupations (Evans & Carrère, 1991). The epidemiological evidence accumulated shows substantially higher percentages of mortality and morbidity on this occupational group, in comparison to other occupations. Specifically, a higher risk of suffering cardiovascular illness, hypertension, gastrointestinal illness and musculoesqueletical disorders are pointed out (Winkleby et al., 1988). On the other hand, urban bus drivers, in comparison to other individuals and other occupations, also have, beyond measure, high percentages of labour absentism, due to stress generated by the traffic environment (Mulders et al., 1988). Nevertheless, it is interesting to point out that very few analysis have been carried out on the stressful microaspects of this working environment.

Some recent studies on this subject suggest that some elements of this psychosocial environment of bus drivers are associated with stress. Gardell et al. (1982) found out that bus drivers distinguished their job as a highly generator of tension. Evans et al. (1987) report on the significant raising of psychophysiological stress of these professionals during their work fulfilment.

The most frequently mentioned features as producers of stress on bus drivers are pressure to stay on schedule, frustration in their inability to fully assist passengers because of the time pressure, and disruptions of family and other social activities because of rotating work-shift schedules (Gardell et al., 1982; Mulders et al., 1988; Bartone, 1989). Near these psychosocial stressful conditions some others have been pointed out -in this case also related to non professional drivers- as pollution, nouse and traffic jams, being all these factors capable of producing anxious behaviours (Finkelman et al., 1977; Jonah et. al, 1981; Reig, 1987; Bartone, 1989; Evans & Carrère, 1991).

It is obvious that the task of driving a vehicle bears the nearly chronic presence of stressors of higher or minor intensity. Among them, the stressors that has been the aim of a greater amount of work is traffic jams, mainly in the so known "rush hours". These situations are potentially stressful due to the delays they impose and to the hostility they sometimes cause (Turner et al., 1975). A study carried out by Novaco et al. (1979) evidences that automobile commuters traveling more congested routes, in comparison to the those who travel on fluid ones, show higher blood pressure, a decrease in their motive skills, as a high index of somatic symptoms. Schaeffer et al., (1988) also find on the drivers exposed to traffic jams, raises on their blood pressure and deficits on the carrying out answers, specifically driving to work on congested routes is associated to significant increases on the systolic and diastolic blood pressure, indicating physiological anxiety.

In a recent work of Evans & Carrère, (1991) in which the connection between traffic jams and psychophisiological stress on public transit operators, the authors clearly find a higher secretion of urinary catecholamines as the exposure to traffic jams in the rush hours is higher.

Other investigations designed to analyse the consequences of exposures to traffic jams, genuine or simulated, show notable increases of the cardiac rate (Simonson et al., 1968; Shiomi, 1974), skin conductance (Heimstra, 1970), secretion of urinary catecholamines (Bellet et al., 1969; Mulders et al., 1988), or changes in the respiratory rhythms (Shiomi, 1974).

We can infer from these works, then, that the exposure to certain conditions of traffic environment can be related to increases on the activity of our Nervous System Sympathetic (cardiovascular changes, an increase of the electrodermic activity, as of the musculoesqueletal tone and the respiratory rhythms). Eventhough it is genuine that it is not possible to indistinctly use any physiological answer as an activation index, certain consistency has been found through the individuals according to various physiological measures. The answers to skin conductance and cardiac rate seem to form and adequate index of the state of anxiety, eventhough some limits must be kept in mind. In all cases, and eventhough no isolated measurement of the physiological answers seem to be predicative of anxiety under various traffic conditions, a stronger relationship exists between the cognitive evaluation that the driver does of the traffic situations and the physiological answers that expresses (Shiomi, 1974; Jonah et al., 1981; Hoyos & Kastner, 1986). Thus, Robertson (1978) using the *Driver Behavior Inventory* (Gulian et al.,1988; 1989a& b) -self-report directed to evaluate driver's stress- with the physiological measurements, found concomitances between two factors of the inventory (driving alertness and overtaking tension) and acceleration of the cardiac rate on individuals driving self-propelling vehicles.

The work group that develops the *Driver Behavior Inventory*, originated around Edith Gulian's figure (Gulian, 1987; Gulian et al., 1988, 1989a & b, 1990; Matthews et al., 1991), approaches the studies on the driver stress, in an attempt to explain the dimensions that define it and the factors that contribute to its appearance and maintenance. The term "driver stress" is essentially used in their investigations as a synonymous to the subjective perception of stress informed by drivers and only refereed to the driving task, not the generated by the possible effects of externals factors to driving. Neverthless they consider "driver stress" as a function formed by intrinsic factors (traffic conditions) and extrinsic factors (personal live to driving). On one hand, family or working problems can substantially contribute to the driver's stress when interfering with the driver's ability to help the traffic environment's demands. An the other way round, stress originated in traffic events cannot only be experienced while driving but also in other following activities. They point out that pleasant life conditions (health, family, work, etc.) can attenuate the driver' s stress levels, while the damage on some of these areas could influence the driver's answer to specific traffic incidents and to driving in general, contributing in all levels to increase the driver stress.

The approaching of these authors to "driver stress" is based on Lazarus' Transactional model of physiological stress. Stress appears when the perceptions of task demands, in this case the driving, exceeds the driver's abilities to face them (Lazarus & Folkman, 1984). Driving is assumed as a stressing activity; so to speak, as a group of external circumstances to the driver that can imply some extraordinary and unusual requirements, pointing out the existence of strong individual differences, its susceptibility to stress when driving. Driver stress is defined as a group of answers associated to perception and the cognitive valuation of the driving task. The assumption that driver stress is probably a complex syndrome determined by an interaction of local and personal factors, is implicit in this transactional approximation. The answer to stress can be an emotional reaction (p. e. an increase in the cardiac rate) and/or behavioural answer (p.e. adopting an aggressive driving style). Anxiety is, though, considered as a reaction to stress; a subjective experience that is directly connected to the gravity and the lasting of the threat. At the same time they point out that the psychophysiological and behavioural answers to traffic events are affected by the evaluation of the situation that drivers' do (Gulian, 1987; Hoyos & Kastner, 1986).

They consider that the driver's stress can be experienced into two different levels, eventhougth they are conected:

1.- In agreement with Lazarus and Cohen's (1977) classification of the stressing factors, at a first level stress could be induced from traffic events that only take place in certain occasions and other which the driver has only a limited control, this is the reason why they turn into situations susceptible to elicit anxiety on the drivers. The higher anxiety level in these situations acts attenuating the drivers'ability to rapidly and correctly process the information and prevent the use of the required answer patron.

2.- On a second level, the driver's stress can arise as a result of a continuous exposition to the traffic situations that exceed the driver's ability to act in a secure and correct way. Following Lazarus & Cohen (1977) again, the result would be little that occur daily with accumulative effects. Here driver's stress is the consequence to emotional, cognitive and physiological answers, accumulated during traffic situations, like large distance trips and daily journeys (Stokols & Novako, 1981).

On the other hand, Sholomo Giora Shoham & colleagues (Shoham, 1975; Shoham et al., 1974; 1976; 1977; 1984) undertake the studying of anxiety in the driving ambit from the investigation on personality trait, adopting an exposition based on the theory of trait. These authors understand anxiety as a trait of personality, and answering predisposition relatively independent from the situations. The departure hypotheses in their work is the following: the individuals inclined to have accidents and/or perpetrate traffic offences do not have a unic and distinct personality pattern, but rather behavioural expression of two different personality pattern, that is: the anxious and reckless drivers. The anxious driver, due to the structural imperfections of his innate personality, tends to adopt an anxiety state when facing risky traffic situations; this is, the anxiety level of a driver at a certain moment is affected by the interaction of two components, his personality trait and stimulative properties of the traffic situation. The anxious driver id defined as an individual with a high anxiety-trait level, a high ability to learning, and easy conditionability and a low level of impulsiveness. The extremely anxious driver accepts the normative system of traffic laws as legitimate and he will be a citizen that will accept and accomplish the law in every field, including the traffic one. The hope to undertake risks decreases as a consequence of the deeply traffic laws are internalized. His search for sensations is not high so he does not take any unnecessary risks while driving. Nevertheless, when he finds himself in a conflictive or ambiguous situation on the road, he will tend to assume higher risks as a way of facing the situation and freeding the tension. This driver mixes his emotions with his decisions and will develop an state of anxiety on the situations in which he has to decide rapidly and almost instinctively. The pressures and the ambiguous traffic situations will produce an approximation conflict on him -similar to the one narrated by Fuller in his model of Threat-Avoidance- provoking as a result, confusion and a loss of control over oneself and one's vehicle which will probably make him commit an infringement or he will be involved in an accident.

A final investigation, also bases on the anxiety trait' theories, is the one accomplished by K. Tiwari & P. B. Behere in 1983. These authors tried to state that accidents do not occur hazardously, but that the personality variables have an important role in their determination. They pay attention to their exploration of anxiety as a personality trait that increase the probability of a car accident, finding out that the injured individuals show higher anxiety trait levels, in comparison to the non injured. The anxiety state in this investigation was not, however, capable of distinguishing between both groups of drivers.

3. ANXIETY EVALUATION IN THE DRIVING AMBIT

We have repeatedly refereed to the scarcity of studies on anxiety and driving. This scarcity is also proved in the number or self-reports specifically designed to evaluate anxiety and/or stress generated by traffic. Specifically in the literature reviewed we can only find two of them: the *Driver Behavior Inventory* (Gulian et al., 1988, 1989a &b) & the *Anxiety Questionnaire* (Shoham et al., 1974).

The *Driver Behavior Inventory* (D.B.I.) includes 97 items that contain the following areas: demographic, accidents and attitudes towards them, health state and driving consequences, work and personal relationships, occupational, personal and domestic problems, emotions and attitudes towards driving, towards traffic situations and the other road users and facing strategies to general or specific traffic situations. It measures the frequency in which certain behaviours (always-never) happen or categorizes behaviours or opinions (a lot-nothing) into a four point scale. The D.B.I.'s analysis reveals that a general driving factor (General Driver Stress) exists, as a five other factors that define the general appraisal that the person has on driving:

1.- Dislike of driving and related anxiety
2.- irritation when overtaken
3.- driving aggression
4.- driving alertness
5.- overtaking tension

The apparition of driver stress is linked to an increase of aggression, annoyance while driving and frustration and irritation provoked by interaction with others drivers, mainly in connection to overtaking and alert increases. Only this last factor, according to the inventory authors can play a positive role in complicated traffic situations.

On the other hand, the *Anxiety Questionnaire* (Shoham et al., 1974) is based on the *Manifest Anxiety Scale* de Taylor (1953) and the *Anxiety Questionnaires for drivers by Sarason y Mandler.* The scale is composed by 8 items that are answered affirmatively or negatively. The items represent as much the physiological components of anxiety (before a long trip I feel that my heart beats rapidly; when I get near a crossroad, my heart beats are faster than usual; my hands sweat while driving) as the cognitive answers of anxiety (driving with a lot of traffic gets me nervous; insecurity makes people drive with precaution and have less accidents; when nervous I drive worst than usual), however the locational spectre gathered is minimum and the answers are only taken as expressions of this anxiety trait.

The rest of the investigations used the Manifest *Anxiety Scale* (Taylor, 1953) (p. e. Shiomi, 1974) or the *State-Trait Anxiety Inventory: Trait Scale* (Spielberger et al. 1970) (p. e. Tiwari y Behere, 1983; Jonah et al., 1981) or direct physiological measurements as the cardiac rate (p. e. Simonson et al., 1968; Shiomi, 1974), blood pressure (Novaco et al. 1979; Schaeffer et al., 1988) skin conductance (Heimstra, 1970), catecholamines' secretion (Bellet et al., 1969; Mulders et al., 1988; Evans & Carrère, 1991) or changes in the respiratory rhythm (Shiomi, 1974), not being any direct measurement of the motive answers to anxiety found in any work probably due to the difficulty that the act of controlling the locational context which these behaviours take place would suppose.

4.- THE INVENTORY OF ANXIOUS SITUATIONS IN TRAFFIC (I.S.A.T.)

By the light of these investigations and due to the fact that in Spain there is no proof that it has been designed with the purpose of evaluating anxiety regarding traffic situation, we proposed to work out a general type of inventory, that we named I.S.A.T. (Inventory of anxious situations in traffic) directed to evaluate anxiety in front of traffic situations able to generate them, as a first step towards a future development of an self-report that will make possible the reactivity's evaluation of the three answering systems -cognitive, physiological and motive ones- in front of a representative sample of the potentially anxious driving situations.

The development of this inventory requires departing from a theoretical model able to analyze anxiety from an up-to-date- perspective with a higher consensus among the investigators during the last years the most relevant and fructiferous theoretical contributions to the studying of anxiety are the ones derivated from the interactive and behavioural models (Miguel-Tobal & Cano-Vindel, 1989). Since the interactive model behaviour has been pointed out as being determinated by personal and locational factors, but mainly by interaction between both of them (Bowers, 1972, 1973; Endler, 1973). This model emphasizes the need to consider the situation's nature in the study and evaluation of anxiety, from the verification of the existence of specific locational areas connected to individual differences on anxiety's traits. On the other hand, after the important changes emerged in the conductism since the 60's, and the definitive introduction of cognitive variables in its theoretical frame, anxiety stops being considered as an exclusively peripheral phenomena in order to acquire a cognitive and main significance, making the conductual conception of anxiety advance from the unitarian model to multidimensional ones, where the emphasis is put on the need to evaluate in a independent way the 3 anxiety answering systems (cognitive, physiological and motive) and on the evaluation of specific answers in front of concrete situations.

At last, in the anxiety evaluation field, we can actually observe an increasing interest, as much in the methodological item as in the clinic practice, due to the development of self-reports that adopt and interactive format including a broad variety of situations potentially anxious and a considerable number of answers to the three systems in front of these situations. Questionnaires that appraise locational areas connected to individual differences and questionnaires that make and evaluation of the reactivity of the three answering systems possible, are required (Miguel-Tobal & Cano-Vindel, 1990).

A review of situations connected to driving capable of generating anxiety on population exposed to traffic has been due to term in order to develop the I.S.A.T., as of the existent literature on the subject (Carrère et al., 1991; Duffy & McGoldrick, 1990; Evans et al., 1987; Evans & Carrère, 1991; Fernández-Seara & Navarro, 1984; Furnham & Saipe, 1993; Gulian et al., 1988, 1989a & b, 1990; Mattews et al., 1991; Monterde et al. 1991; Novaco et al., 1979; Ragatt, 1991; Reig, 1987; Shoham et al., 1976, 1984; Stokols et al., 1978). We selected a total of 40 situations that we classified into four types of general situations potentially anxious: situations that imply evaluation, situations to imply an impossibility or an obstacle to reach an aim, situations of a real danger and situations that include non specific stressors (Bañuls et.al., 1993). The establishment of these four logical classifications relies on different empiric works that have verified the existence of patrons that differentiate anxiety trait according to the type of locational dimensions (Endler, Hunt & Rosenstein, 1962; Endler & Okada 1975; Endler et al. 1976; Endler & Magnusson, 1976b & c; Endler, 1978; Flood & Endler, 1980; Miguel-Tobal, 1985; Miguel-Tobal & Cano-Vindel, 1984, 1989; Cano-Vindel & Miguel-Tobal, 1990; Bermúdez, 1983).

After a preliminary process of depuration, the definitive inventory included 32 situations. In the following paragraphs we point out some of the most relevants characteristics of it.

VALIDITY

The I.S.A.T. validity content is verified by the inventory work out itself, which's items gather a representative sample of potentially anxious driving situations selected by rational analysis, by consultation crossed to expert on the relevant fields and investigations on the subject.

The inventory structure was studied with the help of the Factorial Analysis Method (Analysis of the main components with oblique rotation). This first exploratory analysis allowed as to identify four locational ambits, relatively independent. Thus the 32 situations that constitute the I.S.A.T. are gathered in four factors with their own values higher than the unit, that all together are capable of explaining a little more than 48% of the total variance.

TABLE 1: FACTOR ANALYSIS OF I.S.A.T.

EVALUATION: SELF-EVALUATION & EXTERNAL EVALUATION (I.S.A.T.-1)	Nº ITEMS= 17	EIGENVALUE= 8.78 PCT OF VARIANCE= 27.2%
CRITICISM & AGGRESSION (I.S.A.T.-2)	Nº ITEMS= 7	EIGENVALUE= 2.82 PCT OF VARIANCE= 8.8%
EXTERNAL OBSTACLES AND RETENTIONS (I.S.A.T.-3)	Nº ITEMS= 8	EIGENVALUE= 2.13 PCT OF VARIANCE= 6.6%
AUTHOTITY'S EVALUATIONS (I.S.A.T.-4)	Nº ITEMS= 8	EIGENVALUE= 1.75 PCT OF VARIANCE= 5.5%

First factor, (I.S.A.T.-1), gathers 17 significant items. On this factor high saturations are obtained by the items connected with self-evaluation in situations that the driver establishes as difficult or dangerous and before which he can feel or not capable of facing them (I reach a complicated crossroad, I have to drive at night-time, to drive on unknown roads, etc.), and situations that implicate external evaluation (the people with me in the car do not feel safe, they fall asleep, some other drivers honk the horn, people look at me when parking, etc.). It is the most powerful factor on the inventory, as to be hopped, considering the highly importance that the evaluation situations have in all inventories on anxiety [looks p. e. the *Inventario de situaciones y respuestas de ansiedad* (Miguel Tobal & Cano Vindel, 1988), the *Inventario de actitudes hacia situaciones generales* (Bermúdez, 1983), the *S-R Inventory of General Trait Anxiousness* (Endler, 1978; Flood & Endler, 1980), the *Endler Multidimensional Anxiety Scales-Trait* (Endler et al., 1989) or the *Endler Multidimensional Anxiety Scales-Perception* (review) (King & Endler, 1989)].

On the second factor (I.S.A.T.-2) high saturations are obtained on the items connected with criticism and aggression towards the driver proceeding from the other drivers or pedestrians (another driver says something against me, he shows me his anger, he insults me, the threatens me...) this factor establishes another step towards evaluations (in fact all these situations are of an obvious criticism).

On the third factor (I.S.A.T.-3) the situations that highly saturate refer to external obstacles and retentions; traffic jams, impossibility to overtake, etc., so to speak, situation connected to the traffic environment that could imply a delay to the driver in reaching to his destination at the time scheduled. In general, this sort of situations appears in other investigations strongly distinguished as stressful and associated to sensations like irritation, tension and anxiety. In general, the situations gathered in this logical group (not being able to overtake, to travel in a jam, retentions, traffic jams, traffic-lights...) are associated to aspects like impatience, a variable that has been repeatedly considered as a factor of risk when driving, since Mira's first studies (1922), to our days (Monterde, 1989; Reig & Soler, 1986). They nourish themselves on the model of frustration, demanding on the driver constant tone of activity and greater resistance to frustration. Frustration originate by the impossibility to reach an aim leads the person to accumulate unpleasant feelings, possibly leading to a state of tension that could end in emotional disorder like anxiety.

On the last factor (I.S.A.T.-4) high saturations are obtained on the situations that imply an authority's evaluation. It includes all the situations in which directly or indirectly the authority is reflected (an accident, the sound of fire-engines, the police, an ambulance...).

Concluding, this factorial analysis has let us identify four locational areas relatively independent, in which the individuals driving self-propelling vehicles differ on susceptibility to show out anxiety reactions. The low correlation obtained between the four factors verifies its relatively independence.

TABLE 2: FACTOR CORRELATION MATRIX

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
FACTOR 1	1.0000			
FACTOR 2	-0.2429	1.0000		
FACTOR 3	0.3298	-0.2334	1.0000	
FACTOR 4	-0.3258	0.3386	-0.3238	1.0000

We adopted as an external criteria of anxiety for the study of the criterial validity, the I.S.R.A. (Miguel-Tobal & Cano-Vindel, 1988), one of the anxiety test with the greater analysis of validity vigour and based on the same theoretical model of anxiety chosen for our investigation. In global terms, the analogies obtained between both instruments are sufficiently higher with a trustful level over on per thousand.

TABLE 3: CORRELATIONS I.S.A.T. WITH I.S.R.A.

I.S.R.A.	I.S.A.T.	I.S.A.T.-1	I.S.A.T.-2	I.S.A.T.-3	I.S.A.T.-4
TOTAL	0.608 P= .000	0.614 P= .000	0.412 P= .000	0.464 P= .000	0.473 P= .000
COGNITIVE	0.590 P= .000	0.575 P= .000	0.404 P= .000	0.452 P= .000	0.465 P= .000
PHYSIOLOGIC	0.535 P= .000	0.579 P= .000	0.332 P= .000	0.407 P= .000	0.420 P= .000
MOTOR	0.477 P= .000	0.467 P= .000	0.347 P= .000	0.364 P= .000	0.360 P= .000
FACTOR 1	0.576 P= .000	0.593 P= .000	0.367 P= .000	0.403 P= .000	0.475 P= .000
FACTOR 2	0.431 P= .000	0.440 P= .000	0.268 P= .000	0.326 P= .000	0.380 P= .000
FACTOR 3	0.484 P= .000	0.496 P= .000	0.334 P= .000	0.413 P= .000	0.347 P= .000
FACTOR 4	0.438 P= .000	0.437 P= .000	0.268 P= .000	0.355 P= .000	0.342 P= .000

Finally, with the results handled at the moment, we can state that the I.S.A.T. -as much its total method as its factors- aims towards a high validity.

RELIABILITY AND INTERNAL CONSISTENCY

I.S.A.T.'s reliability calculus was carried out with the help of two procedures: Cronbach alpha (internal consistency) and the test-retest method (empirical appreciation of the reliability's coefficient).

TABLE 4: RELIABILITY AND INTERNAL CONSISTENCY OF I.S.A.T.

-ALPHA DE CRONBACH

I.S.A.T.	I.S.A.T.-1	I.S.A.T.-2	I.S.A.T.-3	I.S.A.T.-4
0.9105	0.8575	0.8544	0.8158	0.8078

-TEST-RETEST

I.S.A.T.	I.S.A.T.-1	I.S.A.T.-2	I.S.A.T.-3	I.S.A.T.-4
0.8166 P= .000	0.8225 P= .000	0.7458 P= .000	0.7656 P= .000	0.7321 P= .000

-CORRELATIONS BETWEEN THE DIFFERENT PARTS OF I.S.A.T. AND THE I.S.A.T.

	I.S.A.T.	PROBABILITY
I.S.A.T.-1	0.920	p= .000
I.S.A.T.-2	0.752	p= .000
I.S.A.T.-3	0.771	p= .000
I.S.A.T.-4	0.810	p= .000

The alpha's obtained for the total I.S.A.T. and its factors are, as you can appreciate very high.

On the other hand, the I.S.A.T.'s temporally reliability and consistency's index also reach very high values, even more if we keep in mind that the stretch of time test-retest was two months, wild the customary is four months. next to his the correlations between the different parts and the total (internal consistency) are highly significant (p=.000). We can concluded from all the results exposed that the I.S.A.T. has a high internal consistency and a good reliability.

5. CONCLUSION

Till now we have developed a first inventory that fulfils a traditionally neglected area in the evaluation of the variables connected to driving and traffic safety, this is, the traffic environment one as an anxiety generator on the driver. The I.S.A.T. provides a global punctuation at the same time as punctuations in four distinct locational ambits (situations that implicate self-evaluation and external evaluation; criticism and aggression; external obstacles and retentions and situations that implicate evaluation by the authorities); from it, we believe to have contributed, for the moment, with sufficient information on its soundness (validity), reliability and its behaviour connected to some variables associated to driving (sex, reckless, driving experience, etc.) (Bañuls, 1993). Now we have a first instrument, even with books of tables, to deepen more in the traffic anxiety problem, which we hope will contribute to activate the investigation on this field, which we find very interesting.

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DRIVER RELIABILITY AND TRAFFIC SAFETY: THE USE OF ERROR DATA IN ASSESSING ROAD TRAFFIC INFORMATICS (RTI)

Report - working group C

The working group had only three contributions, the announced speech by Mr. Ridwan from Indonesia could not be presented.

The overall congress title was on "Safety Evaluation of Traffic Systems: Traffic Conflicts and Other Measures". Our group did not touch the topic of traffic conflicts, but was concerned with "other measures". These were human error data as a possible measure of safety, in-depth accident analysis and interviews.

Wolfgang Fastenmeier gave an overview of our recent investigations using error data to evaluate the effects of new technology in the car. He presented some selected results from studies on in-car navigation systems, from an examination of information needs of different subgroups of drivers and from a presently evaluated dual mode route guidance system.
The aim of his presentation was to show how error-counting methodology works and how it can be modified for different research purposes, and he wanted to give examples of the kind of results you can get using this kind of error data. So his presentation mainly relied on empirical work we have done in the last few years.

Heiner Bubb in his presentation showed a theoretical approach to driver reliability or error research. He is trying to model the information processing of the driver on the guidance level of the driving task. The idea of his modelling is to describe error mechanisms that can be used in understanding accident events and thus help to avoid the reocurrence of these errors, respectively.

Both contributions have been discussed together. After the speakers had answered some informational questions to exclude misunderstandings, a broader discussion on the use of error data arose. Nobody denied the probable utility of failure research in traffic safety in general, but it became clear, that much conceptual work still has to be done.

Some of the central questions research work in the future has to try to answer are the following:

Is it possible and useful to distinguish between errors and traffic violations?

Which of the existing taxonomies of human error can be applied to the traffic context?

Errors themselves cannot be observed or counted-only their behavioural outcomes. What does that mean with regard to observation methods and the interpretation of results?

How should errors be defined in relation to normative task analyses?

What are the causes of errors - how can the causal approach to human error enrich the outcomes of the frequency approach to errors?

Is traffic a sufficiently well-structured area, so that research is able to define errors as deviations from a correct normative behaviour?

Of course, not all the questions raised in the discussion could be answered satisfactorily in the working group. But I think that the discussion was an encouragement to give the error approaches more attention in the future.

After this discussion, Pierre van Elslande gave a paper dealing with the evaluation of RTI-technology by means of in-depth accident analysis and opinion investigation of users. Results showed, that the users preferred informational over automatic aids; they accepted automatic devices for situations of extreme urgency, only. Credibility and public use of the aid will depend on the usefulness of the messages, their timeliness and of course on system reliabilty.

In total, the results showed marked differences between what the users of RTI systems wanted and those functions that the RTI system designers nowadays give to them. This difference has been debated at shortly. Because -especially in the DRIVE- and PROMETHEUS context- system designers have got lots of feedback and information from users and behavioural scientists on what is expected by drivers, it was inferred in the discussion, that users and system designers might have quite different objectives in mind, when they develop ideas for the car of the future.

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APPLICATIONS OF ERROR DATA IN TRAFFIC SAFETY EVALUATION: A REVIEW ON OUR RECENT FIELD STUDIES

1 Introduction

Most efforts, projects and measures dealing with the development of new information/control strategies and technologies in vehicle equipment aim at an improvement of traffic safety (e.g. PROMETHEUS, DRIVE). Therefore, it has to be highlighted that there is a need for supplying criteria and methods for an evaluation of possible safety effects, because all measures have to be applied and approved under real traffic conditions. Research indicates evidence that an evaluation of safety effects completely relying on accident data will not provide reliable future safety assessments. Without aiming at a detailed discussion about the pros and cons of the accident criterion, one important fact should be taken into account in any case: accident data will not be at our disposal at that time when new technologies are available and ready for use in real world traffic. Therefore, it is necessary to develop a set of criteria and methods to be used for a quick and efficient road safety evaluation without having to rely on retrospective accident data analysis.

2 An Interaction Model of the Traffic System

In the contexts of industrial safety or air traffic control the notion of "critical incidents" has a long tradition (see e.g. Flanagan, 1954). These critical incidents can be ranked on a scale representing the dangerousness of an event. We call the scale "safety continuum", i.e. we consider traffic safety (or the degree of safety of a specific, observable traffic situation) to vary between the extremes of correct behaviour and accidents. Errors in the behaviour of road users, slight traffic conflicts or near accidents should be somewhere in between the two poles. In the direction of the accidents events become more dangerous but less frequent.
The safety continuum as a theoretical idea can be transformed into discontinuous units by clustering similar traffic situations according to certain observable criteria or operational definitions. Thus, the safety continuum can be replaced by a model of the traffic flow that consists of system states and transitions between states. Such a concept is illustrated in figure 1.

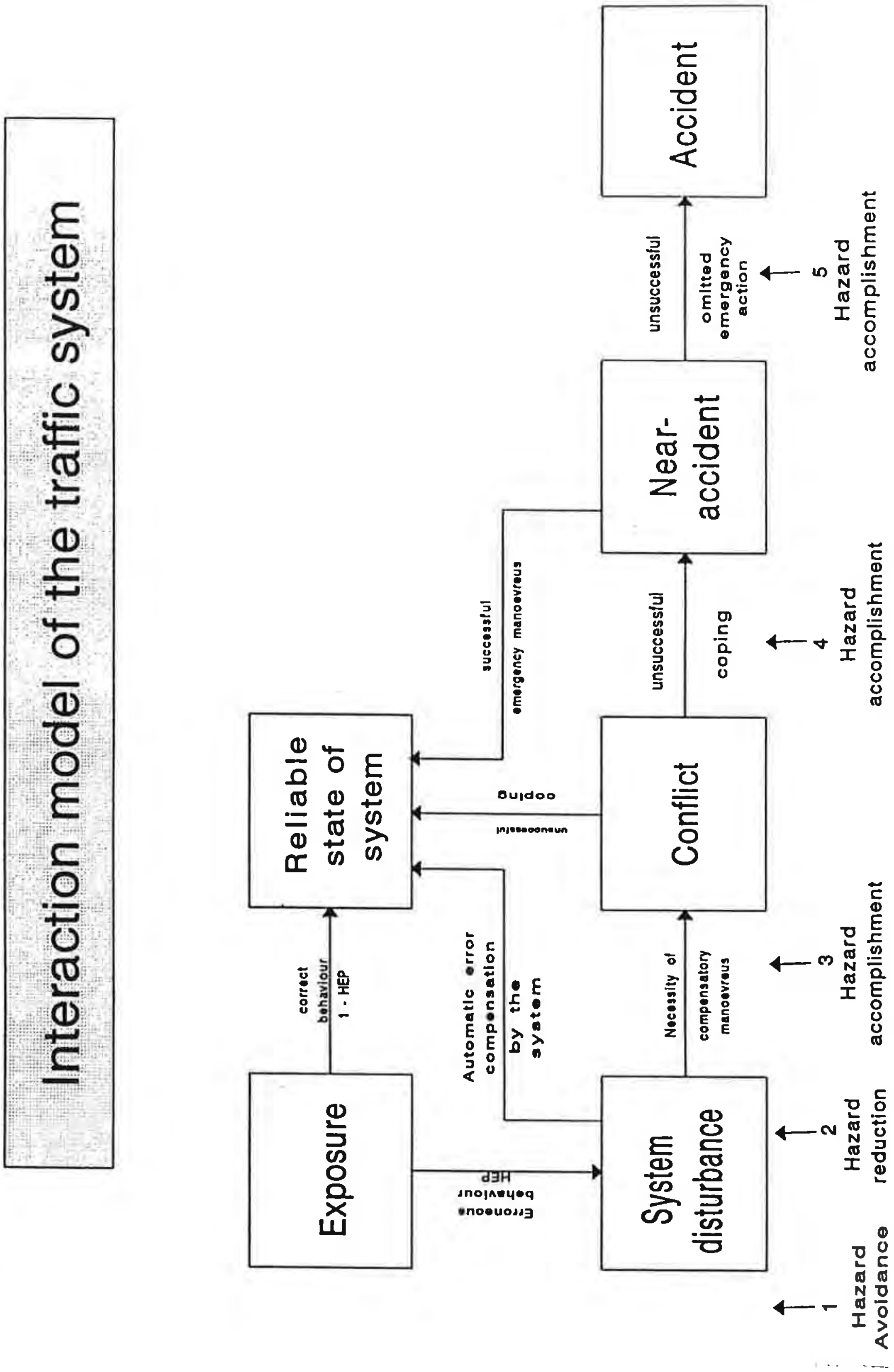

Illustration 1: Interaction model of the traffic system

The bottom row of illustration 1 shows that the accident is regarded as the end of a sequence of events. One would expect an accident to have been preceeded by dangerous situations and erroneous behaviours, i.e. disturbances in the traffic system. The less disturbances occur, the more reliable the system will be. The number of errors introduced to the traffic system by its various elements gives an estimation of its hazard potential.
Analogous to the human reliability approach from systems engineering we define the driver's reliability by using the ratio between erroneous and correct performance, i.e. by human error probabilities (HEP's).

The arrows in illustration 1 point to different parts of the model and show strategies in safety efforts:
(1) hazard avoidance by decreasing the exposure to hazards (e.g. by seperating traffic streams by means of signalisation)
(2) hazard reduction by increasing the driver's reliability given a specific exposure to risk (most automatic devices in the car are examples of that strategy) and
(3) hazard management: coping with situations including disturbances in the traffic system. As the model illustrates these situations can be of different degrees of dangerousness - depending on safety margins provided by road infrastructural elements, the possibility of error compensation by other traffic participants and the necessity and time available for compensatory action.
The arrows in the model not only structure safety measures and countermeasures but also show different levels at which the traffic system can be diagnosed. The potential of the reliability analysis is given by the simple equation

$$\text{number of errors} = \text{exposure to hazards} \times \text{HEP}.$$

The number of errors (or the amount of disturbance) in the system gives an estimate of the conflict or accident potential and can be reduced by the intervention strategies (1) or (2). According to the model an accident cannot happen without a system disturbance, i.e. the reliability of the system will be closely connected to its safety in terms of numbers of accidents (as long as the transition probabilities between the system states in the "unreliable" part of the model remain unchanged).
A precise definition of all system elements is given in Fastenmeier, Gstalter & v.Benda (1992) as well as a list of errors and operational definitions of the related exposure measures. We shall not go into too much detail here, but describe some typical applications of the error data approach in the next chapter.

3 Examples of Recent Applications of Error Counting Methods for Different Purposes

The prerequisite for an effective application of behavioural and error data is both a precise and detailed definition of these incidents and an objective and reliable observation technique. In this context our working group has produced various techniques which have been applied in several field studies. Some results of these recent field studies will illustrate the broad scope of applications of error counting methodologies.

<u>Safety evaluation of LISB</u>
One example for using behavioural data is a study which evaluated safety effects of a new electronic in-car navigation system (LISB - Leit- und Informationssystem Berlin) on driver behaviour. LISB, which is based on the SIEMENS-EuroScout-System, supplies drivers on the road with current and individual route recommendations which are transmitted to and displayed in the cars. In this study an observation technique for non-standardized test routes was used combining both registration of situational characteristics and driver behaviour (Galsterer, Fastenmeier & Gstalter, 1990; Galsterer & Gstalter, 1990).

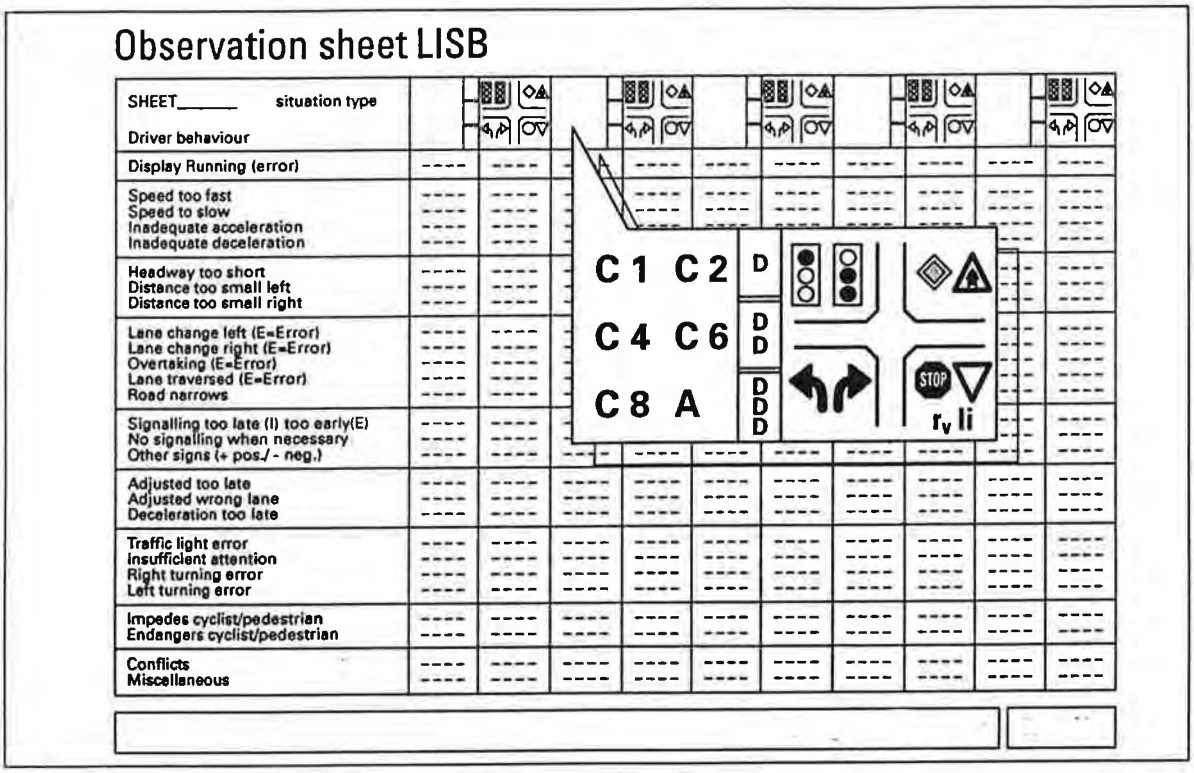

Illustration 2: LISB-Observation sheet for non-standardized test-routes

To get an idea of if and how LISB has an impact on safety and driver behaviour, in a first part of the study a related sample of 25 drivers out of the 700 in total in the large scale test was accompanied by an observer at three different phases: without LISB, shortly after the installation of LISB and nine months later after the drivers had got used to the system. The observer scored errors and traffic conflicts during routine trips of the subjects on a standardized observation sheet, based on the "Vienna Driving Test" (Risser & Brandstätter, 1985). Driver behaviour was assessed according to various aspects of speed, intervals and gaps, tracking and lane use, blinker-signals and communication, guarding in general, approaching intersections, behaviour in intersections and behaviour against non-motorized traffic participants. How the observer has to assess driver behaviour is fixed by means of observation guidelines. Two examples of error definitions shall illustrate how the observer has to judge the observed driver's behaviour:

1. Speed too fast: the running speed of a driver should be as it is both prescribed by law and recommended by characteristics of the traffic situation. Driving more than 10 km/h above the speed limit is regarded as an exceedence of speed not being adequate to the traffic situation. In residential roads even driving at the recommended speed limit can be regarded as inadequate.
2. Lateral distance too short: the driver has to keep an adequate lateral distance both to other cars, objects or obstacles and to non-motorized road users being on the same carriageway or on a lane for opposing flow. As a rule of thumb we suggest: a correct lateral distance against moving objects should be at least 1,5 m, against fixed objects at least 1m. In this context, the speed is of importance, too. This rule also holds true only for cases, where circumstances in the traffic surroundings do not force other manoeuvres upon the driver.

The observer also collected several kinds of exposure data: he described the traffic situations, i.e. characteristics of road segments and intersections, by indicating their type in the top row of the sheet. In addition, he counted the frequency of different manoeuvres of the drivers, e.g. lane-changing, overtaking and turning. These measures served as basic exposure information so that error rates for different driving tasks in defined situational classes of the traffic environment could be calculated. The traffic situations are classified by means of a classification system for traffic situations (Fastenmeier, 1993), which combines traffic engineering characteristics of traffic situations with the driver's point of view. So far, this system could be labelled as a "fuzzy classification system of traffic situations", because its categories are based on the drivers' subjective representations of traffic situations, which then have been classified according to technical standards. This classification system contains various elements with a number of categories as follows:

A Type of motorway / highway (5 categories)
L Type of rural and country roads (2 cat.)
C City roads (7 cat.)
H Horizontal shape (2 cat.)
V Vertical shape (2 cat.)
E Lane closures, bottlenecks (2 cat.)
F Direction (3 cat.)

The system is completed by time-variable characteristics such as traffic density, visibility- and weather conditions.
In the observation sheet, shown in figure 2, for instance the abbreviation C1 represents city roads with two carriageways and seperating strip (ring roads) and the abbreviation C6 stands for smaller residential roads.

Some of the main results were as follows: exposure data showed marked changes with respect to the type of roads and intersections used. With LISB both the proportion of main roads and the relative number of signalized junctions increased. The frequency of lane-changes, overtaking and turning manoeuvres decreased.
With only few exceptions the error rates followed a V-shaped distribution over the three different investigation periods: after the introduction of the navigation system drivers behaved safer and drove more cautious and exact. The overall error rate dropped significantly from 32% to 27%. The number of speed errors was smaller than before. Nine months later, nearly all of these positive effects had vanished or at least had become smaller; the overall error rate was up to 30% again at that time.

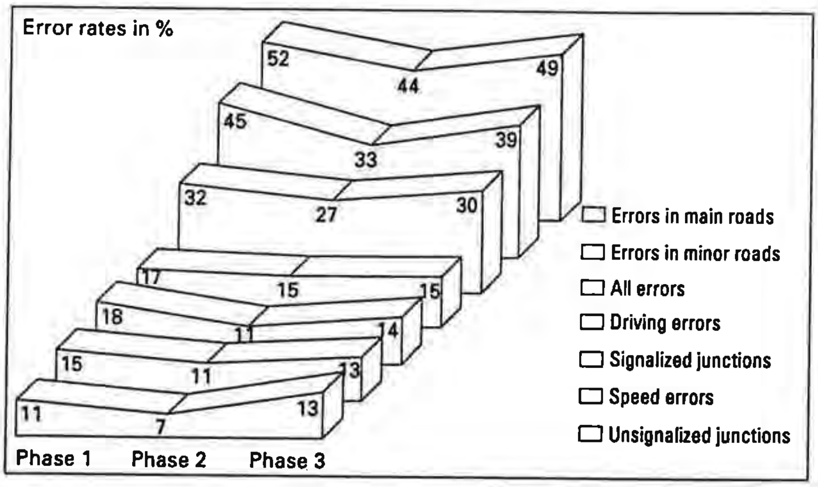

Illustration 3: Error rates with and without LISB

Our explanation is, that we can find here a typical habituation effect. The initial tension and attention with the new system had become routine. During nine months that the drivers had been guided from the same sources to the same destinations, they had been driving all variations of streets possible. If a system message came now at the beginning of the trip, the driver could clearly guess which alternative would be used that particular day. It follows that longer term planning for the driver was possible again and driving behaviour shifted into the direction of the initial behaviour.

The usefulness of a navigation system like LISB should clearly increase with decreasing knowledge of the area the driver has to find his way in. The orientation task increases the mental workload of the driver and less cognitive resources are left for the guidance and control level of the driving task. Therefore, 18 of our original subjects were observed during trips in unknown areas of the Berlin network. In order to compare their driving performance with the routine trip results all other independent variables were held constant. One remarkable working step of this analysis was to compare those error data with some accident data, demonstrating a significantly increased accident risk of strangers in bigger German towns (accident data taken from Engels & Dellen, 1989).

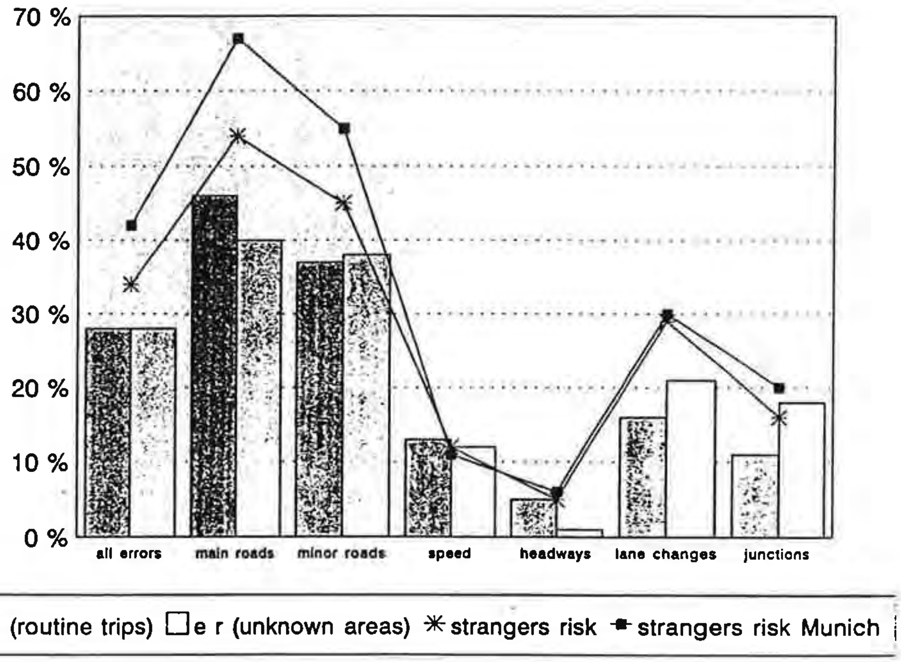

Illustration 4: Comparison of error rates (e r) and strangers accident risk

Illustration 4 shows the error rates for the routine trips (left column) and the corresponding values for the unknown areas (right column). The rectangular and the star represent estimates of an expected error rate value, based on the average accident risks for strangers in general (stars) and for Munich (rectangular), respectively. The total error rate remained unchanged. The expected rate was clearly higher: the conclusion is that the navigation system had been helpful. The next two pairs of columns show the error rates on broad main roads (C1/C2/A) and on minor roads (C4/C8). Here, the influence of LISB is evident: error rates between intersections do not rise in unknown areas but even show a strong tendency to drop, whereas the usual strangers risk is high for these classes. Obviously, the early announcement of the route direction, the lane recommendation by the system and the bar graph -an analogous indication at the display of the remaining space to the next turning point- had been powerful means in supporting the drivers orientation task.

Errors in speed (driving too fast) and distance (too short headways) are not specific for the orientation problem. Therefore, the accident causation risk is equal for these accident types both for residentials and for strangers. For that reason we did not expect the error rates to change in the unknown environment. Indeed, errors according to speed and distance even decreased in that part of the field study where trips in unknown areas were under observation.

A different result could be noted in the intersections: Error rates went up for all types of errors inside the junctions in the unknown parts of the road network. This is primarily because LISB has nothing to offer in helping the drivers in their orientation task within the intersections. The rise of the error rate for all kinds of errors in junctions was as big as we had expected from the stranger's risk data (compare Gstalter, 1991).
As a whole, the structure of the accident risk data and of the error rate data show a very interesting correspondence that should attract more attention in the future.

A study on driver information needs
The second example for an effective application of behavioural and error data is a field study dealing with different driver populations. The purpose of this study was to analyse driver information needs in order to know more about how different types of drivers (unexperienced, routine, elderly and expert drivers) could be effectively assisted, i.e. which kind of information-assistance is adequate and appropriate in which kind of traffic situation (e.g. Fastenmeier, Reichart & Haller, 1992).

This was based on the assumption that various kinds of driver-assistance- and driver-information systems are needed in order to compensate group-specific driver deficiencies:

- information processing of drivers in general is dependant on distinct situational characteristics to be found in traffic reality
- heterogeneous types of drivers are confronted with these varying situational demands, i.e. there are different levels of driving experience, driving skills and performance characteristics
- there are different kinds of critical tasks and situations for different kinds of drivers as well as there are different information needs for different kinds of drivers

In this field study one of the main elements of analysis was an observation sheet for representative and standardized test trials. This was, because on basis of detailed drivers' exposure data, a catalogue of traffic situations for representative trip purposes was compiled and transferred into the construction of a representative test route suited to the traffic reality of Munich (Fastenmeier, 1993). This catalogue includes traffic situations for representative trip purposes of drivers as follows:

- Driving from/to work: this comprises the daily route from/to work (this catalogue was taken for the representative test route).
- Driving for carrying out purposes such as: consulting doctors and authorities, to go shopping, etc.
- Driving for leisure purposes: all kinds of driving in leisure time, usually for short distances, in order to visit friends, performances, etc.
- Driving on weekend: as far as it is cross-country and leading back downtown.

This representative test trial

- allows for a generalization of results e.g. gained by investigating driver behaviour,
- takes the quantitative and qualitative exposure of drivers into account,
- contains "typical" traffic situations, i.e. tasks, drivers are confronted with daily, and
- includes the analysis of the task complexity of each traffic situation on the test trial.

Driver behaviour and driver errors were observed by means of categories and variables quite similar to the LISB-study, but due to the purpose of the study on a much broader scope.

The data gathering logic of this study worked well as for example a vast number of variables differentiating between the examined samples could be revealed and some relevant recommendations for individual/group specific aids could be given. Due to the registration of both situational and behaviour-related data, again error rates and rates of correct performance could be calculated on a very detailed level.

Giving a short survey about driving performance of the subjects in general, this study indicates evidence that elderly and novice drivers could be labelled as "problem" groups.
Examination of unexperienced drivers showed marked deficiencies according to the following list:

- errors in lane keeping and lane changing
- low guarding in general
- low guarding especially in the presence of non-motorized traffic participants
- avoiding obstacles
- too short lateral distances to pedestrians/cyclists
- slow speed combined with sudden inadequate accelerations
- high speed in "easy to handle" situations
- corner-cutting
- orienting in general.

Viewing strategies are remarkably ineffective: when gathering information prior to executing manoeuvres (lane changes, merging, curves, turning) novice drivers are significantly more often turning their head around (instead of using mirrors) than experienced drivers. Moreover they prefer more direct looks, fewer glances to the outdoor mirrors of the car and fewer glance sequences.

Elderly drivers rank high especially on topics such as
- red-light errors
- passing intersections with right of way for other road users
- turning in intersections in the presence of pedestrians/ cyclists
- inadequate deceleration
- velocity either too slow or oscillating
- lane keeping and lane changes
- corner cutting
- guarding in general
- loss of car-handling skills.

The viewing behaviour of elderly drivers shows significant reductions in several aspects: decreasing use of information acquisition by outside and inside mirrors of the car and omitting turning their heads prior to executing manoeuvres, on the contrary more direct looks to the front.

Moreover it turned out that experienced drivers seem to be worse than their reputation, because this field study revealed a relevant number of marked deficiencies as well (especially lane keeping, turning in intersections, traffic violations and the frequency of critical incidents), whereas the "expert drivers" could be labelled as "best-case"-drivers with high preview and anticipation capacities, high information processing speed and highly automatized handling of the car.

Error rates in %

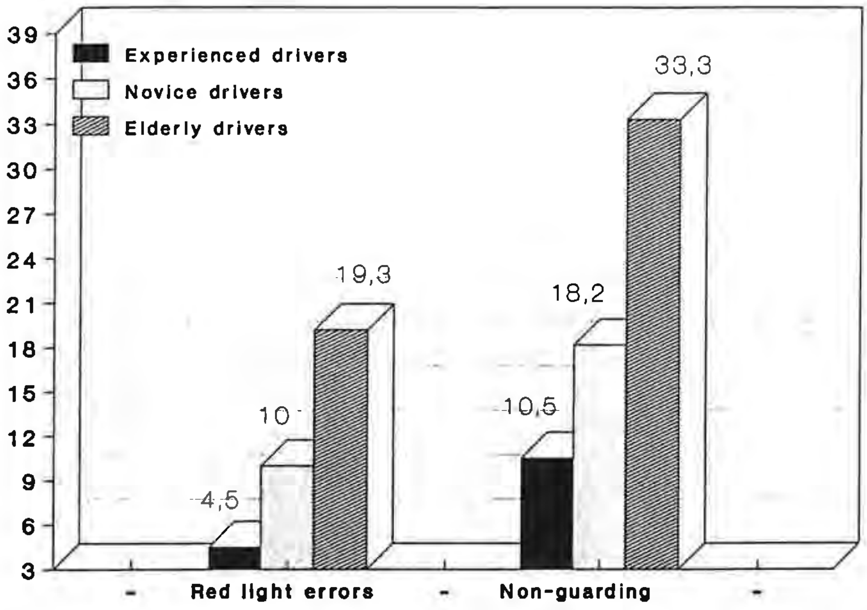

Illustration 5: Red-light errors and Non-guarding of experienced, unexperienced and elderly drivers in C2-K1-situations -

Illustration 5 gives an example, demonstrating the more detailed level of analysis: In an intersection, regulated by traffic lights (K1), on a special type of a broader main road (C2) we can find a strong and significant correspondence between red-light errors (please mark: not intended red-light violations!) and non-guarding of all driver groups of the study as well as we can find distinct differences between unexperienced, experienced and elderly drivers; but especially elderly drivers are "worst cases" in this type of situation, which is a typical example of a class of situation with high task complexity, deficiencies in road layout and where the driver needs parallel information capacities. Some solutions to be discussed in this case are improving the visibility of traffic lights by other placement, better contrast-control and supplying in-car traffic information, e.g. by Head-up Displays.

Another example for attaching specific aspects of driver behaviour to specific types of traffic situations is shown in illustration 6. By means of this error counting methodology it is not only possible to demonstrate significant differences in general between various populations of drivers as far as their viewing strategies are concerned, but also to show in which kind of traffic situation which kind of viewing behaviour can be found. In nearly all kinds of roads and situations both unexperienced and elderly drivers show marked deficiencies in their viewing behaviour and in information acquisition. As -for instance- the use of the car's outdoor mirrors is concerned, this holds true especially for main roads such as city roads with two carriageways and seperating strip (C1) and roads with one carriageway, at least 4 lanes and a fixed-guideway transit system as well as for smaller roads with one carriageway and 2-3 lanes (C4, C5), residential roads (C6) and one-way roads (C7). The only exception in this case are broad main roads with one carriageway and about 4-7 lanes.

Type of road	Experienced (Group 1)	Unexperienced (Group 2)	Elderly (Group 3)	Significant Differences
C1	29,39	21,61	17,60	1 vs. 2 | *1 vs.3*
C2	27,57	22,42	24,61	n.s.
C3	20,45	11,93	9,61	1 vs. 2 | 1 vs.3
C4	25,97	14,28	9,34	1 vs. 2 | *1 vs.3*
C5	24,54	8,18	15,38	1 vs. 2
C6	19,31	9,65	8,65	1 vs. 2 | 1 vs.3
C7	22,72	14,09	15,38	1 vs. 2 | 1 vs.3

Illustration 6 : The use of the car's outdoor mirrors by experienced, unexperienced and elderly drivers in different road types (frequency in %; $p < .05$; *p<.01*)

As mentioned above, we also did some more theoretical work on the driver errors' topic recently. So far, we can supply a classification of driver errors and respective exposure data, which is theoretically sound. In the context of PROMETHEUS, our methodology is actually applied in field studies, dealing with Dual Mode Route Guidance Systems (CED 9) and Autonomous Intelligent Cruise Control Systems (CED 5). Altogether, our error counting approach and methodology is to become one important element of an integrated safety assessment by efficiently supporting already existing methods (accident estimations, expert assessments, safety checklist).

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RELIABILITY OF THE DRIVER A METHOD OF DRIVER MODELLING FOR PREVENTION OF DRIVER FAILURE

1. Introduction

As in other technical areas the human operator plays an important role as initiator of accidents in traffic on the public road. Even if accidents are starting from a deviation from the normal and usual course, whereas of course these deviations can have technical reasons (e.g. a breake down of traffic lights, insufficient tire pressure), in most cases the human operator is the main cause of accidents (estimations are speeking in an order of magnitude of >95%). This observation may not be surprising, as the driver actively involved in the traffic system in nearly all cases would have been able to avoid the accident either by correct reaction or by correct precausious behaviour in the phase before the accident. In this connection the question arises if an exact knowledge of the typical human lapse could give a contribution to the aim to avoid this in advance by technical, organizational or training measures.

2. Definitions and fundamentals

If limits of acceptance given by the system are exceeded, this fact can be designated generally as human error or more exactly as wrong action. The task of the driver can be defined as such: To move an object from starting point A to aiming point B without any contact to the curb, stationary or moving objects (= other trafic participants) on the road, such contacts can be assigned as primary errors. Traffic regulations as e.g. speed limits, prohibition of turning etc. should guarantee to avoid these primary errors. To ignor such regulations can be categorized as secundary errors.

As certain errors would not arise in any case under given conditions, the human error is to be defined by the means of probability:

> **The human error is the probability (Human Error Probability = HEP) to do an action out-of-tolerance during the observation period.**

Mathematically the human error can be quantified by the relative frequency while the number of incorrectly accomplished tasks is related to the number of accomplished tasks:

$$\text{HEP} = \frac{\text{number of incorrectly accomplished tasks}}{\text{number of accomplished tasks}}$$

The human reliability is defined as the mathematical complement to the error probability:

The human reliability (HRP) is the probability of successful performance of human activities for either a reliable or an available system.

$$HRP = 1 - HEP$$

The fundamental problem of these definitions lies on the one hand in the determination of the number of performed tasks (in this connection it should be considered that driving is a continous task, which can be described in many regards by means of control theory) and on the other hand in the observability of the lapsus itselfe. Fig. 1 shows the basic structure of every man-machine-system, which can be applied to the task of the driver: The driver transfers the information needed for the driving task, which he transforms into adequate movements of control elements - turning the steering wheel, changing from accelerator to brake or clutch , etc.. The vehicle will now perform the desired movements on the road. The driver constantly observes this result to compare with his task. Recognising any deviations he deduces again changes in the position of control elements. Additionally to this feed back of the result the driver uses directly the proprioceptive feed back of the position and forces of the control elements and further feed backs from the vehicle (e.g. the engine sound). In principle there exist two locations in this interaction structure where human errors can be observed:

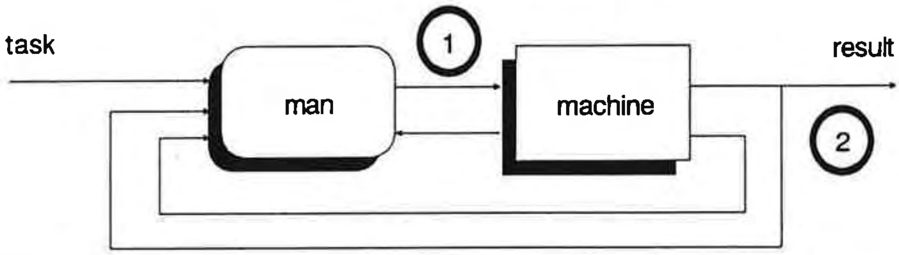

Fig. 1: Possible observation points within the structure of the man-machine-system

1. *directly by observing the human action*; this is possible by observing the positions of the control elements. But, in order to detect errors in the meaning described obove the knowledge of the "correct" movement of the control element had been necessary. If this would be known in every situation, a completely automatic driving realized by technical means could be possible. Except in artifical research situations (e.g. experiments in driving simulators) this observation location is excluded in practical cases.

2. *indirectly on the result.* In this case the deviation of the car from the correct course respectively from the correct velocity is specified as an error. This location of observation also gives reasons for difficulties during the practical judgement of errors, which are given by the impossibility to determine the correct nominal course in any situation. But, the accident goes unmistakebly beyond the bounds of acceptence. Therefore accident research is an essential resource for the human error research. Furthermore today the observation of "nearby accidents" or even nonspectacular driving errors (see the contribution of Fastenmeier and Gstalter in this booklet) is getting more and more important.

Irrespective of the described problems of observation there exist basicly two possibilities to classify human errors. By separating the exact conditions of the error and by asking "Where", "How", and "When" the so-called *event orientated classification* is created. The usual accident statistic is one form of such a classification. Fig. 2 shows as an example the relative accident frequency in the Federal Republic of Germany after the ADAC-accident-statistic of 1991. This statistic points out that the best potential of success lies in the categories "ignoring the right of way", "excessive speed", and "wrong turning", but without knowledge of the reasons for the observed behaviour measures for improuvement can not be derivated effectively. This serves the *cause orientated classification* of human error, which asks for the "Why" of the wrong behaviour.

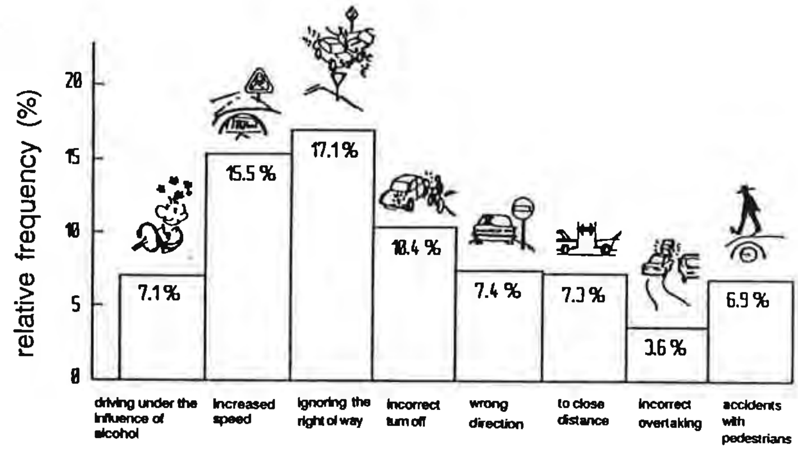

Fig. 2: Relative accident frequency of different driver errors according to the ADAC statistics (1991) as an example for "event orientated classification"

3. Causes for human errors

There exist different systems of categorization, by which the causes of human errors are systematized. In Fig. 3 a synopsis of well known classification schemes is given, developed by Hacker (1997), Norman (1986), and Rasmussen (1981). In every case the human information processing model can be seen as a basis which consists of seriell connected boxes, "sensory perception", "information processing", and "motor processing", which are additionally provided with the boxes "internal connecting feedbacks."

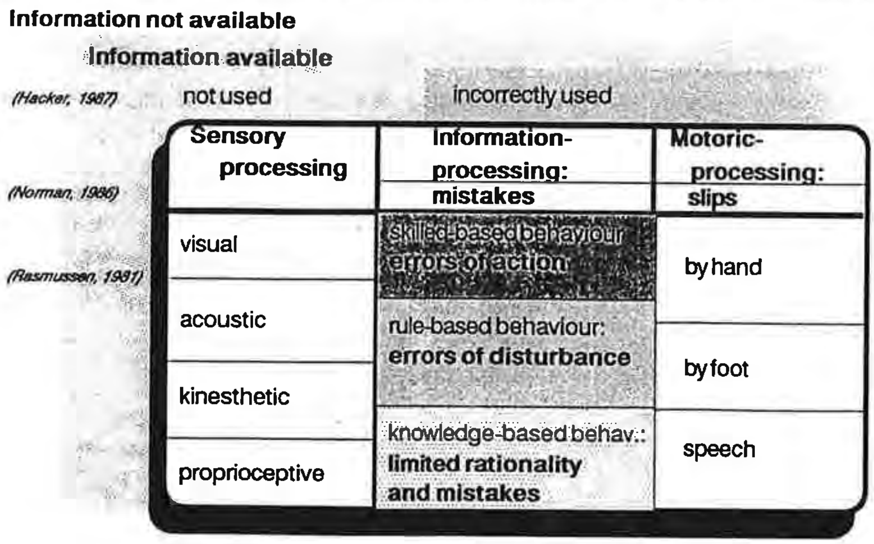

Fig. 3: Schedule of cause orientated classifications of human error

The categorization of Hacker (1987) proceeds on the fact that in a given case the information, necessary for action, is *not available*. Fig. 4 shows by an example that such effects occure very often in the daily traffic practice. Hidden obstacles can be objects in the surrounding area, the car itselfe (e.g. hidden by the left respectively right A-column) or passengers. The possibility of errors is increased by the fact, that the human eye is only able to see clearly within a viewing range of 2° - 3°, and therefore information can be perceived only by glancing directly at the information source. If the glance is averted, the human organism proceedes on the assumption that meanwhile, based on individual experience, the process is following the "normal pattern" expected according to the first glance and impression.

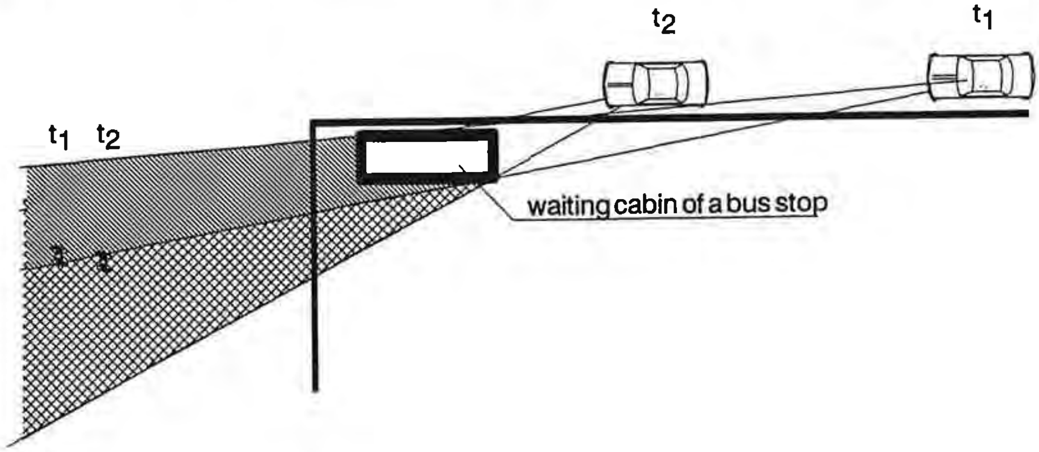

Fig 4: Hiding effect. Here: The pedestrian (left) crossing the road is hidden from the view of the driver by a bus stop waiting cabin.

The area of *utilisation* of information is devided by Norman (1991, 1986) into mistakes and slips. By *mistakes* errors are ment while generating the intention of an action and by *slips*, errors while carrying out an action. The former can be assigned to "information processing", the latter to "motor processing".

The three level model of Rasmussen (1981) is concerned with the information processing and considers different levels of skilledness of the driver. On the lowest level of skilledness are the peak cognitive processes, which are characterized by weighing up and deciding on different alternatives. On this so-called *level of knowledge based beaviour*, possibilities of error are characterized by limited rationality and genuin mistakes. Especially on this level the limited capacity of information processing by the working (= short term) memory of 7 ± 2 chunks (Miller, 1956) is of great importance. Getting more and more familiar with the problem, more and more comprehensive "chunks" are created, which now appear as complex rules in the so-called *rule based behaviour* and select, by triggering stimulus configuration, the applicable corresponding action. Errors on this level can be indicated as errors of disturbance or description. In the case of peak skilldness no concious concern of problems takes place at all, on the contrary, the action is carried out automatically. Here the typical errors are the so-called "stereotype errors" which means "act like allways (before)" allthough the inducing situation has allready changed. Such errors are called "errors of action".

4. Human Errors performing the drivers tasks

Especially the model of Rasmussen is a good basis to compare the requirements of the driving task with the level of human information processing. Fig. 5 shows an illustration of the partial tasks by which the driving task is composed of (after Bernotat, 1970; Kelley, 1968, and Johannson, 1976). During the *navigation task* the special way between the starting point and the destination point is selected. From this the course and the average velocity is derivated. This data is the task of the below following level of task, the so-called *guidance task*. On this guidance level, depending on the actual traffic situation, a nominal course is tracked into the visual recieved traffic scene, which, according to a speed profile, created also on this level, is to be patroled. On the next lower level, the *stabilization task,* these values are transfered into reality by the machine i.e. the vehicle. So on this level the control elements are activated. The modelling of man by the methods of control theory (e.g. Mc. Ruer et al. 1965) generally refer to this level of task. The result created by the machine has to match at all times all levels of the driving task. It is an interesting fact, that, in case of impossibility to perform the task on the level of stabilization, a change to the next higher level i.e. the guidance will be initiated. For example, the experience of a too extreme lateral acceleration leads to a genaral reduction of speed level on the corresponding road section. In a similar manner road blocking on the level of guidance, which prohibits a progress in the desired way, means a change in the navigation task: a new way i.e. a diversion must be found.

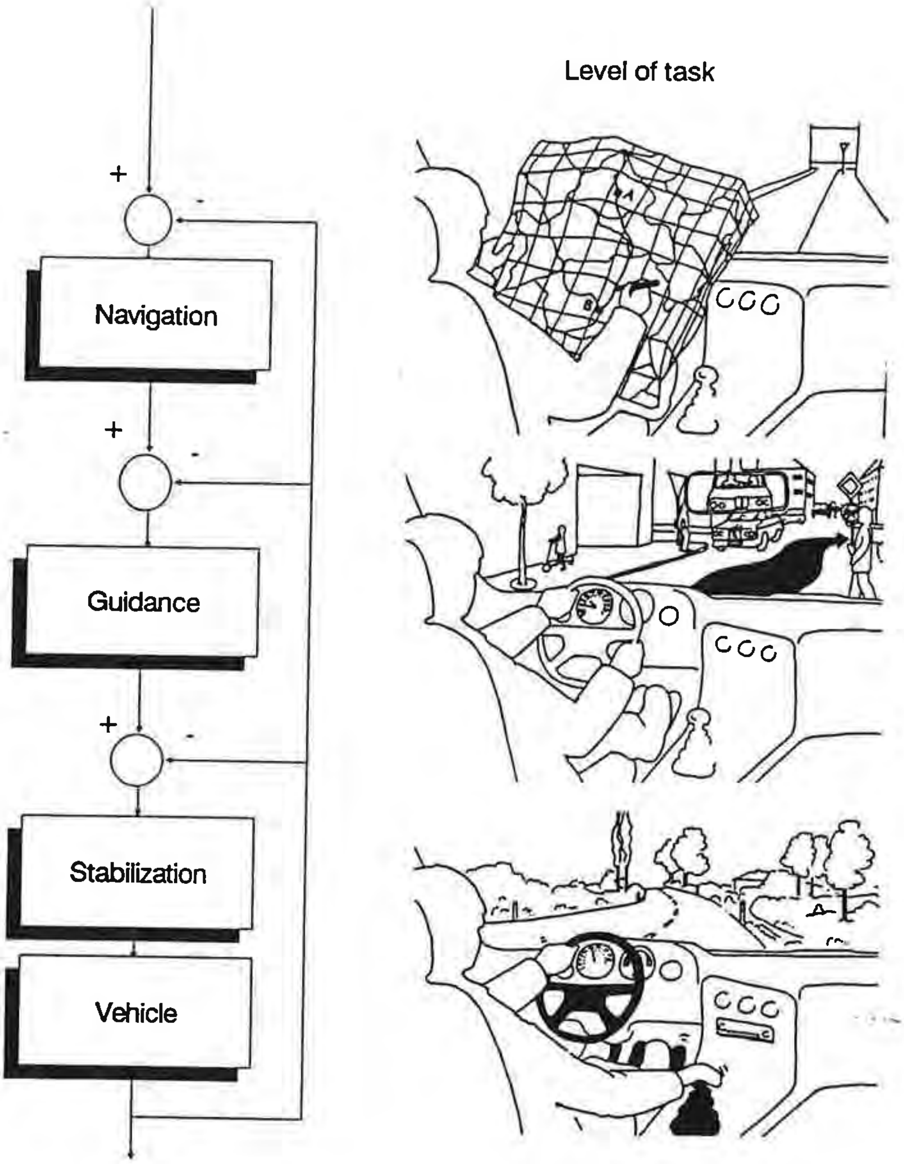

Fig. 5: The hierarchical encapsulated partial tasks "navigation", "guidance", and "stabilization" of the total driving task

Hale et al. (1990) juxtaposed the described levels of the driving task and the levels of cognitive information processing by specific examples (see tab. 1). It is very important, that on the one hand, depending on the level of processing, different time periods are necessary; and on the other hand, on the side of the task levels, only limited time periods depending on the situation are available. It can easily be understood, that a dangerous situation arises, when the necessary processing time is longer than the available time.

	Time needed	Planning (Navigation)	Manoeuvre (Guidance)	Control (Stabilization)
Time availible		sec -(min)	sec	ms
Knowledge	min-h	Navigation in strange town	Controlling a skid on icy roads	Learner on first lesson
Rule	sec	Coice between familiar routes	Passing other cars	Driving an unfamiliar car
Skill	ms	Home/work travel	Negotiation familiar junctions	Roadholding round corners

Table 1:Juxtaposition of the levels of cognitive information processing after Rasmussen and the different levels of the driving task. (after Hale et al., 1990)

As already described modelling of the driver was carried out especially on the stabilization level. Significant and promising beginnings of modelling of the guidance task are not known as jet, this is a shortcomming, since on this level most of the errors occure. This is important, as nowadays by the successively improved vehicles hardly any errors on the level of stabilization occure. Errors assigned to this level by superficial consideration have often occured already on the level of guidance (e.g. "deviation from the road driving curves" often is assingned to drivers error - "loss of control of the car"; in reality this error occured on the level of guidance since the speed chosen was too high in view of the situation). In the following, a beginning of a drivers modelling is proposed and explained giving some examples how a gain of knowledge can be principially achieved by it.

The basis of the performance of the guidance task is the creation of trajectory between the center of the own car and the perspective vanishing point of the observed road (see fig. 6). Not in every case it is possible to see this vanishing point directly. The human sensory perception of special perspective interpretation helps to interprete realistically mental extropolation of the left and right side of the road boundary, which improves by increasing drivers experience (see fig. 7). This trajectory has generally to be changed depending on the traffic situation. Fig. 8 shows as an example the deflection by a stationary obstacle. As illustrated by fig. 9 the situation becomes already more complex, if an obstacle is moved in the same direction and if additionally an other car is passing on the opposite road side. In this case the trajectory not only must be deflected appropriately but also in a complex interaction of the different influences including the time-dependance.

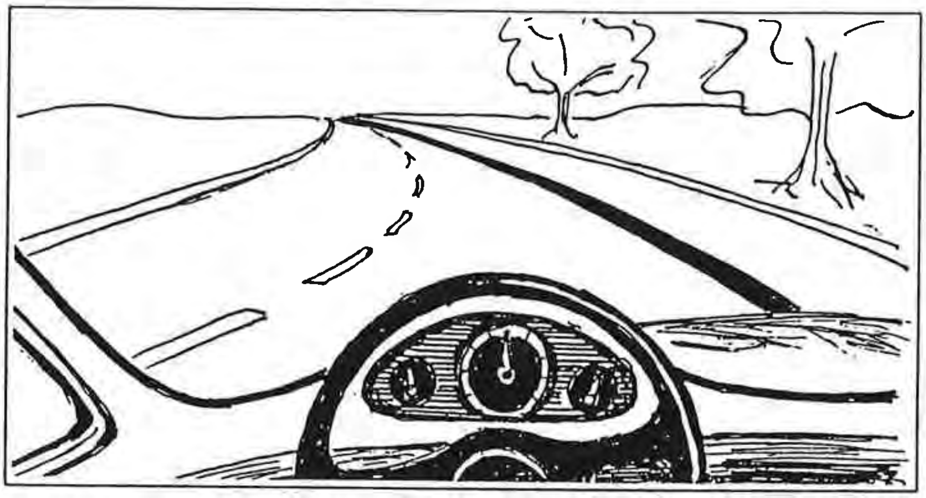

Fig. 6: Trajectory between the center of the drivers car and the vanishing point on the horizon mentally created by the driver as basis for the performance of the guidance task

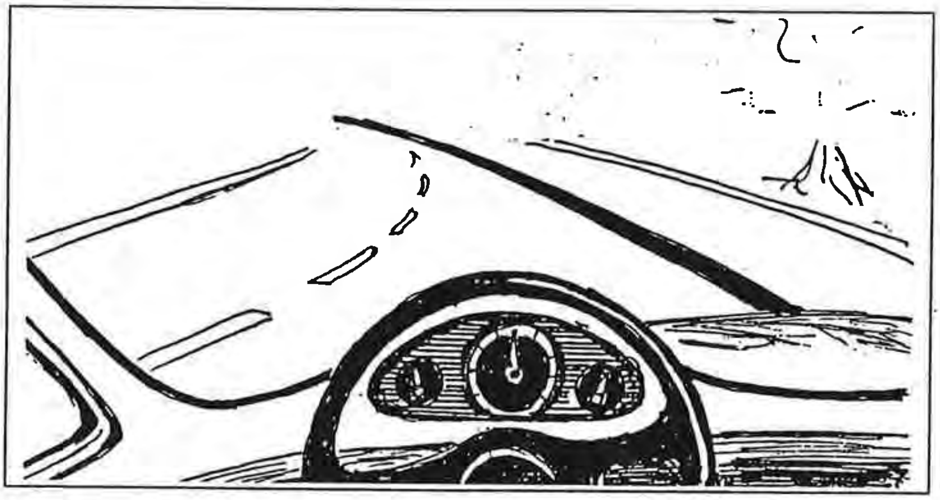

Fig. 7: Creation of the trajectory under the condition of reduced visibility

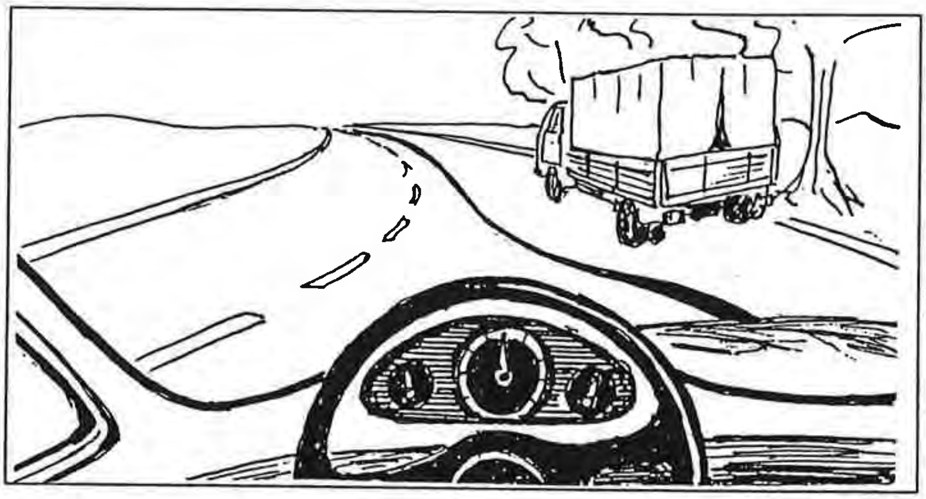

Fig. 8: Deflection of the trajectory by a stationary obstacle

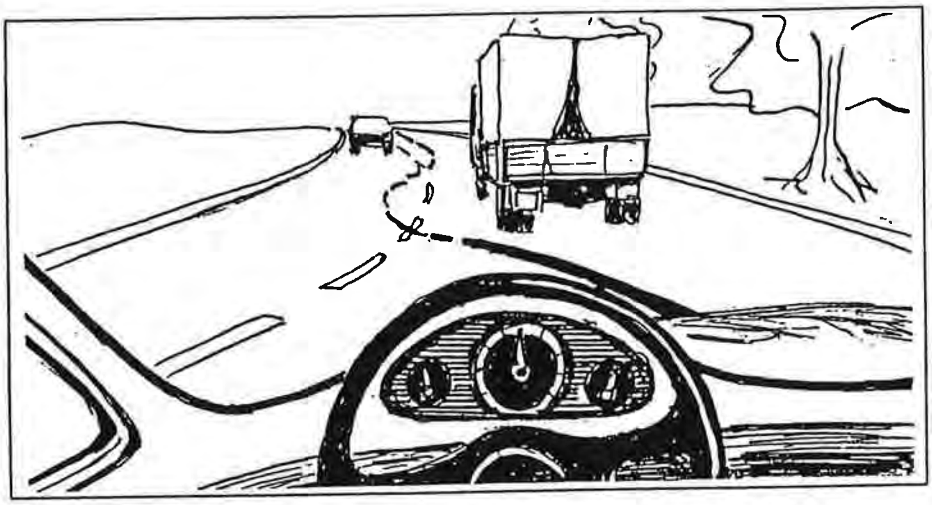

Fig. 9: Illustration of the dynamic deflection of the trajectory by moving trafic participants

Simultaneously to the creation of the particular trajectory a corresponding speed profile must be generated. In the flow diagram of fig. 10 this connection is illustrated in the form of partial tasks (represented by rectangulars) and decisions (represented by diamonds). It can be seen, that the guidance task is put up between navigation and stabilization. The output of the navigation task and simultaneously the input of the guidance task is the particular locus and the actual and nominal time. From the "locus" finally the nominal course x_{nom} and from the actual and nominal time the nominal speed v_{nom} is derivated. Depending on the estimated visual range and the expected lateral acceleration the nominal speed is - except for the influence of speed limits - modified. Further modifications arise by obstacles, other traffic participants, crossings and junctions. These influences can also be represented by the here used technique of flow diagram; however, they are very comlex structures, which cannot be demonstrated in this context (see Schemmerer, 1993). But already fig .10 makes it possible to demonstrate the basic errors of the driver on the level of guidance, which occure over and over again in the same manner during the mentioned detailed analysis. Two basic causes of error can be observed:

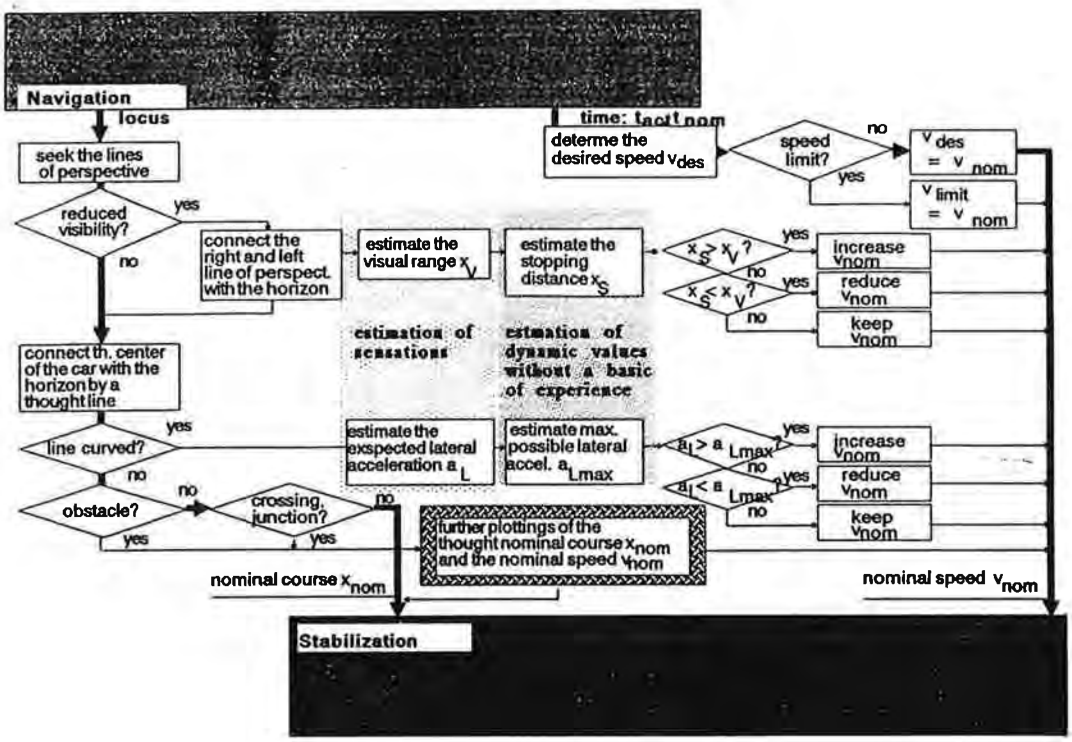

Fig. 10: Modelling of "internal models" (nominal condition) of the driver necessary to perform the driving task

1. Simplifications

Under the point of view of road safety - the necessary widespread network in the decribed nominal behaviour as shown in fig .10 - is not realized in the given real case. That means for example that generally the transverse branches "estimate the visual range" respectively "estimate the stopping distance" remain untreated. This is quite understandable where the driver is concerned, since on the basis of fundamental mechanisms of perception and of experience a good estimation of the vanishing point of the road boundaries is possible and consequently the trajectory can be tracked reliably in their basic form. By the way, this could be a simple explanation for the strange behaviour of many drivers, in situations of reduced sight conditions, after the event. Such simplifications often show up when describing treatment of complex trafic situations: For example frequently a crossing is blocked, because the driver only realizes the branche "reduce distance to the car ahead" but does not observe the side branche "in case of a crossing......".

2. Estimation on an uncertain basis

Many a decision in the daily traffic must be made on the basis of experience data. Fig 10 shows as an example "estimate stopping distance" and "estimate maximum possible lateral acceleration". These values can be estimated only with sufficient accuracy if the driver has built up a large amount of exprience following manouvres like repeated breaking respectively repeated taking and cutting of bends and curves on the road, reaching his physical limits and even exceeding these. The occasional exceeding of these limits combined with a shock as it occures during normal driving practice as well as a never repeated special cours in driver training will not be enough. Safety can only be achieved, if, by technical means, it is ensured that driving occures on a level secured by own experience. As a measure for that, the author (Bubb, 1980, 1991, Bubb and Reichard 1992) proposed the indication of the stopping distance respectively of a safe distance by a contact analogue Head-Up-Display A further measure can be the Active Control Element (Bolte, 1992). As the already mentioned analysis shows, there is a great number of further situations which make actions necessary on the basis of such uncertain estimations. In this context we might just mention overtaking or approaching a crossing where the driver has to give right of way.
In future, further even more detailed analyses of the guidance task extended by the methods of Fuzzy-Control-Theory will give indications for technical measures of error prevention as well as a solid base for driver education.

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IDENTIFICATION AND PRIORITISATION ON ROAD SAFETY PROGRAMMING

Generally, lack of the integrated view of road accident, give us the difficulty on the identification and priority setting on road programming. We need the integrated analysis on road accident; process, causes, impacts and elements of transport system related.

If the accident processes be analysed deeply and integrated in the road accident model, we will find that the interrelation between driver, vehicle and road are very important in the accident. Neglige these aspects in the process design or driving, it may be the causes of the accident. The characteristic of the interrelationsship may be for example:

Relationship	Subject to
<u>Driver - Vehicle</u>:	
1. Communication	Information panel, ability to react, together and lighting
2. Adaption	Ergonomic pilotage and wagon
3. Protection	Vehicle interior, safety facilities
<u>Driver - Road Environment</u>:	
1. Communication	Design and position of road signal, lighting ect.
2. Adaption	Color of road signal
3. Protection	Physical design of road and its environment
<u>Vehicle - Road</u>:	
1. Compatibility	Standardisation etc.
2. etc.	

The above analysis and modelling can guide the programmer to define the specific programs on road safety. The objectives of the programs can be:

1. Minimize the technical error of the vehicle, road and driver
2. Minimize the risk of accident
3. Minimize the risk of the post accident - rescue programs.

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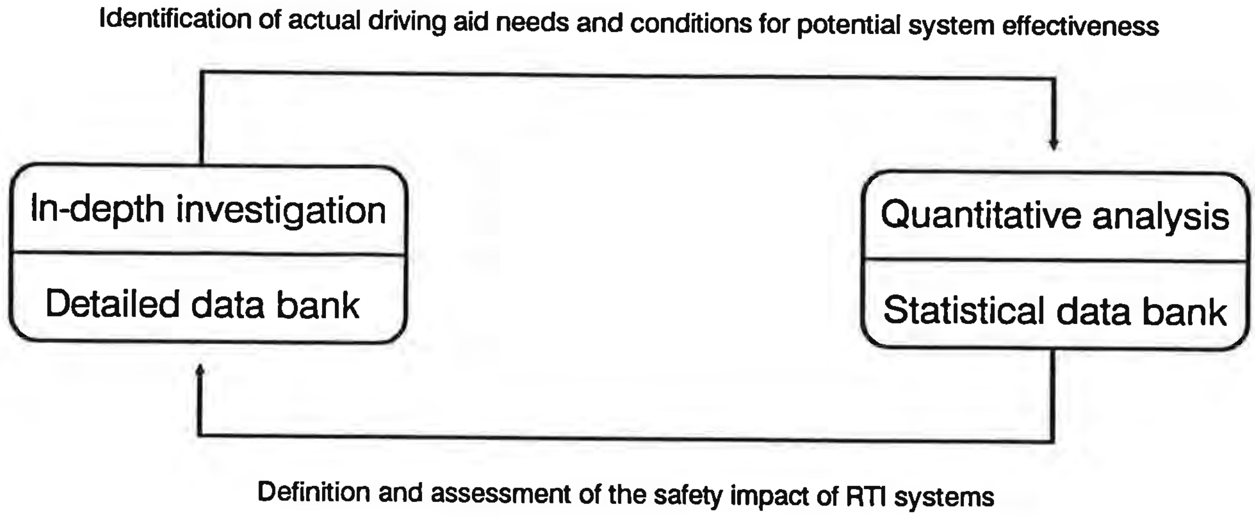
A QUALITATIVE EVALUATION OF RTI DEMONSTRATORS USING IN-DEPTH ACCIDENT ANALYSIS AND OPINION INVESTIGATION

I - INTRODUCTION : PREVIOUS RESEARCH WORK

The present study follows a trend in research carried out over several years by the French Road Safety Institute (INRETS), on the *a priori* safety assessment of driving aids.

In spite of the biases necessarily associated with this type of method, insofar as we evaluate systems that do not yet exist, in situations where they are therefore not present, the advantage of an *a priori* evaluation is that it leaves room for ergonomic conception: in other terms, we seek to define in a prospective way, before these devices are actually manufactured, how the aids are to adapt to road situations and the functioning modes of operators who will have to use them ; rather than wait for problems to occur before they can actually be corrected. Correction ergonomy is, of course, an essential factor but one that is better suited to the final stage of this type of research dynamics.

The work performed in collaboration with the Laboratory of Driving Psychology, the Department for Accident Research and Evaluation and the INRETS Accident Mechanism Department, is in keeping with a dialectic that consists of using the respective advantages and mutual benefits of quantitative and in-depth road accident analysis.



<u>Research trend dynamics</u>

The first stage of the work (Van Elslande & Malaterre, 1987) was qualitative, and dealt with the identification of actual driving aid needs, based on a detailed analysis of accident data collected on the spot.

In the second stage (Fontaine et al, 1989), the importance of these needs for drivers involved in accidents in France was evaluated quantitatively, using a nationally representative sample of police accident reports.

A third stage of work (Malaterre et al, 1992) consisted of estimating, still in a statistical context, the appropriateness of the projected aid functions (as they could be defined from the PROMETHEUS documentation) with identified driver needs. It also entailed drawing up an assessment of the relative ability of the functions to prevent specific types of accidents, and to what extent.

As these latter assessments are based on assumptions for the optimal use of aids by drivers, one of the last stages of this research (Van Elslande & Nachtergaële, 1992, 1993a) was again based on in-depth accident data, so as to identify the different parameters in the driving context, in an accident-causing situation, likely to have a negative influence on the way drivers assimilate the information provided by these devices (e.g. psycho-physiological status, distraction, mental load, conflicting expectations, pursuing various objectives at one and the same time, etc.).

By revealing these potential limitations to the assimilation of this information, we were able to put forward certain specifications that could be used to adapt these aids to the operating modes adopted by drivers when faced with a problematic situation and to the types of task in which these
difficulties are encountered.

II - OBJECTIVES

The progress in work performed by car manufacturers within the framework of PROMETHEUS (1990, 1991) has enabled them to draw up specifications for aid demonstrators (a demonstrator can be described as nearly a prototype), by defining in greater depth the functions they perform and the various device specifications (e.g. detection range, operating capacity, etc.).

Thus, by taking a step further forward in the preliminary research logic, we sought to evaluate the potential effectiveness of two of these demonstrators designed primarily to promote safety: the CED4 (for "Common European Demonstrator n°4") and the CED5*.
It should be noted that the specifications considered for this estimationprovide only a picture that corresponds to a given time. The projects are progressing rapidly (Kemeny, 1992 ; Ducarre et al, 1993 ; for example) what raises the problem of how long estimates remain valid.

So, using specifications drawn up in 1990 and 1991, a quantative study showing accident reports (Malaterre & Fontaine, 1992) has enabled us to define the safety implications of the CED4 and the CED5 for those involved in the accidents that occur each year in France.

This is also how the in-depth analysis which is now presented originated.

* The general specifications of both of these devices taken into consideration for the present study are given in annexe.

The aim of this study, which is essentially qualitative, consists of defining and further investigating the a priori evaluation of the safety impact of these driving aid systems, using an in-depth study of accident cases that correspond to the scope of application of the CED4 and CED5. The main objective was to obtain a detailed description of the information needed by users to enable them to better manage the critical situation facing them, as these needs are revealed when analysing the collected accident cases. It also entailed taking into consideration the opinions, interests and expectations of accidented drivers, with regard to the proposed aids.

These different points were investigated so as to obtain a definition of some suitable driver-aid interface specifications.

II - METHOD

To reach these various work objectives, research was based on the one hand on an In-Depth Accident Study (EDA) that consisted of the collection of real time data by a multidisciplinary team (psychologist, road and vehicle technician) on the scene of the accident. A sample of 18 accident cases was collected. These corresponded to the range covered by one or another of the functions of the two demonstrators under consideration. This research was moreover based on a supplementary opinion poll (18 interviews) on drivers in less recent accidents.

The data collected was analysed to illustrate:

1)- accident situations covered by the aid functions under consideration, their main characteristics, and the failures that can be identified in the operating mode of the drivers involved (perception, evaluation, prediction...) and which could be compensated for by these aid functions,

2)- real and concrete driver needs for informative aids, that explain the type of information required for the user to predict the accident situation,

3)- opinions, interest shown and expectations of accidented drivers with regard to the systems proposed :
- the information transmission modes they see as best suited to the driving task,
- the conditions in which the information will or will not be considered,
- the acceptability of automatic aid systems and the system operating modes on which they will base,
- the negative effects envisaged,
- together with their interest in acquiring such systems and how much they are prepared to spend on them,

4)- an *a priori* assessment of how effective the aid functions would be, in terms of safety, when applied to the driving task. As this evaluation required us to take into account the kinematic parameters reconstructed using collected data, it was performed only for the 18 accidents examined within the EDA framework.

*III - MAIN RESULTS**

Drivers in our sample are interested essentially in information-based assistance that would enable them to compensate for some of their "failures" (whether perceptive, evaluative or predictive), and at the same time, retain the control and command over the situations and the actions to be performed.

* For further details, cf Van Elslande & Nachtergaële (1993b).

It is because of this reluctance to relinquish management of the driving activity that most of the drivers in question were to some extent reticent, or even totally opposed to automatic aid systems, particularly in heavy traffic conditions. In these situations, drivers could only see themselves using them as a last resort, in conjunction with an informative aid, and only when the urgency of the situation necessitates rapid and appropriate action that the user himself would not be able to perform as well as the automatic device.
For most of these users, automatic aid systems would therefore be used only to solve situations of extreme urgency that drivers find difficult to manage themselves.

However, drivers' interest in informative aids and their use in situ will depend upon the ability of the systems to respond to driver needs and expectations. To give only a brief indication, it would appear essential for these systems to be able to filter all the driving situation data and only provide the user with information that is both useful and relevant if a probable accident is to be avoided. Drivers are in fact strongly opposed to any information with a normative content that is felt to be more of a constraint and an additional load than an "aid", in that it only repeats "what they already know", would only prove to be a further nuisance and would increase the volume of information to be processed.
The informative aid should therefore be used only to warn the user of a real immediate danger, whether it results from a road-related difficulty or interaction with another vehicle, that may modify previous driving conditions and requires the driver to re-adapt his strategy.
One of the major difficulties that designers of informative systems will have to resolve if actual driver needs are to be met, is the way in which synthetic messages are presented. These messages must include vital situational information that enables the driver to identify the specific nature of the risk situation and its location in relation to their approach, and so produce the appropriate response in terms of both the attention to be focused and the preventive manoeuvres to be performed.

In short, and despite the difficulty of meeting driver needs to the full, this study has clearly shown that the safety effectiveness of aids could only *a priori* be obtained if the systems respond to the expectations expressed by drivers. These expectations are both specific, e.g. the timeliness (neither too early nor too late: at the time the driver has to act), usefulness (need to filter the relevant information) and validity (neither false alarm nor omission) of the messages provided, and more general, e.g. system reliability (no breakdows). All these specifications ensure credibility and optimal usage of the devices.

IV - CONCLUSION

On an optimistic assumption that aids are "perfectly" adapted to driver needs and expectations, most of the accidents studied within the context of the in-depth analysis could potentially have been avoided had an aid been used. This possible overall effectiveness is provided essentially by aids in informative mode, as they are well accepted by users and will consequently be used by a considerable number of drivers. However, although they may, in principle, correct almost all the problems being studied (only a few of the accidents were dynamically unavoidable), the *a priori* evaluation of the impact of automatic aids produces a much lower level of effectiveness as users in our sample are extremely reticent to use them and that, always assuming these devices will be activated at the discretion of the driver, they would probably not have been used to the full.

ACKNOWLEDGEMENT

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ANNEXE

CED4, or "COPDRIVE", is a system aimed at promoting the co-operative driving of interdependant cars, and based on an active transmission of information between vehicles and between the roadside and the vehicle.

The system integrates different functions, notably :

- "Medium Range Pre-information" (MRP), which operates on the basis of roadside beacons that transmit information to the driver, indicating: a recommended speed, warning of poor visibility, road surface variations, heavy traffic and other hazardous conditions.
- "Intelligent Cruise Control" (ICC), aimed primarily at regulating inter-vehicle gaps, either by informing the driver or by automatically regulating car speed.
- "Intelligent Manoeuvring and Control" (IMC), that provides the user with information on the practicability of an intended manoeuvre (e.g. lane changes and overtaking), or can automatically prevent this manoeuvre.

CED5, or "Autonomous Intelligent Cruise Control", is a less sophisticated system, and is restricted to the cruise control function. Its advantage lies in its autonomy in that it is based on an optical system and that other vehicles are not required to carry additional equipment. Because of this, there are also certain limitations : for example, it detects only on straight sections and takes only moving objects into account (does not detect stationnary obstacles).

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STATISTICAL AND IN-DEPTH ANALYSIS OF ACCIDENTS

Report - working group D

Whatever the technical system, and this includes road traffic, accident analysis is thought to be an indispensable tool for the improvement of safety.

This is not, however, necessarily obvious as it refers to an event with a sequence that has already been completed when data is collected. It is not therefore sufficient to have available data, it is also necessary to have the data we can work with.

Just counting the number of accidents does not suffice, as for many of these accidents, although they involve bodily injury, no police report is drawn up. This situation may however vary, particularly with regard to those involved and the number and seriousness of their injuries.

The reliability of information collected when an accident is subject to routine police investigation depends to a great extent on the type of data involved. Certain factual variables are easily detectable e.g. date, when other ones are not always reliable, e.g.- in all countries - location.

To go deeper into understanding the relevant mechanisms requires each case to be analysed individually. This is done first by returning to the site, which enables us to understand the malfunctions by analysing infrastructure design and the behaviour observed.

When this operating mode is not sufficient, a second stage is carried out by conducting an ad hoc collection on the accident site, and setting up a technical investigation at the same time as that carried out by the emergency services and the police.

*

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Before dealing with data collection and accident analysis, the objectives and underlying models for this work should be indicated. This procedure, natural for a researcher, then enables us to understand and categorise the different types of work listed under the heading "accident analysis". Reference in this respect could be made to the speech given by Siem OPPE during the course of this conference.

There may be different types of objectives. First, accident analysis can be used to understand unsafety-related problems and thus system malfunctions. It is needed if we are to answer the essential question: "which is the best system, A or B?". This question will serve as a guideline when choosing the person to head this inquiry.

Sometimes the question is not raised in this alternative form, but is more likely to involve the direction in which the system should develop to ensure greater safety. Thus our attention, and consequently accident analysis, is no longer focused on the malfunction and the unsafety problems this reveals, but on the relevant mechanisms that have to be understood if a safer system is to be designed.

After diagnosing and planning the relevant action, the newly created situation should be evaluated to assess the progress made with regard to safety and the behaviour of those involved. This is a necessary stage if we are to gain experience and improve our knowledge, in particular that of system modifications. When following up safety measures this is obviously essential, to be able to adapt their application procedures and restrict the negative effects.

The system may be analysed at the different stages to which the different levels of understanding and action may correspond. There are therefore different levels of accident analysis that depend, in particular, on the degree of data aggregation. This therefore influences the choice of data source for the accidents used:
- accident files, already available on a computer
- police reports, that require an analysis of existing documents
- in-depth investigation, when the routine data collection is insufficient.

*

* *

All the papers presented during this session refer, each in their own way, to these different questions and show how they are dealt with for a specific problem.

Two papers consider aggregated data and refer specifically to the statistical aspect of accident risk with the more or less short term objective of comparing different road layouts from a safety standpoint.

The paper presented by Karin BRUNDELL-FREIJ and Lars EKMAN from the Department of Traffic Planning and Engineering of the Lünd Institute of Technology emphasises the difficulty of comparing situations using accident rates calculated in relation to exposure.

The empirical data used to illustrate their comments is the number of conflicts between cyclists and motorists at intersections in relation, more specifically, to car flow. Statistical analyses show the non-linear relationship between these two variables that may be explained by the influence of different factors, notably infrastructure. Layout characteristics are indeed significantly related to traffic level.

This data leads on to a discussion on the statistical models that are generally used, in particular, the use of linear regression to describe relationships between variables. Continuing this statistical analysis work could be a promising way of both interpreting the empirical results and examining the relevance of the use of an exposure measurement when calculating accident risks.

Work by Herbert NOWAKOWSKI of the Highway Administration of the Federal Ministry of Economical Affairs in Vienna also deals with a level of aggregated data analyses on unsafety. In this instance, the aim is to identify road sections where the road surface is in need of repair. The road is indeed resurfaced almost every ten years, but this work is programmed according to the urgency of the work required. The epidemiological approach used in this work compares skid coefficients and rut depths in the road with accidents. Data was collected on a large scale using high capacity measurement devices over several thousand kilometres of motorway throughout Austria.

Statistical analyses show the links that exist between the various geometrical road characteristics. It also makes it possible to reveal the ability of the driver to adapt, as particularly unfavourable conditions do not always give rise to high accident risk.

*

* *

Other work is based on an analysis of police accident reports. The methods of analysis clearly raise the question of the models referred to and, in particular, those used to describe how the human operator functions.

Wolfgang BERGER from the Traffic Institute of the University of Bodenkultur in Vienna presents his experience in the context of black spots. He emphasises the various levels of analysis. Statistical analysis is used to focus attention on locations with the highest risk rate and so reorganise these areas as effectively as possible. Empirical work dealt with more than one hundred black spots for which the accident reports had been analysed and completed by an analysis of traffic organisation and on-the-spot behavioural observation.

The analysis of reports refers to knowledge regarding the ability of operators to acquire and process information. In most cases, the accident analysis reveals a "failure" on the part of users in the course of these processes. This then goes on to reveal the informational inadequacies of the various sites before being able to remedy them.

This work shows that the analysis of information sequences required by the individual sometimes produces unexpected results on the cause of these accidents.

Piet NOORDZIJ from the Institute for Road Safety Research (SWOV) in Holland, presents his work on accident analysis using police reports.

The accident data base is in some instances limited. Firstly it is not exhaustive, as all the accidents are not recorded. This apart, the recording contains a considerable amount of information that is not always relevant and above all makes it impossible to rediscover the accident sequence dynamic. Numerous attempts in this direction have proved unsuccessful.

This consideration therefore results in working directly on accident reports and adapting the information available. Work is backed up by two different experiments : one involves accidents that occurred on roads with a speed limit of 80 km/h and the other accidents that involve bicycles. Work consisted of revealing each accident scenario and then categorising all the cases to present a review of the safety problems specific to each of these two situations.

The main conclusions of this work are to reveal the need to modify report coding by replacing useless or unreliable information by other more relevant information and formalising behavioural dynamics, which again requires considerable research work and co-ordination with other work.

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When the information usually collected on the site is not sufficient, it becomes necessary to design a data collection specific to the accident site.

Yves GIRARD from the Institut National de Recherches sur les Transports et la Sécurité (INRETS) in Salon-de-Provence, France, presents the experiment conducted by the Department of Accident Mechanism Analysis with regard to in-depth investigation. This work was performed for research purposes and to reveal the mechanisms involved in the accident sequence. Data is collected by a multi-disciplinary team, first on the accident site by investigating the accident sequence. A second collection is performed at a later date and involves more in-depth questioning. By using a model designed specifically for this purpose, a kinematic reconstruction is used to obtain at each instant the respective position, speed and acceleration of each of those involved. During the analytical phase the sequence is broken down into different phases that can then be studied separately to reveal the relevant mechanisms and how they are linked.

An accident example is presented to show this research process at work and the advantage of integrating in-depth investigation into a complete research programme to compare other forms of analysis involving accidents, the road, vehicles and behaviour.

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The discussion that took place during this session showed the importance of correctly defining the analytical objective and the models to be used as a reference. All these presentations deal with this aspect, that opens the way to any analytical work. This is well worth remembering as all too often, researchers are asked to study accidents in cases where there is thought to be a specific safety problem.

The action procedure comprises various phases: diagnostic and revealing problems, action planning, setting up, evaluation and follow-up. Accident analysis should obviously be used in the first and last stages of this process.

Analyses can be performed on very different overall levels ranging from a clinical approach to highly aggregated processing. The resources used therefore depend on the level of accident analysis.

The question of the reliability and relevance of data is therefore significant for an event analysed a posteriori. The same applies to the choice of variables and coding. Discussions showed the advantages of co-operating and exchanging analytical models and formalising information.

Accident analysis is not a tool to be considered in isolation in a research process. This aspect is implicitly present in most of the papers presented. It should therefore be co-ordinated with other tools such as conflicts which reveal certain malfunctions, in-situ and laboratory behavioural observations, which include simulators, functional analyses of the road system, risk exposure analysis...

In other words, accident analysis in its many different forms has its place - no more but no less - in the overall process of research aimed at improving safety. This was clearly shown in the course of the discussions that took place during the session devoted to "Statistical and in-depth analysis of the accidents".

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INFORMATION RELATED ACCIDENT COMPONENTS FOR INCREASED FREQUENCY ACCIDENT LOCATIONS

The presentation of the working-group's subject focuses mainly on "statistical" and "deep-structured analysis of accidents". I would like to concentrate mainly on the 2nd area.

In order to be able to efficiently analyse accident causes and to redevelop accident locations, a statistical processing of accident occurrences is extremely important. Extensive and actual data analysis makes the decisive identification of places possible, which are extremely dangerous in behalf of road safety and which, in extreme cases, represent increased frequency accident locations. Not only the exact locality of the accident but also the driving direction of the persons involved and the accident type give first insights on the actual accident happening at frequent accident locations.

My collegue at the Institute for traffic studies, DI Pichler and I have analysed nearly 100 such frequent accident locations in the viennese area alone, mostly crossroads. The consequent studying of the traffic accident files of the police turned out to be a major factor. It is possible to derive first evidence for accident causes from the accident sketches, but most of all from minuted statements of involved persons together with witnesses' statements. Some of the evidence found at a specific scene of accident can then be identified as being typical for this location. The local examination of the frequent accident location can then be carried out in a much more efficient way.

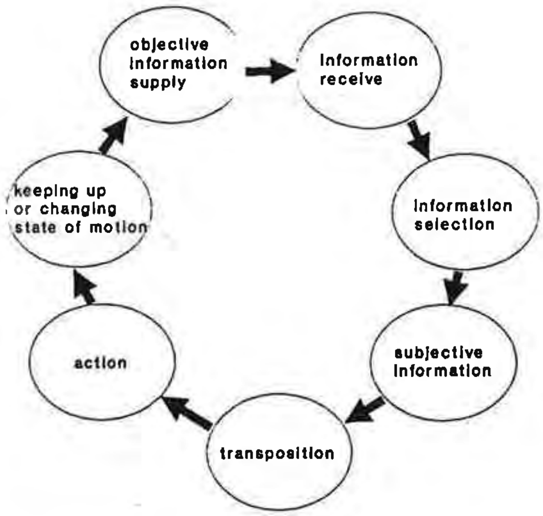
Accidents are known as the result of previous situations that at least one of the persons involved could not deal with in the appropriate way. It is our approach to work out those components that keep evoking critical situations at a location. In order to successfully redevelop a frequent accident location, one has to manage to eliminate dangerous situations from the beginning. For, whether an already dangerous situation does not have any consequences at all, whether it leads to a manageable traffic conflict or ends in an accident, whether some people are injured or even get killed, is in most cases decided by chance, especially when it comes to town traffic.

The reasons that can lead up to critical situations are manifold and to some extent of a completely different nature. They can either have vehicle-technical, road-construction-technical, environmental and/or human causes. Most of the time some of these reasons happen at the same time and influence each other either directly or indirectly.

I would now like to shortly try and describe the human being as one very important accident cause component. To express it more exactly: the human ability - or perhaps better the disability - to pick up enough information while being in road traffic and to put it into action in the right way.

How does a human being perceive? Here is a very much simplified sequence pattern of the information processing (see pict.1):

Succsession of Information



pict.1: circulation of information processing (in diagram form)

One has to deal with a permanent circulation, which happens very quickly and most of the time even unconsciously.

Out of the whole range of objective information, some data are perceived and relevant information is being selected. The remaining subjective information is translated into reality and leads to action. Depending on the type of action the state of movement either changes or not. Quite often the action is only used to continue perceiving information.

The objective information offer is constituted by:
> the traffic area and speed of one's own movement,
> one's own vehicle,
> the presence and movement of other road-users, plus
> general conditions such as lightness, weather etc.

It is obvious that the objective information which is given about a straight highway with a so to speak "laminar" course of events [comp. STOOVELAAR 1987], as described in pict.2,

pict.2: highway with little traffic at driver's eye-level

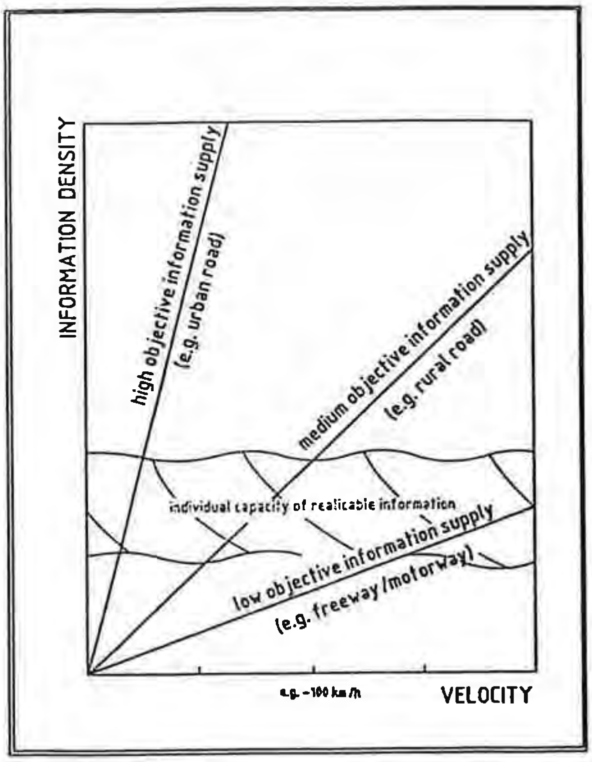
is a lot less than the information given in turbulent town traffic (see pict.3).

The perception of objectively present information depends on physical and psycological prerequisites of each indiviual and takes place essentially through four systems with the help of the sense-organs:

- visual system through the eyes,
- audio-system through the sense of hearing,
- vestibular system through the balance organs,
- mechanosomatic system either through the skin or through receptors in muscles and joints.

pict.3: "turbulent" town-area

It is not possible to give the exact amount of stimulus, which a person is able to perceive within a certain time unit. Projections drift within the orders of 10^8 to 10^{10} bit/s. The by far biggest part of the perceived information is used for carrying out different body-activities, for ex. simply for sitting straight, for standing or walking.

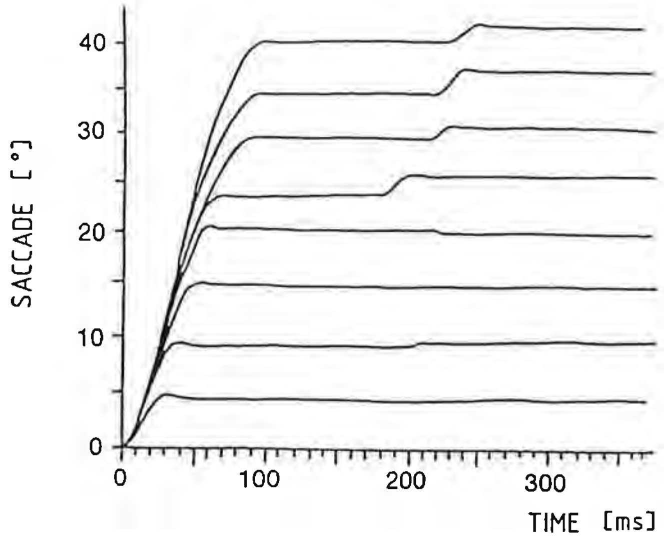


pict. 4: information density versus speed

What does that mean in practice then? This illustrates picture 4: depending on the objective information offer and a certain time at disposal an information density emerges. The time limit is mainly constituted by one's own moving-speed or the relative speed of other road-users. Different traffic situations result in different information densities, all depending on the speed. In a demanding town area limitations of perception capacities are already reached or exeeded at a low speed. This has to be seen in comparison to a ride on a highway at relatively high speed, which still leaves quite a remarkable amount of reserves.

How much information is effectively useful in road traffic? According to the latest scientific research, the eyes, the most important sense-system in road traffic, are thought of as having 40 bit/s of "psycho-physical channel-capacity" [BIRBAUMER/SCHMIDT 1992]. It concerns the maximum flow of information during complete concentration of attention. Under "normal demands" one can possibly subjectivize between 4 and 6, but not more than 8 bit/s of information which is relevant for traffic. This amount of information constitutes the basis for all actions, with the help of which a human being moves and orientates himself in traffic, which he matches to his environment and to the behavior of other traffic participants.

On top of that, the perception of information through the visual system happens with a quite considerable temporal discontinuity. It is known that a person carries out about 3 eye movements per second, while moving in road traffic [comp. for ex. COHEN 1987]. With each of these eye movements the central fixed object in the field of view changes and the picture on the retina has to be built up again. The time-requirement for the eye-rotation depends on the amplitude of the eye movement (see pict.5).



pict.5: time-requirement for the eye-rotation during the eye movement

For the development of each new picture one has to consider about 50 ms each per eye movement [comp. LACHENMAYR 1987]. So for "normal" looking-behavior it happens quite quickly that about 20% and more of the time available for information-perception are not at disposal. This normally is not realized, because the previous picture remains consistent until the next one is at disposal for the brain.

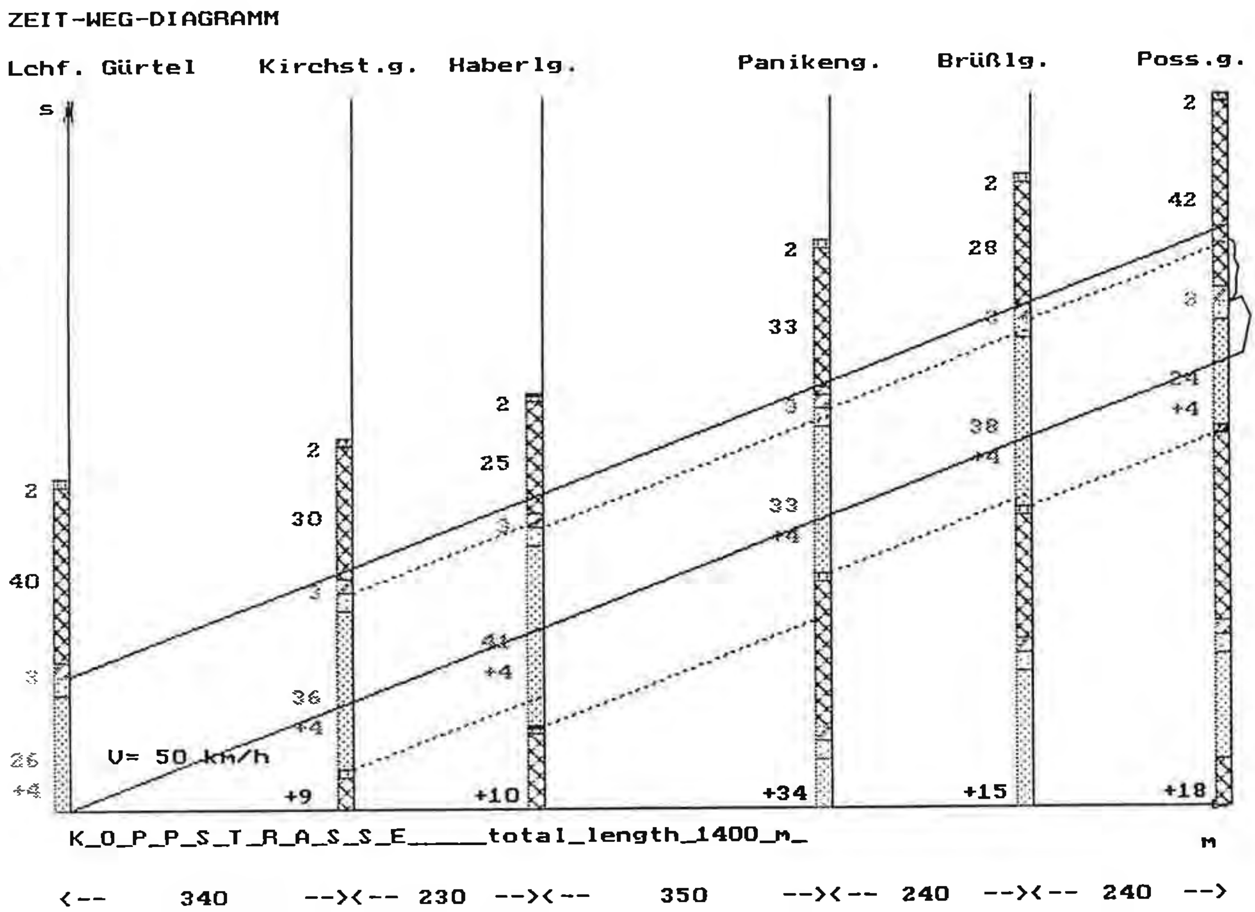
The person who is on the road, therefore has to permanently, but with temporal discontinuity, select the personally relevant stimulus out of the immense amout that influence him and he has to use this for building up his subjective state of information. This selection process is in principle also shaped by psychological components like for ex. motivation. Of great importance is also the experience in when, where and which information perception and realization (also which one is neglected or objectively wrong) has got a certain effect.

The world a person perceives very strongly depends on a certain consistency assumption. Humans basically take it for granted that an identified state is kept in its consequence until a change is noted. This is also true for the whole, very complex area of movement perception and speed estimation. Taking additionally under account the perception threshold for another person's movements one can for ex. deduct that a straight moving driver perceives, under particular circumstances, a just starting oncoming motorist turning left as standing still for as long as 2s or even longer [comp. MARX, PFLEGER, BERGER et al. 1993].

At the same time something not percived stays subjectively non-existent until the moment it is perhaps nevertheless perceived due to a controlling look done out of experience. One must therefore definitely not assume that everything which is theoretically visible is really perceived as well. The perception of movements and speeds, may it concern one's own or another person's, is never estimated in figures, but the movement is - most of the time in linear form - extrapolated. The result of this extrapolation is, if neccessary, corrected in relation to newly happening perception.

On the basis of previous perceptions there are continuously expectation attitudes being built up, which already regulate the following selection cycles or control the awareness. The higher the information density and therefore the selection pressure, the more central the area tends to be, which can be used for selecting optical information. This heightens the danger that relevant information within the periphery of the field of view is not percepted.

At practically all analysed frequent accident localities, mistakes which were subjectively not or too late realized in the perception and realization of objectve information turned out to be an extremely important component for accident causes. This has to be taken into account when one looks at all the following examples.



pict.6: Time-distance-diagram of a road network

At coordinated road networks a mislead expectation attitude turns at least sometimes out to have a share of the cause for frequent accidents at crossroads regulated by traffic lights: Pict.6 shows the coordination of a light-signal-system, which proposes a constant speed over several crossroads (50km/h).

But at the last crossroads the green-period-end is brought forward. This does not at all correspond to the until that moment formed expectation attitude of the passing-through driver: end of green period at 50 km/h. This contradiction to the expectation attitude may lead to mistakes in perception, which then makes the danger of unattentional red-lights disregarding move up.

pict.7 : Side street with no right of way but with "phenominal right of way"

Another simple example: Experience teaches that being on a straight and wide road, as shown in pict.7, quite often gives you the right of way. On the basis of the optical situation this very expectation attitude (= phenominal right of way) comes up, at least with non-local drivers. The danger that contradictory information, in this case the optically relatively unobtrusive "yield"-sign, does not last the selection process and does not at all or too late turn into subjective information, is very high.

The crossroads represented in pict.8 nearly offer a surplus of objective information. Your first glance will probably fall onto the red over-head signals. The signals for turning left are comparatively unobtrusive. At least with two accidents the drivers, according to their own statements, probably were victims of a mixing-up, namely: nonconformist selection, while advancing towards the crossroads. The over-head signals, at this moment on green, lead to the expectation attitude "clear run", the red light of the turn-left-signals had unfortuately not been perceived.

pict.8: The signals for turning left are difficult to perceive in the surplus of objective information

pict.9: Signals which are hanging very closely next to each other are outshined by the streetlights

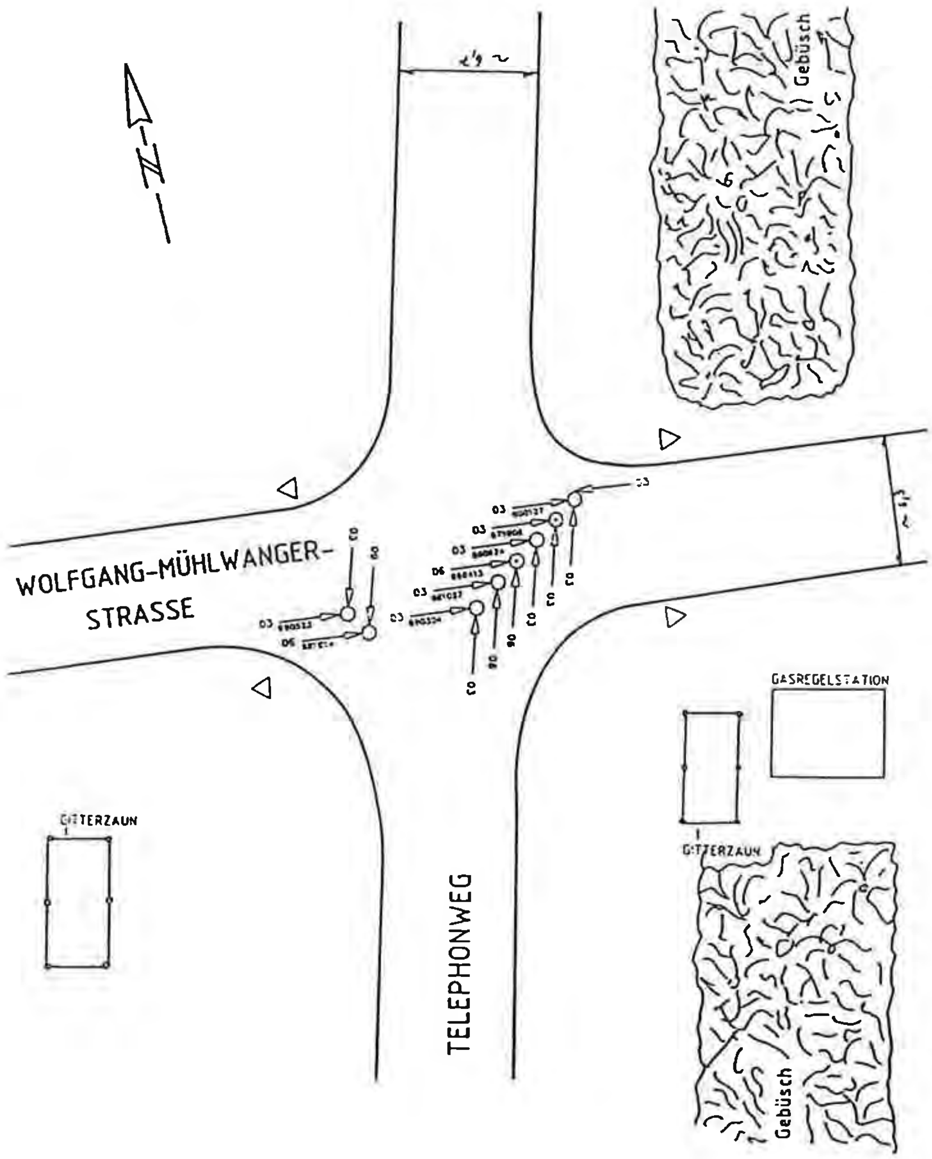
At the crossroads presented in pict.9 a lot of accidents happened at night , often with oncoming vehicles turning left .The drivers persistantly passed through red lights in the direction shown. The signal pictures of the signals hanging next to each other -one for turning left and one for straight ahead - are hardly possible to be identified in the right way from a longer distance because of the outshining of the streetlights. In addition to that, the signal for turning left is hanging exactly in extension to the left traffic-lane for the drivers going straight, while advancing to the intersection. Only directly in front of the crossroads the traffic-lanes swing to the right. Here again psycho-physical dependent perception mistakes in the form of confusion, resulting from non-conformist expectation attitude, give the most probable explenation for the accident-causing disregarding of the red lights.

But practical accident research, with taking into account the perception behavior, can also keep leading to completely new hypotheses. One of them I would like to present with the help of the following example:

pict.10: Right-angled accident-crossroads with country road characteristics

The shown crossroads (pict.10) concern a at first nearly not explainable location for right-angled collisions, which happened there with increasing frequency. Both road networks give country road feeling, although they are within Vienna's city limits, and also the speed level has got" country road characteristics".

The accidents (see pict.11) all happened during daylight, nearly without any exception from the advancing-direction described and mainly with vehicles from the right, therefore having the right of way. The accident analysis with the help of traffic accident files showed that in most cases the drivers who did not have the right of way wanted to pass the crossroads in one go. Therefore they had not seen the individual vehicles, having the right of way, at all or they had percepted them much too late.



pict.11: Collision diagram

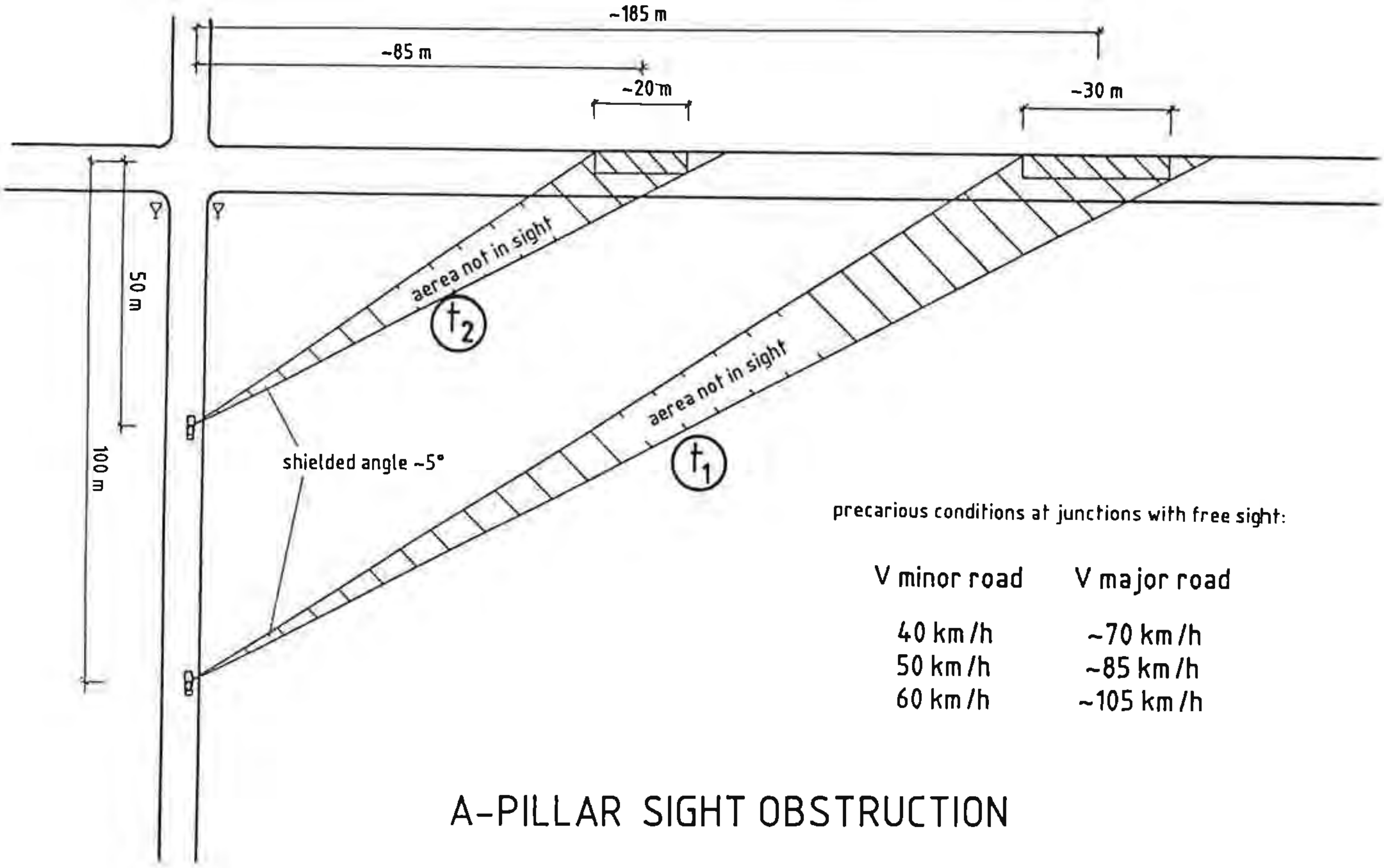
The sight onto the prior road is possible from about 120 m in front of the crossroads. Assuming that the driver who is on the minor road now approaches at a constant speed of 60 km/h with a realistic stopping distance, in case of some danger, of 40 m in front of the crossroads, about 80 m or 4,5 s remain for the identification and right judging of the situation.

But what happens, if the approaching driver with his first glance to the right has found a similar situation to the one which is shown in pict.12?

pict.12: Blocked view because of right front windshield column while looking to the right

The yielded vehicle approaching from the right is nearly or even completely hidden behind the right windshield column of the other vehicle (= a-column), with the contrast being very low anyway due to the shadow of the trees.

The diagram of the situation, see pict.13, clearly points out that, when the vehicle not having the right of way is still at quite a distance from the yielded road, out of about 100 m carefully assumed 30 m are hidden behind the right a-column. Should the yielded vehicle move at about 105 km/h on the normally deserted road, it will stay in the blind spot area for some seconds. This area still is 20 m of the yielded road when the vehicle not having the right of way is about 50 m away. This is enough to hide the vehicle in spite of a controlling look from the not-yielded driver still shortly before reaching the latest possible braking-point. As this vehicle is not expected to show up, the controlling look is probably rather quick as well. The vehicle will be registered in the periphery of the field of view at best very shortly in front of the crossroads. A situation which can be compared to that emerges naturally at each speed relation of 4/7 between yielded/not yielded driver.



pict.13: Diagrammatic sketch of blocked view because of right front windshield-column while looking to the right

All the presented examples do show very clearly how decisive the factor time is for the appropriate information perception and combined with that for the fairly realistic interpretation of a perceived situation in road traffic. Quite often demands are put on the traffic participants' physiology of the senses or the traffic participants put themselves under this pressure, which cannot be dealt with in extreme situations in a sufficient way. Should some other unfortunate conditions occur as well, a traffic conflict or worse an accident are unavoidable.

Before closing there is another example that fully confirmed our method for analysing accident locations.

At this crossroads two high-rated three-lane roads meet, the common extension has got five lanes (see pict.14). From the statistical files we could gather frequent accidents with pedestrians, one of them with fatal end. At first sight there were no bigger deficits in the crossroads-construction visible. But the more exact analysis and evaluation of the police files proved that the serious pedestrian accidents had not happened until the five-lane extension right behind the crossroads. The vehicles involved had been driving into the crossroads at a definitely high speed when the lights were green.

pict.14: Two wide roads meet at a distorted angle, at first unexplainable increased frequency of pedestrian accidents

With this knowledge it was easy to find the path that lead through the bushes next to the tree in pict.15, which offered a considerable shortcut to the underground station in the background.

Obviously this path was quite frequently used by couraged, local pedestrians.

In view of the following pict.16 (no posed photo!) it was not neccessary any more to look for lavish perception-physiological explanations for the accidents.

pict.15: Five-lane extention, next to tree a pedestrian path comes up right behind the crossroads

pict.16: Pedestrian crosses five-lane extention unprotectedly, vehicle at high speed in the background

Just as learning to drive means learning to perceive as well, it has to be taken for granted in accident research that the basic happenings of the traffic participants world are known together with its limitations. Only then can possible situation-dependent deficits in traffic get laid open. In particular one has to involve children and elderly people into the considerations concerning that problem.

Traffic planers and traffic technicians have the chance, if not even the obligation, within the limits in reach, to optimise the objective information offer. Above all the time which is needed for perception has to be maximised, if necessary through speed-deducting measures, even if these might not be terribly popular.

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IN-DEPTH INVESTIGATION OF ACCIDENTS THE EXPERIENCE OF INRETS AT SALON-DE-PROVENCE

I) INTRODUCTION

Since 1980, the Department of Accident Mechanisms at INRETS in Salon-de-Provence (France) has been conducting an in-depth investigation of road accidents (Etude Détaillée des Accidents: EDA). According to the definition given by OECD (OECD 1988), an in-depth accident investigation is one which goes much greater into depth than those currently available. That such a vague definition be applied to such a wide range of activities could, indeed, be questioned. But, these different activities can in fact be grouped together under the same heading, as they have to respond to the same theoretical and methodological questions (Pettersson, 1991; Girard, 1991).

It is not my intention to consider the problematic of in-depth accident studies at great length. This work has already been dealt with by a group of scientific experts at OECD. The purpose of this paper is to present some of the choices made at Salon-de-Provence in answer to the questions that are raised when deciding to conduct an in-depth accident study.

The first of these questions is the necessity of a more in-depth approach: when launching an in-depth study it is assumed that the questions have been defined, and that it is impossible to respond to these questions using available accident collections.

We must then indicate the additional information needed to respond to these questions and define the direction and contents of an in-depth study collection. We must, at the same time, check that this information is readily accessible, and develop the most appropriate data collection method.

Finally, we should not forget to previously define the way in which this data will be used and the context in which it will be interpreted.

This last point assumes the use of a theoretical framework. It is in fact obvious that the question of choosing a theoretical framework is raised as soon as the initial questions are formulated, and also determines which data is to be collected. Experience has shown that this theoretical framework is rarely specified. In all events, conducting an accident analysis assumes that there is a grid by which to read the accident. Many misunderstandings could be avoided if, instead of remaining implicit, this theoretical framework was clearly indicated.

II) EDA OBJECTIVES AT SALON-DE-PROVENCE

The aim of those working to improve road safety is to reduce the number of accidents, and the seriousness of their consequences. But, what do we know about accidents?

An accident is an event that is already over when we are informed of its occurrence. It is too late to observe or record the sequence. The data collected is for the most part the descriptive characteristics of those involved, the vehicles, the road infrastructure, the circumstances in which the accident occurred and its consequences. The statistical use of this descriptive data does indeed enable us to identify groups at risk, the implications and factors that are statistically significant. But this data only provides a static description of the accident.

Investigation into the accident dynamic is aimed at establishing responsibility, and can be resumed in terms of the violation of traffic regulations.

EDA was set up for research purposes. The intention of those who initiated this work was to go beyond the traditional approach of identifying accident-causing factors, to reach the actual mechanisms that produce accidents, by reconstructing their scenarios and analysing their sequences.

In line with this objective, in-depth research work should be directed more towards the stages prior to impact, than to the consequences.

The methodological consequences of this choice was to prioritize clinical case analysis, whilst disregarding statistical representativity. Between 1980 and 1987 four hundred accident cases were analyzed.

III) THEORETICAL BACKGROUND

III-A) The accident:

We consider that we are dealing with a system of mobility. The basic mobility system components are the users, tools and infrastructures used for this purpose. Normally the "output" of this system is to satisfy mobility requirements. If the system is operating correctly, this means that there is a successful combination of the three basic components. Modifying one of the system components will determine the modifications of its interaction with the other components: they cannot operate independently one from another.

An accident is an undesirable "output" of the system, and the occurrence of an accident is the symptom of a malfunction within this system. Operating failures are not to be sought in one or another of the components on its own, but in the relationships and interactions between these different components.

The methodological consequence is that both collection and analysis should be multi-disciplinary, and include the three system components: user, vehicle and infrastructure.

III-B) The user:

This type of approach assumes the use of a human operating model. In the light of developments in cognitive psychology, man is seen to be an information processing system. We are well aware that it is restrictive but it is in our opinion, the most effective at present when used for research directed towards prevention action (Hale, Quist & Stoop, 1988; Hale & Stoop, 1988; Michon, 1985).

This model maintains that the user, as he gains experience, draws up, in his permanent memory, a catalog of road situations that operate increasingly as prototypes to which he refers, and to which utilization modes are associated. A balance is formulated between adapting knowledge acquired when faced with unusual road situations, and assimilating the situations encountered into previously acquired knowledge.

As a result of this, the information provided by the environment is filtered and interpreted according to acquired knowledge. With time, these processes for information processing and use of knowledge become more and more automatic.

Insofar as an accident is an unwanted event, it can be said to illustrate a failure in the information processing process sequence, a malfunction that could be located at different stages and at different levels of the human activity (Rasmussen, Duncan, Leplat eds, 1987; Reason, 1990).

The first consequence of this approach is that particular attention is focused on the account of the accident and the interaction between these road situations and the interpretations of these situations by users. A second consequence is that collection will be directed towards the human conditions that we know, or assume, influence the information processing process.

IV) DATA COLLECTION

Data collection is aimed at reconstructing the scenario that results in impact, and identifying the mechanisms that make up this scenario. It is conducted by a team of two specially trained operators: a technician specialised in infrastructure and vehicles, and an interviewer. The quality of collection is continually monitored by researchers involved in the study.

We are alerted that an accident has occurred at the same time as the emergency services. Survey strategy is based on collecting as much information as possible at the scene of the accident itself. Data collection is three-fold: the user, the vehicle and the road infrastructure. It covers vanishing data: accounts given by those involved and witnesses, location of final standstill point, location of the crash itself, skid marks, traffic and weather conditions, and so on...

The driver is interviewed on the spot, or in the hospital emergency service. He is asked to describe "what happened", and then give further details: what he had intended to do, what he had seen, what he was aware of, what action he had taken, what he had intended or tried to do. The interviews are recorded, photographs are taken, a plan is drawn up.

We then attempt to reconstruct the accident scenario. This is followed by a second complementary collection. This second collection enables us to collect longer-lasting data, such as descriptive characteristics of the driver and the on-going journey, description of the route, road infrastructure and environment, technical vehicle inspection. It is also directed by assumptions made during the first reconstruction attempt.

The final reconstruction is backed up by kinematic calculations: initial speed, time to collision, speed at impact (Lechner & al., 1990).

V) ANALYSIS

The first stage of analysis consists of drawing up the accident scenario in terms of the sequence of events and, in particular, the description of the initial system status, the identification of the triggering event, the reconstruction of the emergency manoeuvre. The second stage is to identify the mechanisms that contribute to the production of this sequence of events: these mechanisms are found in the system component interaction. To achieve this, the scenario is divided up into four phases.

V-A) The driving phase:

The driving situation is, for the driver, the "normal" situation. It is "normal" because there are no unexpected demands made upon him. The driver can adapt effectively, the events unfold according to his predictions, expectations and anticipations. He controls his speed and course, he is "master of his vehicle". On a more basic level, this means that there is a balance between the demands and ability of the system components to respond to one another: alignment, skid-resistance, sight distance, tyre wear and pressure, condition of shock absorbers, speed, degree of driver awareness... It should be noted that "normality" in this case refers to effectiveness, but not necessarily to compliance with traffic regulations. The advantage of this situation is to reveal what the driver considers to be both desirable and feasible in a particular place and in a particular context.

V-B) The discontinuity phase:

Discontinuity is an unexpected event that interrupts the driving situation by destroying its balance and thus endangering the system. The effect of the discontinuity situation is to switch the system components from a bearable level of demand to a suddenly excessive demand in terms of ability to respond.

It should be noted that an "unexpected event" does not necessarily mean "unpredictable", which raises the question of to what extent it really was unpredictable, and if not, why it was unexpected. The driving situation is of considerable use when seeking this explanation.

V-C) The emergency phase:

The emergency phase covers the space and time between discontinuity and impact. If the discontinuity situation is a statement of the problem, the emergency situation is the space-time "credit" available in which to solve it. This "credit" is, by definition, extremely limited.

The emergency situation can be determined in relation to the driving situation by the suddenly excessive demand level imposed on the system components. The driver must solve, within a given time, a problem that is, in principle, entirely new to him. The range of solutions depends on the environment in terms of hostile obstacles or space available for evasive action. The capacity of the vehicle to perform the required manoeuvre depends not only on its design and state of repair but also, with regard to the vehicle-ground liaison, on the state of the infrastructure. The emergency situation reveals the insufficiencies or defects in one or another of the system components, weaknesses that remain tolerable when faced with normally moderate driving situation demands.

The emergency manoeuvre is an attempt to find a solution to the problem. As there is an accident this manoeuvre has failed. The emergency situation is followed by the crash phase.

V-D) The crash phase:

The crash phase includes the crash and its consequences. It determines the severity of the accident in terms of material damage and bodily injury. Once again, the contents of the situation depend on what has occurred previously and the interaction

between the three components: an elderly person is more vulnerable, modern vehicles are better designed to absorb
impact, a protection rail prevents impact with a hostile obstacle.

VI) ILLUSTRATION

One Sunday in March at half past eight in the morning we were alerted by the emergency services and went immediately to the scene of the accident.

VI-A) "On the scene" collection:

- the accident resulted from the vehicle leaving the road on a right-hand bend. Only one vehicle was involved. There were three people in the car, one of them was slightly injured.

- we noted skid marks made by locked wheels on leaving the bend, starting on the left hand side and moving towards the outside of the bend, the vehicle crossed over the shoulder and fell into a ditch on the left.

- it was daytime but the light was not very good, the sky was overcast, the road surface wet, although it was not raining at the time of the accident, there was little traffic.

- the vehicle was a Citroën Visa GTI: a sports model, 105 HP Din, with a top speed of 185 km/h. There were three people in the car.

- The driver, a young man, was unharmed. In brief, he stated he must have approached the bend at between 70-80 km/h, and did not consider this speed to be excessive. He had just changed into third gear and was then taken unawares when half way through the bend: he realised he was "taking it wide" and that his left-hand wheels were crossing over the central white line. He stated that he was afraid of meeting an oncoming car, and braked lightly. The car went straight ahead, and then it all happened! He indicated that finally, there was no one approaching, and that if he had not braked he could have driven through, but as he had kept his foot on the brake, he continued straight ahead into the ditch. He also said he was surprised that his wheels had locked, as he did not think he had braked very sharply.

VI-B) Additional collection:

a) Road and pavement characteristics:

- two-lane rural road
- pavement width: 6.30m
- this occurred when leaving a built-up area, in an area where vehicles pick up speed. The bend is preceded by a straight stretch of 400 m.
- sight distance is sufficient to detect the bend. However, vegetal masking on the right-hand side prevents the driver from seeing around the curve and thus assessing its real difficulty.
- curve radius: the radius on entering the bend is 94m, but this decreases to 60m on leaving.
- the road surface is average in quality when approaching the bend, but deteriorates in the bend (bumpy), and skid resistance is very poor.
- there is no warning of danger, nor any specified speed limit.

b) Vehicle:

- a light and high powered sports car.
- one year old and had covered 40 000 km.
- the car was in excellent condition and no defect was noted in either the steering, brakes, suspension or tyres.
- it should be noted that the brakes on this model are particularly sensitive.

c) Driver:

- a young man aged 23.
- had held a driving licence for 5 years.
- had just purchased a second-hand Citroën Visa and had only been driving it for one day. His previous vehicle was an old saloon car, cumbersome with limited performance.
- in contrast to his previous vehicle, he stated that the brakes of the Visa were sharper, and that he had to look at the speedometer to realise what speed he was travelling at.
- the purpose of his journey was to attend a car rally. He left home at about 7:15h, the route so far had been well maintained and easy. He wanted to arrive on time to find a good place on the rally circuit.
- this was the first time he had driven over this route.

VI-C) Analysis: breakdown and interactions:

a) Driving phase:

- a young male driver, at the wheel of a sports car he is not familiar with and driving over a route he does not know. The car was considerably different to any he had driven before.
- a time constraint: to arrive before the start of the rally to find a good vantage point.
- leaving a built-up area, in an area where vehicles pick up speed, with a good quality road surface.
- the speed was limited to 90 km/h, with no other specific restrictions. The approach speed of the Visa was thought to be 80 km/h. This is high, although the driver is still within the legal limit.

b) Discontinuity phase:

- the acceleration zone leads on to an unexpected difficulty.
- the bend radius is shorter when leaving than when entering.
- reduced sight distance of bend exit.
- no indication of any specific difficulty on this bend.
- Visa thrown off balance by bumps in the road.
- the driver is taken by surprise and has difficulty controlling the course of the Visa: he "takes the bend wide" and starts to panic.

- N.B.: we went through this bend under dry conditions and with a new road surface at the wheel of specially equipped Citroën BX: we recorded a lateral acceleration of 0.7 g at 70 km/h... This poses a genuine course control problem for any driver who is taken unawares.

c) Emergency phase:

- the driver brakes: the Visa, which is more responsive, does not behave as expected and he locks the wheels.
- the road surface is wet and skid resistance poor: he starts to skid towards the outside of the bend.
- he had no experience of this type of situation and keeps his foot on the brake: the Visa continues its skid in the same direction.

d) Crash phase:

- the shoulder is narrow making it impossible to take remedial action.
- it is bordered by a ditch.
- the Visa falls into the ditch and comes to a standstill on its side.
- the front passengers wearing seatbelts are unharmed. The passenger at the rear is slightly injured.

e) Conclusions:

The police report came to the conclusion that this was a typical case of loss of control, due to carelessness and excessive speed, by a young driver who liked driving sports cars. The in-depth analysis shows that the origins of this accident were more complex and could not be limited to a single cause, but were the result of interaction between the three system components. The police diagnosis leaves little place for the prevention of this type of accident, except for clamping down on youthful carelessness, or preventing young people from driving sports cars. The diagnosis of the in-depth study opens wider perspectives. First, it is easier to modify a bend than change someone's personality, and this is something all users can benefit from. Beyond, however, this localised solution, this raises the question of situation sequences and the homogeneity of road sections, and their effect on user expectations and behaviour. Finally, even if the users are guilty of carelessness or errors with negative consequences, it can be seen that these are not committed at random...

VII) CONCLUSION

When the EDA was undertaken, it corresponded to our knowledge and queries at that time: to improve accident analysis methods, better our understanding of the accident process and encourage new directions of research.

This gave rise to work covering such themes as:
- accidents at light-controlled junctions in urban areas,
- accidents at cross-junctions in the open country (Girard, 1988),
- accidents involving heavy goods vehicles (Fleury & al., 1988),
- an analysis of the driving task as seen through malfunctions (Malaterre, 1990).

It has formed a basis for research programmes: reconstruction of emergency situations leading to mathematical modelings, road and driving simulator experiments (Lechner & al., 1991).

It has also provided information on which to base a study of driving aids (Van Elslande & al., 1993).

In-depth accident investigation enables the principal safety problems to be rapidly identified, especially when and where there is no existing accident data base. It provides an open, flexible and manageable investigation framework, which takes account of local specificities. It also provides road safety personnel with educational aids. It leads to the formulation of new assumptions to be validated by alternative methods such as on-site observations, on-board and laboratory experiments.

From this point of view, in-depth accident studies reveal their full potential when they are not required to provide information they cannot produce, and when they are combined with other complementary methods as part of a co-ordinated research programme.

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THE INFLUENCE OF ROAD SURFACE PARAMETERS ON ACCIDENT RATES - A STATISTICAL ANALYSIS

Zusammenfassung: Es wird über die Meßkampagnen zur Bestimmung von Straßenoberflächenparametern des österreichischen Bundesstraßennetzes und die bisherigen Ergebnisse berichtet.

Abstract: The Austrian Federal Roads Administration Programme "Collection of Road Surface Parameters" and the results achieved up to now are presented.

1. Introduction

In 1991 the Austrian Federal Road Administration has started a programme to obtain road surface parameters. 1991/92 the whole Austrian network of motorways and expressways (about 1800 km of roads with the right lanes on both carrigeways measured) was recorded, plus some 2000 kilometers of federal highways (only one lane measured). In 1993, when the first programme had been accomplished, another contract, covering the recording and evaluation of some further 3500 lane-kilometers, was awarded to the Geotechnical Department of the Federal Institute of Testing and Research at the Vienna Arsenal (Bundesversuchs- und Forschungsanstalt Arsenal-BVFA) working in cooperation with the civil engineering company GEST.

The prime goal of the whole project is the acquisitation of homogeneous road surface data covering the total network under the general supervision of the federal road administration (i.e nine road administrations of the Austrian provinces and two state-owned companies, mainly, but not exclusively, reponsible for toll-sections of motorways) thus permitting an efficient Austrian-wide pavement management.

2. Measuring equipment

For the data collection the BVFA Arsenal uses its Stuttgart fricton measurement equipment developed by the Stuttgart Research Institute for Automotive Engineering and Vehicle Engines (Forschungsinstitut für Kraftfahrwesen und Fahrzeugmotoren Stuttgart). The equipment (including a water tank with a capacity of 6000 litres) is mounted on an air-suspended chassis with a diesel engine of 340 kW, both built in Austria. The measuring principle is based on retarding of the measuring wheel with a constant slip of 18%. This wheel is running on a 0,5 mm water film which is applied in the right wheel track . The force that arises between the measuring wheel and the hauling vehicle permits the determination of the skid resistance coefficient. High accuracy measurements at longitudinal distances up to 10 centimeter can be delivered due to latest electronic equipment, the additional recording of the actual wheels loads, the use of an internationally standardized car tyre (PIARC) with a specified rubber mixture and a specified profil. For this particular project an integration distance of five meters was chosen.

At the front side of the truck a rut depth measuring device using ultrasonic sensors was mounted. (Development of the Stuttgart institute). At the measuring speed of 60 km/h, applied during the project, this device only records one lateral profile every 25 m. To avoid random results sets of 10 profile measurements are averaged.

You will notice that this set-up is primarily suited to cover motorways, expressways and non-urban highway sections, but actually the measurements were performed on all sections where the measuring speed of 60 km/h can be kept without running a risk (an algorithm compensates for speed deviations up to about 50 km/h). Perhaps you will also remark that we do not record longitudinal eveness. After some discussion it was decided that road conditions in Austria are on such a high level that in general longitudinal (un)eveness will be strongly correlated to poor skid resistance and/or rutting and therefore this data would not bring much more additional information.

3. Results of the measuring campaign 1991/92

The results for both, motorways and highways (Figures 1 and 2) are nearly identical. With these data and measurements at different speedlevels and on different pavement species (concrete pavement, bituminous layers) the BVFA Arsenal established a so called assessment background ("Bewertungshintergrund", fig. 3, extracted from reference 1) for motorways (this network was measured in full). In this way data recorded at different measuring speeds can be compared and at least roughly evaluated.

The reason why the worst 10 percent of friction coefficient data are classified "bad", can easily be explained. On the average pavements are totally retreaded in a ten years cycle. Therefore the 10-percent limit is internationally accepted. In some countries only the worst 5 percent are classified as "bad". Clearly liability considerations are beginnning to influence decisions.

4. First attempts to isolate the effect of poor skid resistance coefficients

In the light of studies undertaken in the FRG which indicate a strong increase in the percentage of accidents on wet pavements the Federal Road Administration asked contractors to consider this question. A diagramm, mapping the percentage of accidents on wet pavements vs. the average friction coefficient for each motorway section showed a chaotic cluster without any discernible trend. Obviously in a motorway-network which includes huge variations of design parameters and traffic volumes this method does not work. We therefore started a study of our own, taking into account the parameters

- skid resistance coefficient
- uphill and downhill grades greater then 3 percent (each carrigeway of a motorway section being considered as an independent unit with the corresponding accidents)
- bend radii smaller than 1000 m
- traffic volume

Remark: the rut measuring device was only installed in late 1991 and therefore this parameter was not yet available for all sections.

In fact friction coefficients smaller than 0.35 where found to have some influence on accident rates and this had some influence in the priority rating of at least one refacing project. Unfortunately a lot of pavement reconstruction work (filling of ruts etc.) took place in 1991/92. Some projects were incorporated in the study although the pavement surface conditions had totally changed during the reference year. (Please bear in mind that in two years roughly 20% of the pavement change!). Therefore the study has to be regarded with some hesitation and the results will not be published.

5. Regression analysis of the highway data

Nevertheless the applied method, namely the regression analysis, has proven its applicability to this kind of studies and we decided therfore to scrutinize highway data of the 1991/92 campaign. The following influencing factors werde considered

- the skid resistance coefficient (percentage of occurrence of datagroups, e.g. <0.30, 0.30...0.35,....,> 0.60 for each considered road section)
- the rut depth (< = 3 mm, 4...6 mm, 7... 9 mm, > 10 mm)
- the average daily traffic volume (devided in groups < =3000, 3000...6000, 6000...9000, 9000...12000, > 12000)
- percentage of heavy truck traffic (< 8%, 8...12%, > 12%)
- passing through built-up areas (<5%, 5...25%, 25...50%, > 50% of the section length)
- horizontal and vertical alignment (normal, twisting road, corners and hairpin bends; flat, hilly, alpine); a division according to design parameters (e.g. speed) would have been more appropriate
- cross correlations between the groups
- skid resistance coefficients < 0.35 and non-normal horizontal alignment (eg. the twisting roads and hairpin groups)
- skid resistance coefficients 0.35 ... 0.45 and the two alignment groups
- rut depth 3 ... 6 mm and the two alignment groups
- rut depth > 6 mm and the two alignment groups
- the hilly or alpine vertical alignment groups with the summed up skid resistance groups < 0.45
- the hilly or alpine vertical alignements groups with rut depth > 6 mm

Unfortunately there was no possibility to introduce existing speed limits. The percentage of built-up areas and of the horizontal and vertical alignment groups were fixed by studying the topographic maps 1:50000.

Together with the personal injury accident rate (wet and dry surface conditions added up) a 31 * 233 matrix was established, the rows (each representing one highway section) being weighted according to traffic performance (length of section * daily traffic volume * 365) so that every driven kilometer has equal weight.

The solution of the matrix (2½ hour calculating time on a 386 PC) produced the results displayed in table I.

The standard deviation for a highway section with 100,000.000 kilometers driven per year amounts to ±0.10.

The remaining differences between the actual accidents rates and the adjusted values of the 233 sections exceed the standard deviation

σ in 56 cases (theoret. 78 cases)
2σ in 10 cases (theoret. 11 cases)
3σ in 0 cases (theoret. 0 cases)

6. *A short discussion of results*

- Apparently road administrations and/or car-drivers are aware of highly slippery highway sections and deep ruts (official or self imposed speed-limits)
- Much more complex is the situation considering skid resistance coefficients between 0.35 and 0.45. Neither the maintenance personnel nor the driver can perceive the danger at first sight; pavement management will have to pay more attention to this category. Here is perhaps one of the situations of which drivers should be informed (PROMETHEUS activities) by in-vehicle instruments and to my knowledge skid resistance meters for use in everyday cars are being developed in the FRG.
- the fact that accident rates decrease when traffic densities increase, is no new insight
- the increase of accident rates in residential areas is also well known (arguments for the construction of by-pass-roads !?)
- this applies as well to the reduction effect of hairpin-bends
- the influence of rut depthes of 4 to 6 mm (an average covering 250 m, therefore the maximum depth will be much higher!) combined with winding highways is remarkable (obviously the thin water film is not seen by the driver) and can hardly be improved by road maintenance measures, it's just one of the ordinary road conditions (comp. fig. 2)

7. *Prospects for the future*

This is only a preliminary study covering about 1400 km of the Austrian federal highway-network (about 14% of the total network). We will have to wait for the data of the 1993/94 campaign to see more clearly. Owing to the high data density of the skid resistance measurements, it will be possible to evaluate not only the road sections but to describe in addition accident black spots with a multidimensional catalogue of phenomena (including non-engineering questions). Perhaps a cluster-analyse will give us a more precise understanding of accident patterns.

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Road Surface Parameters Programme
Campaigne 1991/92

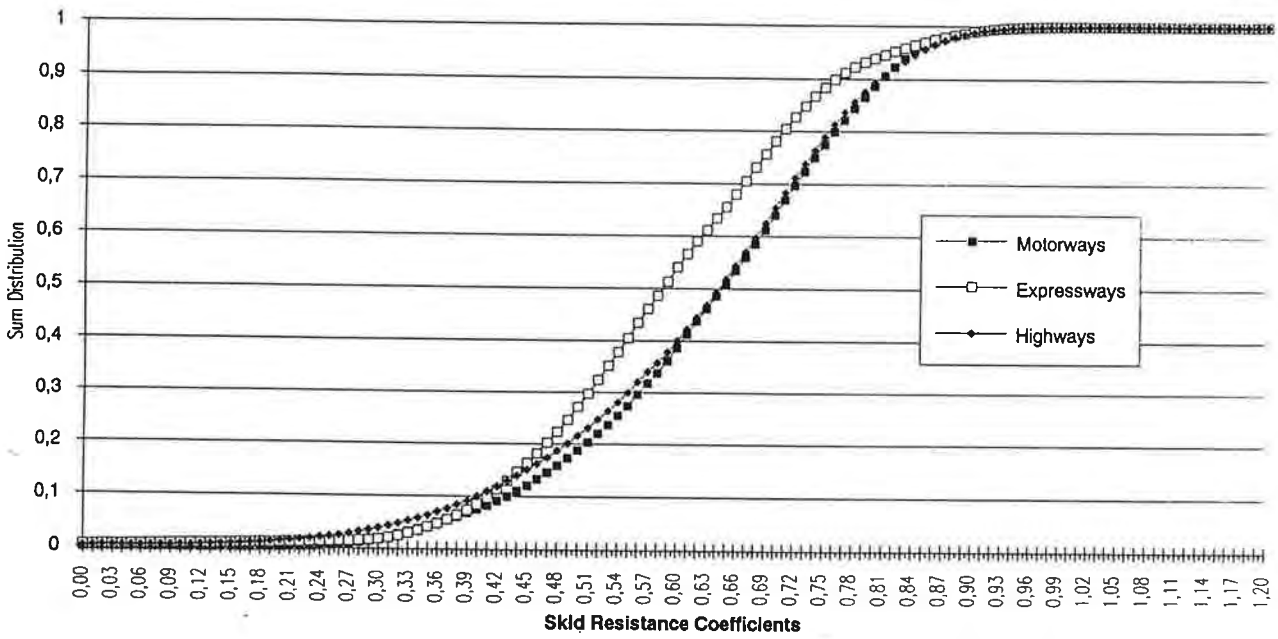

Figure 1

Federal Roads Administration
Road Surface Parameters Programme
Campaigne 1991/92

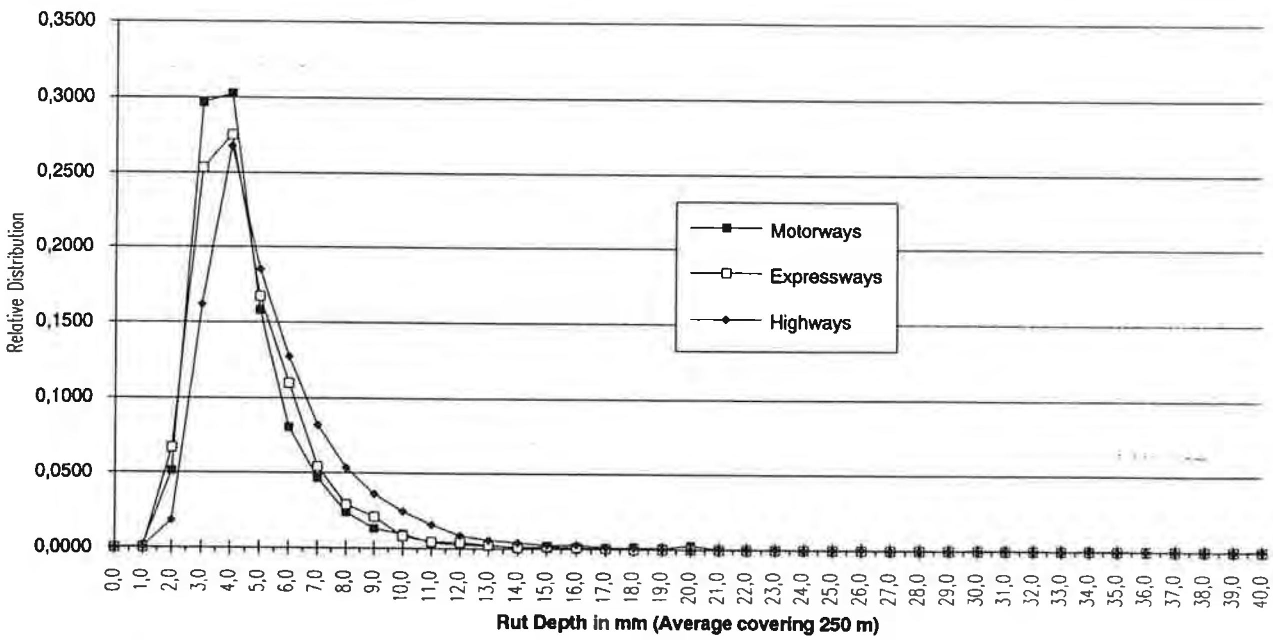

Figure 2

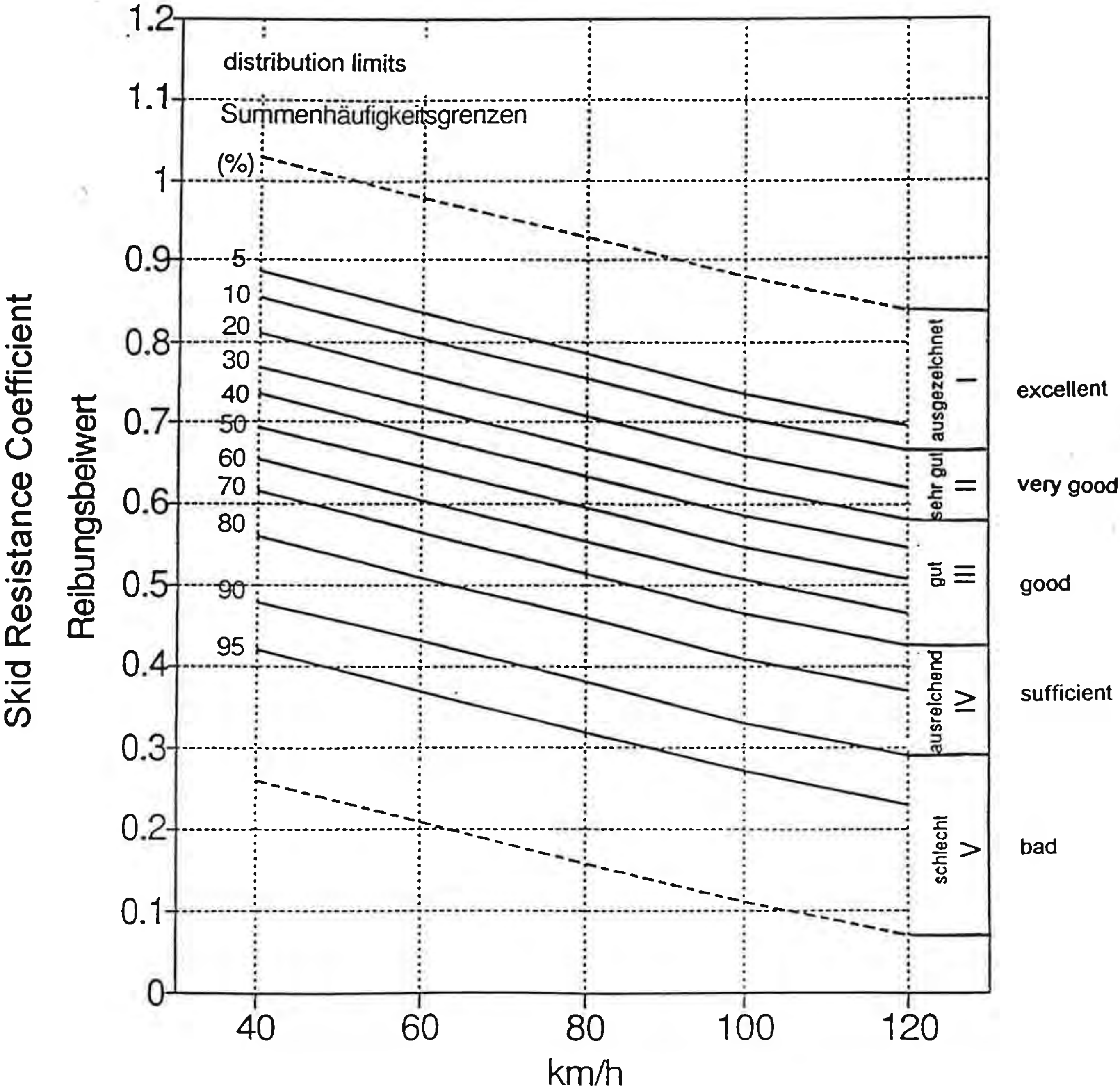

Abbildung 23: *Bewertungshintergrund für die 1991 mit dem Meßverfahren "Schlupf" erfaßten österreichischen Autobahnen*

Assessment background for the Austrian motorways, measurements with a constant slip of 18%

Figure 3

Share of different factors in the formation of accident (casualties) rates of highway sections

Left hand the first run, in the right column the final results after a careful, step by step reduction of parameters:

		1st run	final run
constant factor e.g skid resistance > 0.60 (>0.55) rut depth < 3 mm daily traffic < 3000 truck traffic < 8% residential areas < 5% flat terrain no bends		+0,58±0.18	+0.60±0.10
skid resistance	<0.30	-0.08±0.16	
0.30<	<0.35	-0.30±0.42	-0.19±0.10
0.35<	<0.40	+0.45±0.41	
0.40<	<0.45	+0.48±0.45	+0.44±0.13
0.45<	<0.50	+0.08±0.45	
0.50<	<0.55	-0.58±0.37	-0.22±0.11
0.55<	<0.60	+0.23±0.24	
rut depth	4...6 mm	+0.02±0.18	
	7...9 mm	-0.04±0.17	
	> 10 mm	-0.08±0.23	
daily traffic	3000...6000	-0.13±0.11	-0.13±0.11
	6000...9000	-0.29±0.11	-0.30±0.10
	9000..12000	-0.15±0.11	-0.16±0.10
	> 12000	-0.25±0.12	-0.25±0.11
residential ar.	5...25%	+0.17±0.05	+0.16±0.05
	25...50%	+0.11±0.09	+0.11±0.08
	> 50%	+0.41±0.18	+0.33±0.14
hilly terrain		+0.01±0.37	
alpine terrain		+0.08±0.38	
twisting roads		-0.19±0.39	
hairpin bends		-0.36±0.42	-0.15±0.09
truck traffic	8...12%	0 ±0.05	
	> 12%	-0.01±0.05	

cross-correlation factors

	1st run	final run
skid res.<0.35/bending r.	-0.21±0.24	
skid res.<0.45/bending r.	-0.37±0.53	
rut depth 4..6 mm / b.r.	+0.54±0.50	+0.27±0.08
rut depth > 7 mm /b.r.	+0.26±0.43	
skid res.<0.45/h.+a.terrain	+0.20±0.26	
ruth depth>6mm/h.+a.terrain	-0.05±0.43	

Table I - Results of the regression analysis

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RISK, ACCIDENT RATE AND EXPOSURE
- helpful tools or concealing obstacles in traffic safety work

1 Introduction

The aim of this paper is to discuss the relationship between traffic flow and safety: Why it may be interesting and How it may be observed - in general - and What it seems to look like - in a special data set concerning bicycle safety.

The presentation in section 2 below is based on conclusions from a former research project at the Department of Traffic Planning and Engineering, University of Lund.[1]. Section 3 reports new findings from ongoing research at the same department.

2 Flow and Safety - Theory

2.1 The role of flow in traffic safety analysis

The usual way to treat information on traffic flow in traffic safety analyses is to compute rates: Accidents *per* vehicle km, serious conflicts *per* crossing bicyclist. The computation of such rates seems to be almost compulsory, whenever data that may be interpreted as "Exposure" is available. The motive for the computation, as well as the interpretation of the resulting rate, is most often implicit.

In the earlier project we initially put an interest in the relation between, on one hand, the results of traffic safety analyses as expressed by the computed accident rates and, on the other, the conclusions drawn from those results. We thereby found several parallel ways - approaches - to understand, define and interpret accident rates. These approaches seem to be a common cause of mistakes in analyses, as rates defined according to one approach is interpreted according to another. Most dubious, but very common, is what we called the 'standardization approach'.

The standardization approach is a way to tackle a basic and normal problem in traffic safety analyses: Assume that we have two or more 'systems', they may be e.g. different intersections, different countries or different modes of transport. From those systems we have observed differences in safety outcome (often number of accidents, at our department at least as often number of conflicts). But we have also observed differences in 'amount of traffic', 'exposure'.

We now want to make a more 'general' statement about the safety situation, feeling intuitively that a direct comparison of safety outcomes is 'unfair', as it is 'disturbed' by the differences in exposure. The standardization approach to accident rates now assumes that the lower the accident rate, the smaller the total number of accidents **had the exposure been the same.**

[1] *"Safety and exposure", Brundell-Freij, K.Ekman, E. (1990)*

This chain of deduction can be shown to be based on the following assumptions:

* The total number of accidents for a given system is linearly dependent on some specific
* function of traffic flow in that system
* That function is the same for all compared systems
* That function is the one used as denominator (exposure) to the safety outcome when the accident rates are computed

The way in which traffic flow influence traffic safety is complicated. The most obvious effect of traffic flow may be variations in number of opportunities for collision, but also e.g. road user expectations (and thus behaviour) and the possibilities to take evasive actions will be affected by changes in traffic flow.

Due to such complicated effects the above assumptions are very strong They are in fact doubted intuitively by most traffic safety researchers when made explicit. However, since the use of accident rates is so commonly accepted, the assumptions are normally implicit. Results that are in fact based on those assumptions are presented, and accepted, as if they where direct observations of reality.

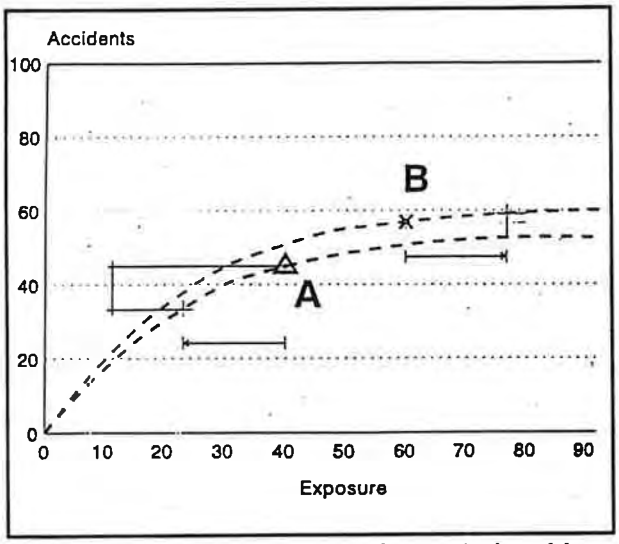

Figure 1 Possible flow-safety relationships for two systems A and B

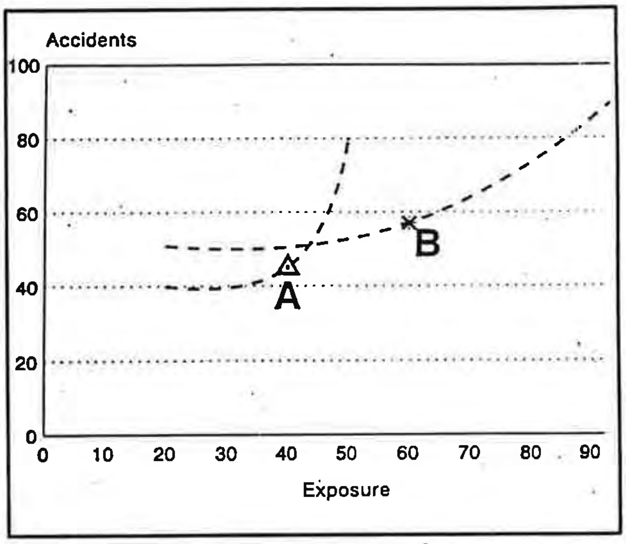

Figure 2 Alternative flow-safety relationships for A and B

Figure 1 and 2 present the two hypothetical traffic systems A and B - their respective observed safety outcome and traffic flow being indicated with markers. Ordinary use of accident rates (with exposure linear in flow) would, in that situation, give the conclusion that system A is the safer - had a lower accident rate. The far from improbable flow-safety relationships, indicated by dotted lines in the two figures, show that it may not be that simple.

In the situation in **figure 1**, system B would always be safer at identical levels of flow. (Nevertheless, it would still be beneficial for safety to, given the present level of exposure, transfer exposure from 'the safer' system B to the 'less safe' system A). In the situation in figure 2 it is not (no matter what sophisticated nonlinear measures of exposure that may be used) possible to answer the 'safer-at-equal-flow' question without defining that level of flow.

Let us conclude:

* there is no obvious function of flow to which the expected number of accidents may be presupposed to be linearly dependent, **without the support of empirical data**
* the relationship between flow and safety is fundamental if we want to generalize observations of safety differences to levels of exposure others than those **observed**
* the relationship between flow and safety may well vary between systems

It thus becomes clear that a method to observe and describe the relationship between flow and safety, and knowledge about such relationships, should be a basic part of traffic safety analysis.

2.2 A method to analyse flow-safety relationships

It is stated above that the form of the relationship between flow and safety for different traffic systems is - one - interesting, and - two - not easily predeterminable. This leads to the conclusion that we would - at least initially - want methods to generate hypotheses about the relationships, rather than to test the significance of any specific such forms, or estimate parameters for specified relationships.

In such a situation the normal first step in the analysis would be to study plots of observed data. In the case of flow-safety relationships there are complications to a straight forward inspection of the plotted observations.

* The discrete nature of the safety outcome - numbers of accidents/conflicts
* The small observed numbers (very often zero accidents/ conflicts) and thus large - relative - random variation - 'noise'- in the plots
* Heterogeneous variation - smaller numbers and larger relative variation at low levels of flow

Figure 3 and 4 illustrate the difficulties with plots of observations from a real data set, conflict studies from 95 non signalised intersections in Malm" and Lund, Sweden (total number of registered conflicts: 193).

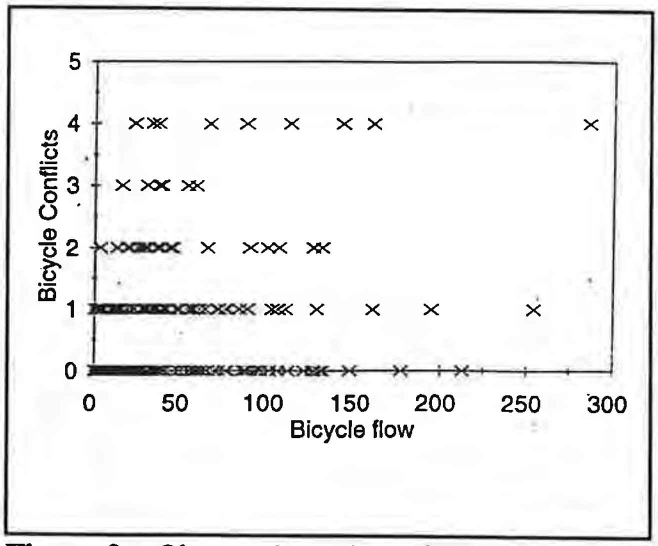

Figure 3 Observed number of conflicts as a function of bicycle flow

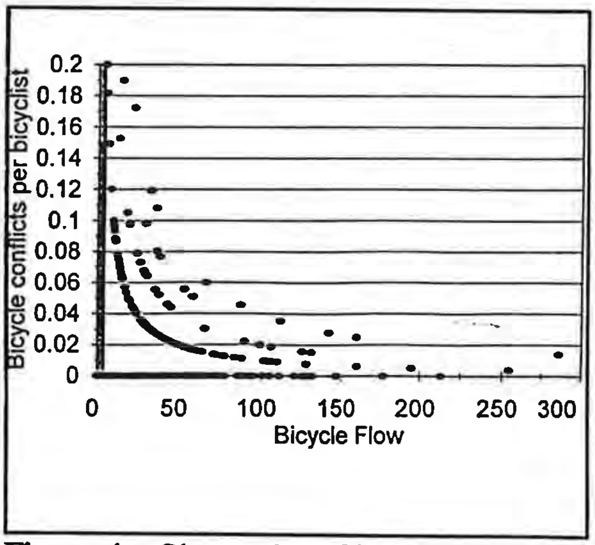

Figure 4 Observed conflict risk (per bicyclist) as a function of bicycle flow

To make a more detaied analysis possible, the conflicts have been divided on the intersection approaches (total number of approaches: 364), conflicts and exposure data from each approach composing a separate observation.

It is obvious that generation of hypotheses about the form of the basic relationships behind the observed plots, based on **figure 3** and **4**, is far from easy.

In our earlier research project we developed a method to reduce the information in plots of the type presented above, to make the generation of hypotheses easier. The basic idea behind the method is natural: to reduce the 'noise' by aggregating observations that are close along the X-axis (exposure/flow) to synthetic observations, representing 'average safety outcome' and 'average exposure' within that interval. Now, how many observations should be aggregated together?

As a first order assumption the number of accidents/conflicts may be regarded as Poisson distributed, with mean (and thus variance) proportional to the number of road users observed. To obtain a more uniform variance in the risk estimates along the X- axis it is thus reasonable to make larger aggregates (as measured by number of separate observations included) where flow is low.

To this aim we have combined separate observations along the X-axis in aggregates of variable size. The number of observations included in an aggregate is determined by a pre-set number of **bicyclists per hour** totally in the aggregate. This number is decided upon as a balance between to goals: The reduced 'noise' by smaller numbers of aggregates (i.e. larger number of bicyclists per aggregate) on one hand, and the more detailed form of the relationship obtainable at larger number of aggregates, on the other.

The information from **figure 4** above does, when processed by this method (aggregate size set to 915 bicyclists per hour), result in the pattern in **figure 5**, which is clearly more interpretable than the original plot.

It seems obvious from **figure 5** that individual bicyclist risk (conflicts per bicyclist) decreases when bicycle flow increases. Such an effect is also intuitively supported by general safety knowledge. As residuals are uniformly and normal distributed (under the first order assumption above, and large enough aggregates) ordinary regression analysis may be performed. The resulting regression line is drawn in the figure and supports the impression from the plot.

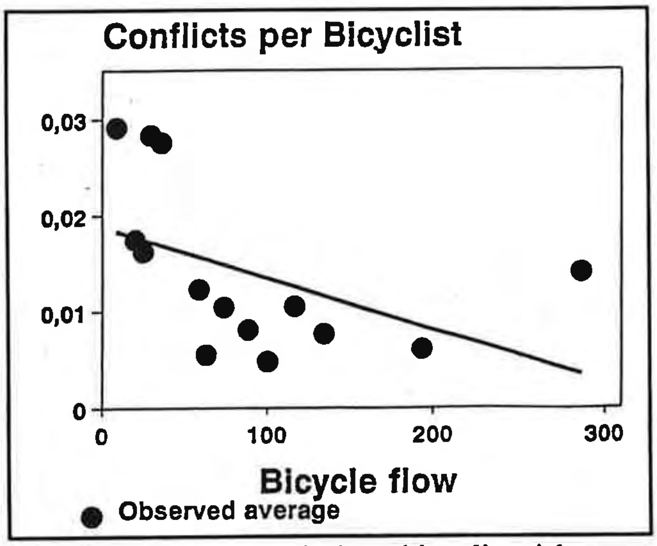

Figure 5 Aggregated plot - bicyclist risk vs. bicycle flow

Another interesting question would be: How is individual bicycle risk affected by car flow? **Figure 6** shows an aggregated plot describing this relation. The aggregation is, as in figure 5, made according to closeness along the X-axis, which in figure 6 means: close in **car** flow. The relevant car flow is computed as a sum of the conflicting car flows for the relevant bicycle movements. Roughly, the car flow measured, this way is equal to **twice** the total number of average hourly flow of cars entering the intersection.

The aggregates are kept equally large as measured by **total bicycle flow** (aggregation limit: 915 bicyclists per hour).

The impression from **figure 6** is not so clearcut as the one from figure 5 was. The estimated regression line indicates, surprisingly enough, an overall trend towards **decreasing risks for bicyclists** when car flow increases. Despite the aggregation made, there seems to be a large variation around the linear regression line. This may be indications of remaining noise, or nonlinear components of the underlying relationship. Initially, we stated our intention to be to search, quite openly, for the form of the relationship between safety and flow. Figure 6 indicates:

* that there may be interesting nonlinear components of the relationship
* that the aggregation method applied does not reduce the disturbing noise in the plot enough to enable the intuitive generation of hypotheses about the general form of the relationship

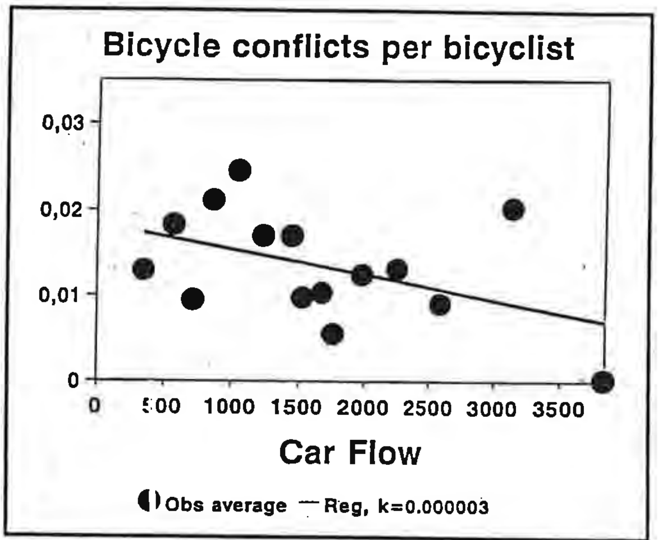

Figure 6 Aggregated plot - bicyclist risk vs. car flow

These questions are further addressed in section 3.

3 Bicycle safety and car flow - further analyses

3.1 Moving Three Point Averages

In order to go further from looking at the tendency indicated by the regression line we want to look at the shape of the relationship between Risk and Exposure. Since there is no old theory that leads us to believe in any standard mathematical relationship like an exponential formula, we use Moving Tree Point Average to get hold of any relationship. Moving average technique is useful since it smooths the data out and enable us to find the general tendency as well as local variations. When we use moving averages, we benefit from the fact that each point in the diagram is constructed in such a way that the variability is about the same in each point.

Looking at the shape of the resulting curve we see that there seems to be an increased risk for bicyclists at rather low car flow. At locations with just a little higher car flow the risk dips down to the lowest value. At really high flow the risk again raises to a slightly higher level.

One problem with moving average is that it may be hard to know if the shape of the curve is mainly derived from a few single outliers. In order to test that we used a computer intensive statistical method called "bootstrap technique[2]."

3.2 Boot Strap Technique

Ideally one would want to have another big data set (originating from the same basic population) to test the stability of the found relationship. It is often impossible or at least extremely expensive to obtain new data. Bootstrapping offers an opportunity to use the data we already have to illustrate the variation that would have occurred if new data sets were collected from the same underlying distribution. It is especially useful when we don't know the true underlying distribution." For a moment we think of the data we have observed as the reality." Bootstrapping deals with what variability would be the result if several different samples were drawn from this distribution.

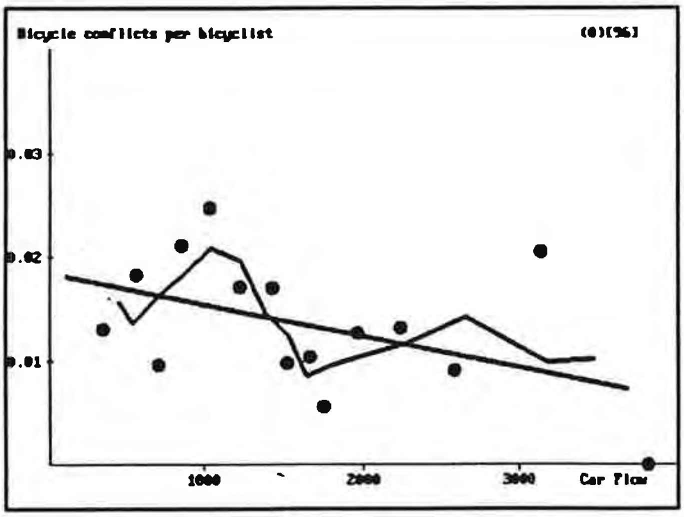

Figure 7 Moving Tree Point Average

From the original data set we select randomly, with replacement, the same number of observations as the total number observed. Since the selection is random some observations will be selected more than once and others will not be used at all. In this case a typical sample could be like; one third of the original observations are not included, 40 percent is included once, 20 percent is included twice, 5 percent is used tree times and 1 percent of the observations is included four times. The reason for selecting the same amount of data, as in the original dataset, is that we now treat our original data as the reality and apply lots of fictive studies on this reality.

2 *"Computer Intensive Statistical Methods", Urban Hjort 1993*

The procedure is repeated many times and thereby an image of the variability is created. If a finding would be derived from a single or even a few observations this finding would disappear each time that observation is not included. If however this finding is derived from a stable underlying trend the finding will be found in all or at least most of the runs of the simulation procedure.

3.3 Result of Boot Strap Procedure

The whole process of selection of data, sorting the data according to car flow and aggregating the data, is repeated one hundred times and the result are illustrated in figure 8. Each line represents a new Moving Tree Point Average illustration and each cross represents new aggregate created in the same way as described in section 2.2.

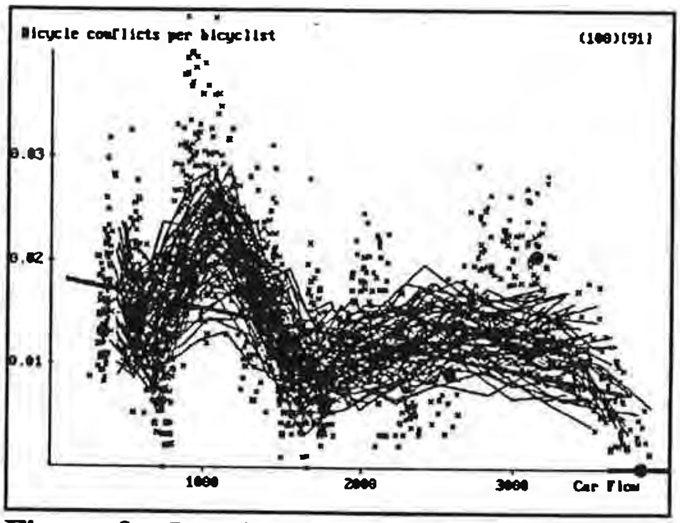

Figure 8 Result of 100 "Bootstrap" runs

It looks rather obvious that the two local minimums in the graph are not be derived from individual observations. It seems like the highest risk for an individual bicyclist is approaches where the "relevant car flow" is about 1000. This graph shows that the relationship between risk and flow is far from simple and certainly not linear.

This could generate lots of interesting hypotheses about why the risk varies along the "Car flow axis." One plausible explanation could be that a specific intersection is extra dangerous and thereby create lots of conflicts. Now we have to bear in mind that this data base consist of lots of approaches, three or four per intersection.

In order to test if the shape of the curve is derived from some specific intersections we carried out similar analyses on parts of the data material. Randomly 50 percent of the intersections were selected for exactly the same analyses. Figure 9 shows four consecutive runs of different selection of the basic data material. It is then clear that the shape of the bicycle risk to car flow relationship seems to be similar in the four different selections. It is also obvious that the bootstrap technique illustrates the increased variability due to the halving of the data material.

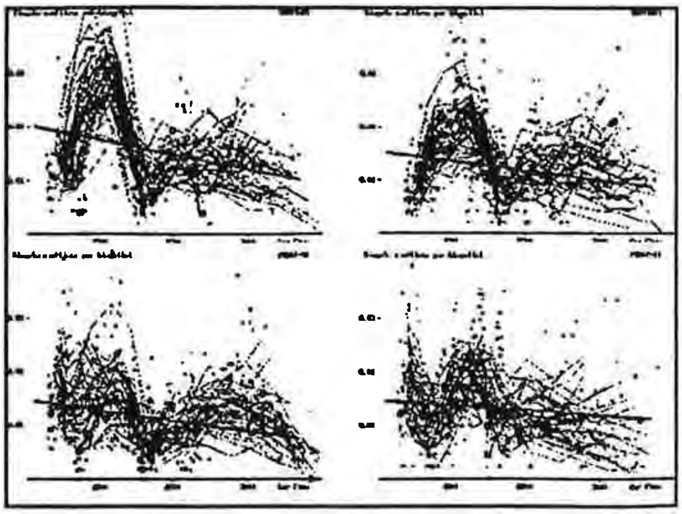

Figure 9 Four consecutive runs of different selection of the basic data material

Despite the stable shape of the curve, it may be derived from some specific layout. This is something we are going to look further into. On the other hand, since this is a random selection of approaches in two Swedish cities the relationship is what should be expected in these cities. It is not self evident what should be regarded as spurious correlation." If we think of rerouting traffic, we could avoid certain dangerous layouts or places were the combination of flows are dangerous. According to modern theories regarding behavioural adaptation one could well imagine that this effect on the objective safety is derived from misperception from the road users despite the layout.

If we are able to change the design it is interesting to study this effect but if we are to give recommendations to bicyclists it could be enough to tell them to avoid places with car flow of a certain size. It is important to stress again that the flow value used is not a micro flow i.e. the flow that each bicyclist experiences, but rather a background flow that describes some kind of quality of the approach.

4 Conclusions

The result of this research shows clearly that knowledge about safety to exposure relationship is essential in safety analysis. There seems to be no simple and general way to handle exposure information. A tool for the illustration of such relationships has ben developed and is described above.

The risk for bicyclists seems to decrease with increasing bicycle flow. The relation to car flow seems to be more complicated. There are indications that certain levels of car flow generate remarkable high bicycle risks. This may be due to correlation between layout and car flow but could however also be an effect of behavioural adaptation. The found relationship is surprising, interesting and needs further research.

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ANALYSIS OF ROAD ACCIDENTS WITH THE USE OF ORIGINAL POLICE REPORTS

1 Introduction

Accident data for the study of accident causation may come from three sources: automated data bases, original police reports and in-depth investigations. The in-depth investigations have never been popular in the Netherlands because of the costs for the special data collection teams. This paper is concerned with original police reports but starts with some comments on automated data bases.

2 Automated data bases

Most accident statistics are based on police reports which have been entered into an automated data base. There are variations between countries in procedure and content but the situation in the Netherlands does not seem to be very different from that in other countries in western Europe. The automated data base provides sufficient detail for standard accident statistics, including a.o. time of accident, number and type of road user/object involved, age and sex of driver/rider/pedestrian. The major problem with these statistics is underreporting (Harris, 1989). Other data in the base refers a.o. to type of location, position, direction of movement and (intended) manoevre of road user, location of contact with other road user/object and a code for a manoeuvre diagram. The latter code is used in a number of European countries, each with its own modifications and dates back to about 1970.

The information is quite detailed and intended for research on accident causation, but is hardly used by researchers. One reason may be that researchers are unable to specify the kind of information they need. More likely reasons are the difficulty to combine the available data into meaningful types of accidents and the lack of some essential data.

2.1 Exploratory study

To find out the limitations of the Dutch automated data base, an exploratory study was done by means of a comparison with the original police reports (Noordzij, 1992). The sample consisted of 50 accidents with injuries requiring hospital admission. The standard form for reporting accidents has a number of (mostly precoded) items and space for a sketch and short narrative. Items were grouped under five headings. In brief, the results were as follows.

<u>Location</u>
Data base: some items much more detailed than necessary, other items too general
Original reports: available for classification

Manoeuvre/collision
Data base: too detailed or too general
Original reports: available from sketch and narrative

Sequence of events
Data base: confusing when complicated
Original reports: available from narrative

Road users/objects
Data base: available
Original reports: available

Behaviour
Data base: violations only
Original reports: some information on visual search and attention

Since it was found that the police forms contain valuable information use in research, the general conclusion from these findings is that the data base needs revision in terms of the coding of information from the police reports.

3 Pilot studies with original police reports

As a follow-up, two pilot studies were carried out in which information was obtained directly from police reports. In fact there are two forms: the standard form referred to in ch.2 and (in a limited number of cases) a more extensive verbal report in addition to the standard form. Both forms were used. The samples of these studies consisted of:
- 133 cases on 80 km roads
- 479 cases with cyclists of 50 years of age and over.

All cases resulted in fatalities or injuries requiring hospital admission. The aim of both studies was to classify accidents into types, based on a reconstruction of individual (most likely) scenarios. By doing this it also became clear which information is needed and which is available.

The common procedure of these studies involved four steps:
- classify case by location and combination of road user
- classify by manoeuvre and sequence of events
- find information on behaviour and circumstances
- classify by scenario.

The term behaviour refers to actions taken by road users as well as to mental processes and any influences on these. The idea behind these successive steps is that the kind of behaviour is related to the type of manoeuvre, which in turn is related to the type of location.

3.1 Accidents on 80 km roads (Hagenzieker & Noordzij, 1992)

Table 1 refers to a selection of 80 cases involving motor vehicles only. A further 53 cases involved pedestrians, cyclists or moped riders. The lines in the table represent successive steps in the selection of cases from the original sample. Each line can be regarded as indicating a type of accident. However, the types become more interesting by including more detailed information from the reports.

One typical accident in this sample is a driver who loses control on the right hand side of the road (29 cases), then tries to make a correction and crosses from right to left hand side (18 cases). This scenario explains why single vehicle accidents occur on left hand curves with cars leaving the road on the inner side of the road rather than on the outer side. Many of these accidents occur at nighttime, both to male and female drivers, who may have been drinking, but more generally suffer from distracted or degraded attention. Some of these drivers are speeding in the sense that they are driving faster than most other drivers under the same conditions.

Another interesting type of accident involves two cars at an intersection with priority signs, with one of the cars having to give way (23 cases. In many of these cases the driver from the side road slows down and looks (or may even stop), then decides to cross but collides with a car on the main road coming from the right (14 cases). It is not clear why he/she make the wrong decision. The driver on the main road usually sees the car coming from the side road, but does not take action, expecting the other driver to wait.

3.2 Accidents with old cyclists (Goldenbeld, 1992)

The original sample contained 479 cases in which a cyclist of 50 years of age or older was killed or taken to hospital.

Table 2 refers to the 388 cases that occurred inside urban areas. Of the collisions with passenger cars (241 cases), at intersections (170 cases), the majority (103 cases) occurred at intersections with priority signs. (N.B. Information on intersection control is not available from the automated data base, but could always be found on the police form). A further division was made between four and three legged intersections. There are some differences between the two. However, they have two interesting types of accidents in common.

The first type involves an old cyclist coming from the side road (33 at four legged intersections + 17 cases at three legged intersections) who collides with a car coming from the left (22 + 14 cases). In many of these cases the cyclist has to cross a muli-lane road, which is an indication that it may be difficult to judge the situation, that cars may have high speeds, that it may take much time to cross. It is also an indication of a high volume of cars on the main road, but the police reports did not mention high volumes at the time of the accident. In a few cases the cyclist acts as if he/she is not aware of crossing an intersection by not slowing down and not looking. But in most cases the cyclist slows down or even stops at the intersection, looks around and then decides to cross. In some cases the cyclist concentrates on one car on the main road close to the intersection and starts crossing without paying attention to another car following or overtaking the first one. In a few cases the view of the cyclist is blocked by other road users. In other cases the cyclist sees the car but judges to have enough time to cross, underestimating either the speed of the car or the time needed to cross or both.

There is no direct explanation why old cyclists collide more often with cars coming from the left than from the right. It may be suggested that they judge the situation to the left some time in advance, then concentrate on the situation to the right without checking the left hand side again.

The other interesting type of accident involves a cyclist on the main road who turns to the left, colliding with a car coming from behind (11 + 10 cases). In the majority of cases the car driver sees the cyclist, but either finds no indication of the intended left turn or assumes the cyclist will wait. The cyclist seems to rely on hearing to find out if there is a car coming from behind, because it is physically difficult to look to the rear. As a result, he/she makes a risky decision. The same type of accident is found on road sections inside built-up areas as well (20 cases).

3.3 Conclusions from pilot studies

In both studies useful types of accidents could be classified, based on location, road user and manoeuvre. Few of these types each covered more than 10% of the whole sample, some covered 5 to 10% each, leaving many rare cases not covered by more general types.

With a sample size of about 100 cases, this classification can be made by hand. Most, but not all of the information on which this classification is based, is available from the automated data base. For larger samples (100-500), an initial classification can better be based on the automated data base followed by inspection of the original reports to obtain information on behaviour. In these studies the initial classification was obtained by successive selection of cases. With large samples some kind of cluster analysis may be more appropriate.

Many of the police reports contain information on behaviour and circumstances which is not stored in the automated data base. This information is useful to describe (sub)types of accidents in more detail, providing suggestions for accident causation. However, the information was incomplete.

4 Study with additional report forms

A study has been planned to test the feasibility of routine collection of additional data. This has to be entered on a separate form, in addition to the existing forms. For practical reasons the additional form has to be short and simple, with little overlap with the other forms. In fact three separate forms were designed: one form to be completed by the police, another to be completed by the local road authority and one more to be completed by a special project coordinator. The items included in these forms are listed below.

Police form (for each road user)
- expectation/preparation
- visual search
- recognition/judgement
- attention/condition
- vision/lightening
- speed estimate
- sequence of events
- trip motive

Road authority form (for each road user)
- type of location
- type of road
- road elements
- traffic volume
- control elements
- position of road users
- detailed sketch

Coordinator form
- initial type of accident
- position and direction of movement of road users relative to each other
- intended manoeuvre

Most of the items have precoded answers. The items on the police form have to be answered as estimates or best guesses rather than as legal evidence (as on the standard form). Some of the items on the road authority form could also be answered by the police, others require more detail. The role of the coordinator is to check the completed forms and to combine and recode some of the data on the other forms.

The results of this study may be used to design a new standard for accident reporting with regard to the data to be collected and stored.

5 References

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Table 1: 133 serious accidents on 80 km/h roads

- 80 motor vehicles only
  - 52 road section
    - 45 one vehicle
      - 29 lost control on right side
        - 18 after correction off road on left side
          - 9 left hand curve
          - 7 straight section
    - 7 two or more vehicles
      - 4 overtaking
      - 3 into tail of slow moving vehicle (at night)
  - 28 intersection (priority signs)
    - 23 crossing
      - 17 car on side road, straight on
        - 14 car on main road, from right

Table 2: 479 seriously injured cyclists, age 50+

- 388 inside built-up area
  - 241 with passenger car
    - 170 intersection
      - 103 priority sign
        - 58 four leg
          - 45 crossing
            - 33 car on main road
              - 22 car from left
          - 12 same direction, on main road
            - 11 bicycle to left
              - 4 from cycle path
        - 45 three leg
          - 28 crossing
            - 17 car on main road
              - 14 car from left
            - 11 bicycle on main road
              - 5 bicycle from right, on left hand cycle path
          - 10 same direction on main road
            - 10 bicycle to left
              - 4 from cycle path

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APPRAISAL AND RANKING OF TRAFFIC ACCIDENTS IN JORDAN

Road traffic accidents continues to create a very pressing problem, and it can be attributed to various human, vehicle, roadway and environmental factors. As a developing country, Jordan has had a rapid growth population over the past several years. The population is forecast to reach nearly five million by the end of this century.

The frequency and severity of traffic accidents are useful indices in describing the level of service afforded by a road segment or system.

During 1991, a total of (18.756) vehicle accidents were recorded. The cost of road accidents in Jordan is obviously a subject for detailed research. In 1990 the cost of road accidents in Jordan was $ 71 million.

The aim of this paper is to study the relationship between number of accidents, injuries and deaths and to evaluate the traffic development rates in Jordan.

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SAFETY EVALUATION BY BEHAVIOURAL OBSERVATION AND INTERVIEW

Report - working group E

As it was indicated by the topic of the congress: 'Safety Evaluation of Traffic Systems', presentations and discussions primarily were expected to focus on safety evaluation and evaluation methods. If accidents are the primary, direct indicators of safety - more correctly 'unsafety' - of a traffic system, behavioural observation is an indirect method that deals with observable and frequent events which are, however, only indirectly related to safety. If the different safety indicators can be classified regarding their directness (and frequency), the scale is perhaps as follows: accidents - traffic conflicts - road user errors - road user behaviour in general. Observation of road user errors belongs conceptually to the behavioural observation category, although a separate working group was dedicated to that topic in the congress (Group C). The interview technique, which was one of the topics of the present group, goes even one step further towards being indirect, by asking about habits, opinions, intentions, etc.

While traffic conflicts are already well defined entities and their safety relevance has been proven by several studies, road user behaviour in general is a very broad and complex area which can not be observed or described in its entirety and there is no standardized method to observe or describe its safety relevant aspects. Although behavioural observation and interview techniques are widely used in traffic safety evaluation, they never give immediate answer on a question regarding safety, and are most of the time combined with other methods.

Road traffic can be described as a system consisting of persons and machines interacting in it, and running under a great variety of environmental conditions. Human behaviour in the system is governed by formal and informal rules. The human road user tries to fulfil different needs, one of which is to operate his vehicle or move within moving vehicles in a safe enough way, so that he/she does not be involved in accidents. Even if behaviour in traffic is somewhat restricted and made uniform by the technical system and by traffic rules, it is still extremely diverse, and only some of its aspects or indicators can be observed and described. It is, therefore, impossible to do behavioural observation studies as safety evaluation without at least some conceptual background regarding those aspects of road user behaviour in the given situation that influence safety. Theories on human behaviour and interaction in traffic were the main topic of Group B in the congress, but the topic was present also in our group in an implicit way. It is important to stress that there was an explicit or implicit behavioural theory behind each behavioural study presented.

Presentations in Group E demonstrated clearly the richness and the difficulties of behavioural observation. Each paper represented a different approach, different methods of observation, different behavioural safety indicators, and different areas to be targeted by behavioural or interview techniques.

The presentation of Marie-Berthe Biecheler-Fretel selected traffic violations as behavioural safety indicators. The hypothesis she wanted to test was that "the more a driver breaks traffic lows the higher is his accident risk". Traffic violations as behavioural safety indicators have the advantage that they are observable and measurable, and there are existing institutions that are supposed to influence the frequency of traffic violations. If the hypothesis proves to be true, then driver and generally road user education and police enforcement can provide the necessary influence on the level of traffic violations and traffic safety can be improved by that. The aim of the research presented is to develop an evaluation tool by comparing observed traffic behaviour, traffic violations using police reports as a source, and accidents. The primary areas of interest at the present stage were speeding and drinking and driving. The study has not yet been finished, therefore results could not support the hypothesis. Discussion following the presentation concentrated on traffic violations and their usefulness as safety indicators. Participants referred to studies that supported the hypothesis, i.e. that attitudes regarding traffic violations and accidents are related. Traffic violations seem to be a well distinguishable group of traffic behaviour that is safety relevant, and also can be influenced by legal means. It seems, therefore, a promising area of study and methodological development.

Reinhard Bauer's presentation reported also about a study which is at present in the state of planning. The presented research will be a diploma work at a psychology department. The task is to observe road user behaviour on pedestrian crossings of tramway intersections of different kinds and develop a theory of safe pedestrian behaviour and the design principles of safe pedestrian crossings. The author tried to approach the problem without any preformed ideas on safe behaviour or safe crossing place, and collect information from all traffic participants of the given situation (tram drivers, pedestrians, tram travellers) as well as use a wide series of methods (interviews with experts, with tram drivers and pedestrians, accident analysis, behavioural observation). He tried to understand the phenomenon studied from the participants' frame of reference. It was quite probable, however, that more conservative safety evaluation methods would also be necessary, as the planned accident analysis already indicated it. Discussion after the presentation concentrated on the possible safety questions the study should answer, e.g. if the relative dangerousness of the different crossing layouts is known, what is the normative, expected behaviour in the situations studied, etc. The author stressed his basic approach, i.e. approaching the problem without any predetermined ideas and expectations.

The third presentation, that of Derek Packham, represented again a different approach. The author presented the methodology and some results of a big study carried out at the University of Newcastle upon Tyne. The aim of the study was to investigate factors affecting judgment of risk and attitudes to road safety. The methodological approach of the study was a combination of different methods: interview survey of people's attitudes related to traffic safety, assessment of risk to themselves and to the average driver at specified locations while driving a car on those locations, assessment of risk as pedestrians at specific locations after having crossed the road at the given location, assessment of risk from video clips made at specific locations either from a pedestrian's or from a diver's point of view. The author specifically stressed the advantage of using multiple methods for investigating complex interactions between behaviour and conditions on the road. Multiple methods have two particular benefits: new insights can be gained by cross comparisons, and corroboration of findings across methods can be assessed. A competitive model of road users had been developed, based on the interviews, and five clusters of respondents' attitudes defined, such as order oriented, community oriented, youth oriented, self oriented and unconcerned. The model proposed that the risk evaluation was affected by prevailing concerns and values rather than being based simply on estimates of statistical risk. The research on which the presentation was based was much more rich than what could have been presented in a short time, but the methodological and conceptual framework developed was the most important message of the presentation in the given context.

The last presentation, that of Wolfgang Rauh on motivation, opinions and riding habits of cyclists in Austria was based on a questionnaire survey carried out in Vorarlberg, one of the federal states in Austria. A questionnaire was sent to every household and contained questions related to cycling habits, use of different bicyclist facilities, opinions about the advantages and disadvantages of bicyclist facilities, motives of choosing bicycle as a means of transport, etc. The presentation itself covered a much broader area than the results of the survey. It was a general overview of the different aspects of bicycle use and bicycle traffic with the basic idea that cycling is an important and socially advantageous way of transport which should be promoted and which could make the whole traffic environment more safe if it got all the support it deserved. A far-reaching and lively discussion followed the presentation which revealed that safety experts present had quite divergent opinions about the safety effects of a bigger share of bicycles in traffic.

The presentations that were shortly summarized above studied different problems and selected their methods accordingly. If a conclusion can be drawn from the work of the group as an entity, dealing with the topic of safety evaluation by behavioural observation and interview, we can conclude that the picture presented was very colourful and far from unanimous.

To start with the interview technique, it is clear that it can be a useful part of a divergent set of methods, clarifying underlying opinions, attitudes, habits, etc. It is not a proper tool for safety evaluation in itself.

Behavioural observation is far from being a standardised method of safety evaluation, and taking possible diverse aspects of behaviour into account, perhaps it never will be. There are different approaches to define those aspects of road user behaviour in general that are related to safety. One of those approaches is based on error data, an other one, presented in this group, used traffic violation as a specific group of dangerous road user behaviour. The safety relevance of traffic violations in general has not yet been proven, even if some forms are clearly safety related. Definition of error is an other conceptual problem in traffic, where correct or safe behaviour can hardly be quantified, and acceptable behaviour is quite different in different cultures, even within Europe. Behavioural observation as a method of safety evaluation can not function without a frame of reference, without a definition of those aspects of behaviour that are safety relevant, and a definition of safe and less safe behavioural variants. It seems to me that safe or unsafe behaviour can not be defined in general, only in a situation-specific way. This means that behavioural observation, at least at the present level of the development of the method, needs always a clear definition of the situation in question, a normative description of the expected behaviour in the situation, and a definition of those behavioural aspects that are expected to be safety relevant, therefore need to be observed. The theoretical background described above includes a clearly defined hypothesis. This do not mean that a study can not be started with a 'beginners mind', looking at the problem with fresh eye. A qualitative, phenomenological approach can be useful at the introductory phase, when the situation is described and behavioural variables are defined. It may precede the systematic behavioural observation. The quantitative verification, however, can not be based on random or standard observations, independent of a hypothesis. Adequate indicators can not be selected in general, they have to be related to questions on which they are able to present an answer.

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COMPETITIVE BEHAVIOUR ON THE ROAD

Introduction

This paper reports part of an interdisciplinary project (Carthy et al.,1993) carried out at the University of Newcastle upon Tyne that was based on a 36 km. route in and around the City. It pays particular attention to the range of procedures adopted with a view to comparing data obtained by subjective and objective methods, as well as direct and indirect risk assessment.

There were four phases to the project. The main attitudinal data were collected from interviews with 319 people in their homes or at the University. 207 people drove the route in their own or a hired car (it was their choice and ended up about 50/50). They provided an assessment of risk to themselves and to the average driver at the specified locations using a 10-point rating scale. 133 people were taken to seven locations as pedestrians where they crossed the road and were then asked to give similar risk ratings. A more detailed, direct appraisal of various attributes of the sites was also obtained and how these attributes might contribute to the risk rating. In contrast to the on-site surveys (ie. the drives and the walks), the fourth survey involved collecting equivalent data indirectly, off-site; it used a novel approach, making use of a specially equipped lecture theatre in the Department of Psychology. Here 473 people typically in groups of 30/40, watched video film of specific locations from the drive route and again gave ratings of risk. They did this on the basis of 10 film clips, 5 from the driver's viewpoint and 5 from the pedestrian's viewpoint, and their responses were made on a small keypad that allowed direct recording onto a computer.
Within each survey volunteers were divided by age and gender forming twelve groups for the purposes of comparison: male/female; 17-24, 25-34, 35-44, 45-54, 55-64, 65 years and over. An important feature was that some participants were involved in more than one survey, for example, 95 people were both interviewees and drivers.

Results

For the purposes of discussing competitive behaviour on the road, attention will mainly be focussed on the attitudinal data and drivers' assessment of risk to themselves although corroborative evidence from the pedestrian walks and the indirect video assessments will also be cited.

(a) Interviews

In order to put the findings into a more general context, Table 1 summarises the mean ratings given by all the respondents across a range of social issues. Each interview took about an hour to complete and contained many sub-divided questions so only the major clusters of attitudes are now discussed in relation to Table 2.

Table I. Road accidents in the context of other concerns (higher ratings out of 5 indicate greater concern)

Issue	Mean rating
Violent crime	4.31
House theft	4.02
Social health care	3.95
Standards of education	3.94
Pollution in the environment	3.93
Road accidents	3.90
Drug abuse	3.82
Unemployment	3.71
AIDS	3.69
The 'cost of living'	3.39
Traffic congestion	3.31

Table 2. Clusters of attitudes

1. *order-oriented:* rule-directed, law-abiding and concern for a well-ordered environment;
2. *community-oriented:* concerned for the fabric of society and the environment;
3. *youth-oriented:* oriented towards the concerns of youth, tolerant, 'anything goes' outlook;
4. *self-oriented:* selfish, everyone for themselves, kicking against social constraints of order and discipline; and
5. *unconcerned:* disengaged, little or no concern with social issues compared with immediate needs, doesn't know and/or doesn't care.

These cluster patterns of attitudes can be more extensively defined by setting out their main characteristics and by observing their intercorrelations. Individuals scoring higher on cluster 1 (order oriented) tends to be more in favour of road discipline, and the perceptual directives provided by road signs and markings. They regard improvements in these road indicators, together with the better discipline of vehicles and pedestrians, as effective countermeasures to accidents. Accidents themselves are viewed as being caused predominantly by slips and errors of behaviour - rather than wilfully committed. Thus, in this ordered context, anti-social behaviour is perceived as threatening.

Those who scored higher on cluster 2 (community oriented) are members of a group which shows concern about social and ecological issues. They view the reduction of vehicles and restriction of their access as effective so that any accident countermeasure that necessarily inconveniences the private motorist would be accepted in a positive frame of mind. For example, the introduction of road humps are seen as a necessary imposition with a beneficial outcome. Similarly, for the good of the community and the environment, stricter laws against drink-driving and more severe laws and punishments would meet their approval.

Cluster 3 (youth oriented) is characterised by attributes which show them to be against stronger law enforcement of any issue that demands greater social responsibility. They do not favour further restrictions on the young, nor consider targeting the young, whether they be drivers or pedestrians, as effective measures to reduce road traffic accidents.

People with higher scores on cluster 4 (self oriented) tend to be averse to any measures involving the banning of alcohol and the setting up of deterrents backed by severe punishments. They tend to disregard the role of external factors, such as traffic density and policy making as having any significant influence upon accident reduction. They see little point in reducing speed limits or the stronger enforcement of the existing limits, and view road humps negatively as an impediment to motoring, rather than as a safety factor.

Higher scores on cluster 5 (unconcerned) show little or no concern about social issues, other than immediate requirements. By opting out, they do not appear to support any positive steps to alleviate traffic accidents. This attitude of mind is characterised by thinking that reducing motorway speeds or other methods of limiting driving speeds would not have any effect on the accident rate. They have no definite views, one way or another, on the social implications of different modes of transport. Nor do they show much awareness of effective safety measures, such as the recommending and the enforcement of wearing seatbelts. They do not regard violations or stupidity as a major cause of accidents.

Attitude differences across 12 sub-groups, male/female and age are also relevant. Cluster 1 (order-oriented) is more prevalent in older groups and more associated with women. Cluster 2 does not show such strong differences although women are more likely to score highly. Of course younger respondents score more highly on Cluster 3 - more interesting is that women are less likely to have this attitude of mind and that drivers score much more highly on this dimension than non-drivers. Younger men are particularly evident as a group holding the self-oriented cluster of attitudes and again drivers score more highly than non-drivers.

From other questions it appears that more competitive driving behaviour is associated with holding attitudes summarised under Cluster 3 and Cluster 4 headings and further that competitive behaviour is also positively correlated with an accident history. Young male drivers again predominate in Cluster 5 and there are high intercorrelations with Clusters 3 and 4.

(b) Driver Assessment of Risk

One way of construing relationships among road users is in terms of relative dominance: drivers, for example, can be seen as occupying positions of fluctuating dominance - from waiting to turn out of a minor into a busy major road, through jockeying for position when lanes merge, up to what might seem the most desirable position of accelerating past slower traffic. Constant amongst all this variation is that pedestrians pose the lowest threat and, given their vulnerability, it is important to examine the consequences for them:-

(i) a major finding from the drive data is that drivers pay little heed to competing pedestrian activity in assessing risk. The drivers' risk ratings, though they correlate moderately with numbers of vehicle accidents, as other researchers have found, bear no relationship to pedestrian accidents. For instance, in relation to two sites, one with the most vehicle injury accidents in the four years prior to our study and the other with the most pedestrian accidents, drivers respectively gave high and only average ratings. These drive data are corroborated in the more detailed analysis made possible via the video presentation from the driver's perspective when people had more time to reflect on their decisions; ratings correlated well with the direct assessments made during the drives but again little account was taken of competing pedestrian activity.

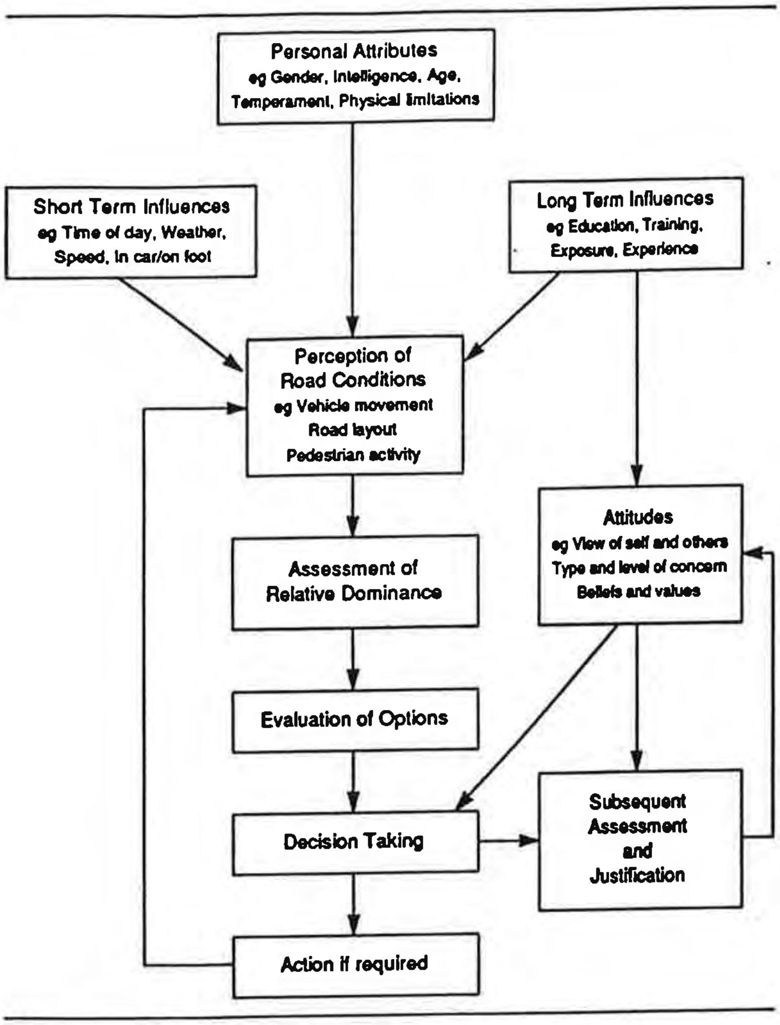
(ii) from the walks data important differences emerge depending on whether the pedestrians also possessed driving experience that would enable them to assess potential dangers in each location from both points of view. The differences in risk ratings suggested that they took into account, perhaps implicitly, their behaviour as drivers. Other studies eg. among older pedestrians (Sheppard and Pattinson, 1986) show that non-drivers are more prone to pedestrian accidents.

(iii) in addition, there is the frequent tendency, at least in the UK as acknowledged in the recently revised Highway Code, for some drivers to threaten pedestrians about to use a designated crossing (by not braking until the last moment). In some cases the right of way may be unclear and the danger is that competition can resolve it - from the pedestrians' viewpoint they may feel secure in exercising their legal right but from the drivers' position it may seem unreasonable to have to stop so quickly. Equally dangerous are instances when drivers explicitly compete with one another by braking late at roundabouts or as lanes merge.

Competition Model

Taking Brown's (1991) model of subjective safety as its starting point, this model offers a means of linking perception of risk and attitudes to road use. As well as providing a means of summarising the types of conflict on the road discussed above, the framework can generate hypotheses about the links between biographical data and driver behaviour, for example, or the processes of attributing causation of and blame for accidents.

Figure 1. **Competition model of road user behaviour**



As shown in Figure 1, external influences at the time combine with individuals' attributes, as modified by their accumulated knowledge, to affect their perception of road conditions. They then assess whether they have priority to proceed before considering the available options. Importantly the model proposes that this evaluation is affected by prevailing concerns and values rather than being based simply on estimates of statistical risk. Our analysis suggests that non-rational factors (eg. the need to assert one's perceived rights) can affect the ways the relationships with other road users are assessed. Moreover, in the absence of clear cues to resolve the ambiguity, the outcome can be a failure to yield which in many instances leads to accidents. Decisions taken therefore may or may not be rational and this applies also to any subsequent justification of the action taken, where the victim, such as a child pedestrian, may be blamed unreasonably.

If the competition model is accepted, then in one sense it simply underlines what traffic engineers have been trying to do for many years, namely to impose some degree of order and clarity of purpose onto the road network. If priorities can be defined more clearly and the requirement for one party to yield can be made more obvious, then such a location is likely to be safer. Markings, signs, and other visual cues should all point unambiguously to the same conclusion for all road users; one traffic stream has priority, the others do not. Whilst our analysis suggests that this approach will yield positive benefits with order and community oriented people, it may produce unwelcome side effects amongst self and youth oriented individuals. These groups may resent too rigid a set of rules and consciously seek to break them. Whilst more rules and clearer guidance can reinforce the values of the order oriented individual, for the more anarchic in society the rigidity imposed is less acceptable. In the limit it may lead to a release of frustration elsewhere on the road network. If the need to compete is stifled at the road junction, it may emerge more aggressively by speeding on the next stretch of open road. Thus countermeasures which act at the unconscious level may be more effective in addressing all road users to behave in an acceptable manner. These might vary from the specific to the general; from the use of spiral markings to indicate positioning in relation to exits from roundabouts to an intervention programme to devalue speeding as an acceptable driving behaviour.

The Use of Multiple Methods

In an area as complex as road safety, many variables interact and their combined effects are seldom easy to interpret. In studies involving any form of self-report the initial approach to the road user will be important if attitudes and the bases for choice are to be accurately reflected eg. any perceived threat or need to avoid attribution of blame could significantly affect responses. Equally, the range of methods used and the opportunity for a proportion of people to participate in more than one phase of a study will necessarily affect the quality of data that will be collected and confidence in making broader inferences from the results.

Moreover, the conclusions that have been drawn here about competitive behaviour have been strengthened by the cross referencing, made possible because a proportion of drivers participated in more than one phase of the overall project. New insights can be gained by the process of cross comparison: about different problems faced by different types of drivers at the same sets of locations, for example. Had we relied solely on questionnaire data, it would not have been possible to assess perception of risk directly and, without the independently_collected accident data, the potential importance of competitive behaviour would have lacked adequate corroboration. More generally, linking objective and subjective measures, direct and indirect assessments should enable us to interpret more accurately the intricate and sometimes paradoxical behaviour of road users.

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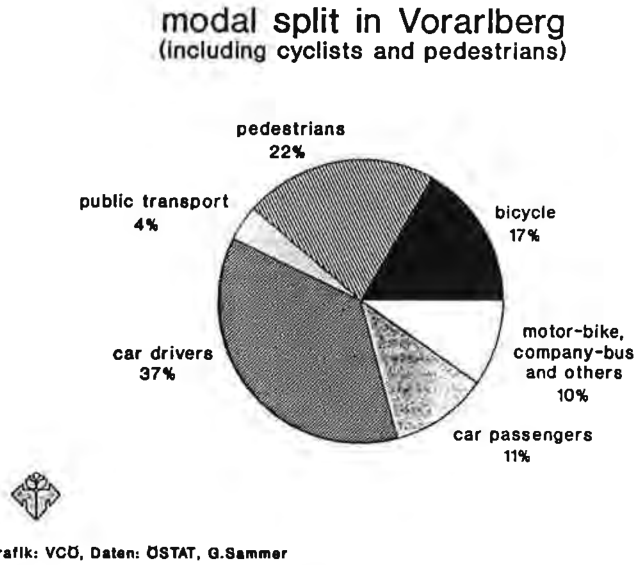
MOTIVATION, OPINIONS AND TRAFFIC-BEHAVIOUR OF CYCLISTS IN AUSTRIA

With the first edition of the "guide to bicycle-friendly organisation of road-traffic - Das Fahrrad im Verkehr" [5] in 1990, several communities became interested in concepts for the promotion of bicycle traffic offered by VCÖ.

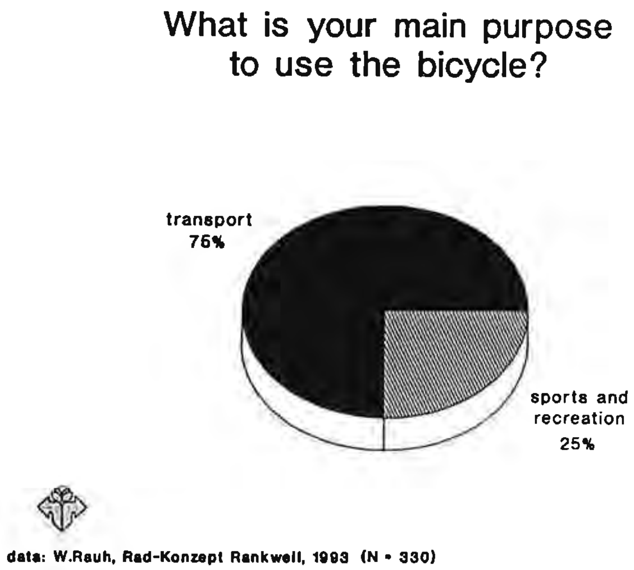
Work on these concepts always started with questionnaires being sent to every household. To be sure that the proper planning-suggestions would be made for the proper places data had to be gathered concerning (amongst many others) the following questions:

* How important is bicycle-traffic in the town or village already (or still)?
* Does the majority of cyclists use the bicycle as a means of transport or for sports and recreation only?
* Is the bicycle used by young people only or is it used by all age groups?
* Can cyclists be seen as vehicle drivers with full traffic skills or merely as "pedestrians on wheels"?
* Do cyclists use the bicycle all year or do they quit cycling as weather and road conditions get worse on rainy days or during winter?
* Is it sufficient to offer safe and comfortable connections to cyclists through side roads or do cyclists have to use the main roads of towns and villages too?
* Is it sufficient to make cycling safer or is there more that in planning for bicycle traffic has to be taken in account?
* How do cyclists appreciate different types of facilities (cycle lanes, advisory cycle-lanes, cycle-paths...)?

Results of questinoning:

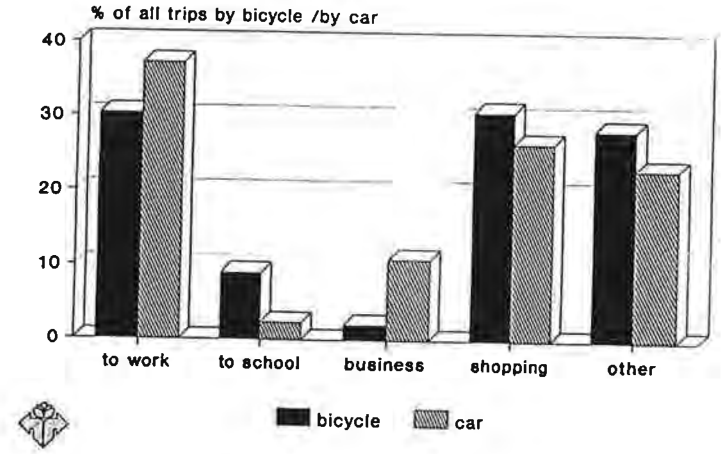


According to the Austrian bureau of statistics in the region of Vorarlberg where the concepts were made, 17% of daily trips are done by bicycle [9][10]. It appeared that this proportion can get as high as 20% to 25% in a town or village situated in flat area.



75% state that they use the bicycle mainly as a means of transport [8]. In this group the number of weekly bicycle trips (another question) in average is 2.5 times as high as with people who mostly cycle for the purpose of sports and recreation.

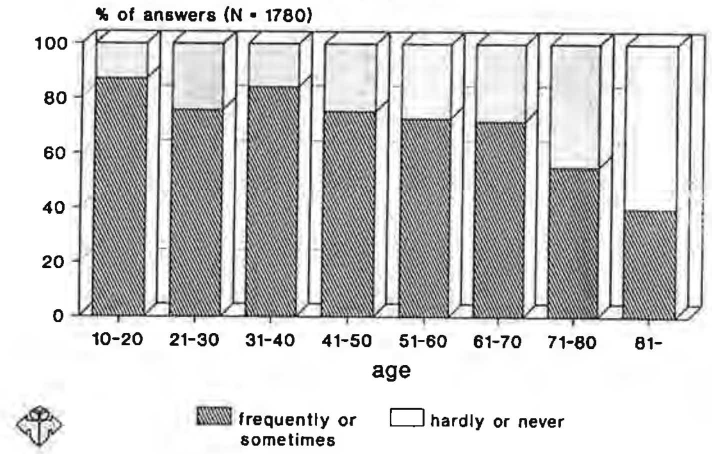
Purpose of trips
(excluding way back home)



data: ÖSTAT, Mikrozensus 1983

The results from the questionnaires seem to confirm older data (1983) from the Austrian bureau of statistics (ÖSTAT) showing that the main purposes of trips by car and by bicycle are almost the same [9].

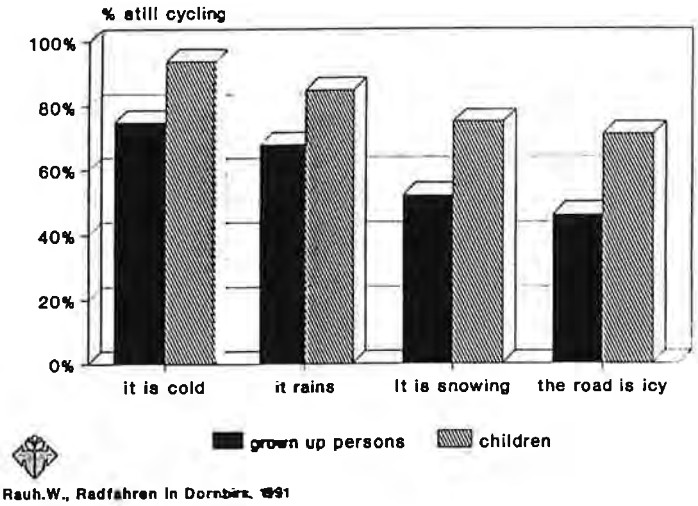
How often do you use the bicycle?
(bicycle use depending on age)



data:O.Hutter, Verkehr in Dornbirn, 1990

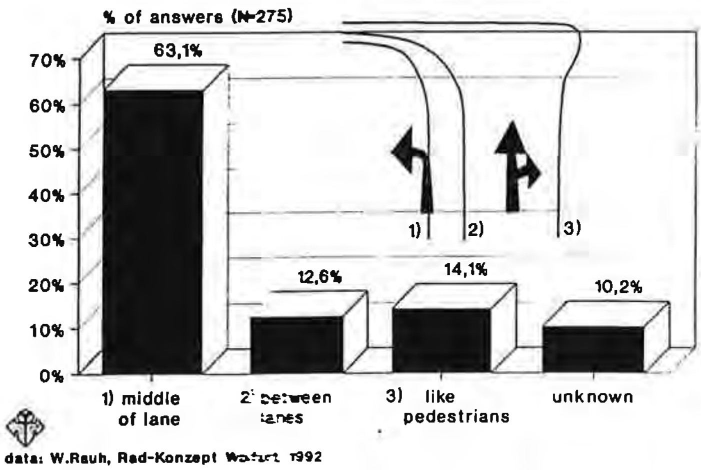
Only in the age-group of 71 and over there is a strong decline in the number of people who use the bicycle "frequently" or "sometimes" [3].

Do you continue cycling if...



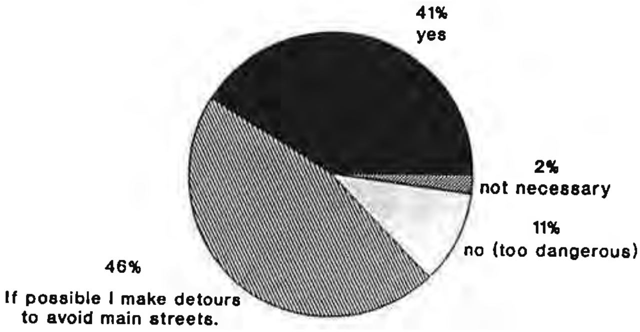
Only in conditions when even driving a car is not advisable around 50% of grown up cyclists and still less children give up cycling [6].

How do you turn left on crossings with left-turning lanes?



Assuming that the way a cyclist makes a left turn can be regarded as an indication of the degree of his or her "traffic-skills", it can be said that the proportion of cyclists who are "pedestrians on wheels" is less than one in five [7].

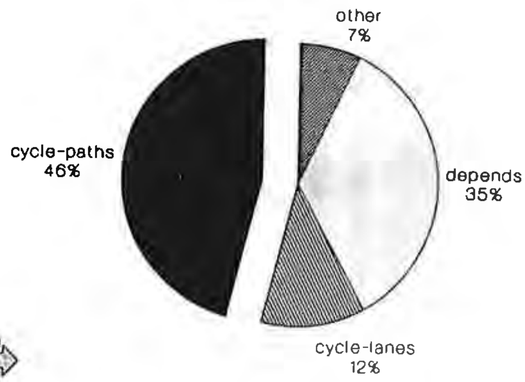
Do you cycle on the main streets?
(Names of streets were listed)



Rauh W., Rad-Konzept Rankweil, 1993

Only 2% state that it is not necessary for them to cycle on the main streets of the town. 46% make detours to avoid cycling on main streets as much as possible and 11% choose other means of transport[8].

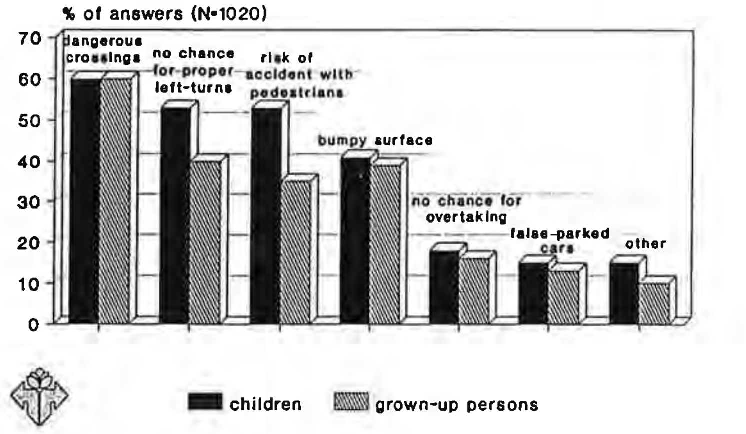
Would you prefer a street to have
cycle-paths or cycle lanes?



W.Rauh, Radfahren in Dornbirn, 1991
N-950

Asked for the best solution to their problems, a relative majority of cyclists opt for the highest degree of seperation from motorized traffic (e.g. cycle-path instead of cycle-lane) apparently thinking that this is the safest solution. Those who probably tend to think more about the problems (not solutions) concede that cycle lanes may in some cases or even in any case be better[6].

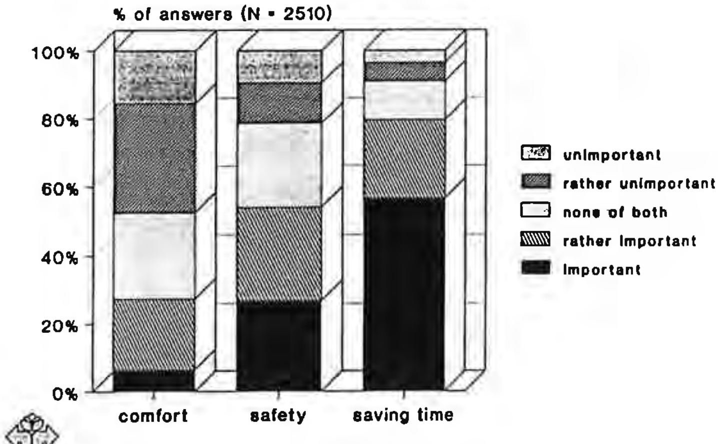
What is most annoying if you use the cyclepaths in Śtadtstraße?



Rauh W., Radfahren in Dornbirn, 1991

Asked directly about the problems that occur on cycle-paths, most cyclists state the risks and hindrances well known from the analysis of accicent data and traffic-conflicts [2][4][6].

How important are the following reasons to choose a certain means of transport?



VCÖ, Unterwegs zur Universität, 1990

There are many reasons to choose or not to choose a certain means of transport. Three of them - comfort, average speed and safety can be influenced by the way traffic facilities are designed and traffic is organized. Among these three motives "saving time" (= average speed of travel) is stated as most important by far [1].

Conclusions:

Most people who use the bicycle use it as a means of transport for their way to work, to school or shopping. Therefore conditions for cyclists have to be improved

where schools, shops and offices are: in the **centre of towns and villages** and within the centre **on the main streets** in the first place.
Cyclists in general are **not "pedestrians on wheels"**. If cyclists are denied the possibility to make proper left turns or if they are forced to share the pavements with pedestrians, this is not a way to promote cycling. Cycling can only become more attractive, if all the main reasons for people to choose a means of transport are taken in account. This means that

cycling must become faster (= without delays or detours)
cycling must become safer
cycling must become more comfortable

Who wants to improve conditions for cycling in a town or village has to find out by observation and questioning where the problems for cyclists ocur. Ready solutions cannot be asked from the cyclists. Solutions with all proper details have to be worked out on the basis of thorough knowledge of the traffic-behaviour of cyclists and of a bicycle-oriented traffic technique.
Building cycle paths unfortunately is not a comfortable "standard recipe" to solve all problems of cyclists. This is specially the case with safety problems. These can get even worse by bulding cycle paths [2] [4]. If there is any "recipe" how to make cycling safer and more attractive in towns and villages it can only be this:
Use all possibilities to make it easier for cyclists to be what they are and what they have to be as long as cycling should make any sense: vehicle drivers sharing the roadway with other vehicle drivers.

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BEHAVIOUR AT TRAMWAY CROSSINGS: CONCEPTUAL AND METHODICAL CONSIDERATIONS ON A PREVENTION-ORIENTED STUDY IN STUTTGART

Abstract

Definition of the problem:
In the field of public local traffic there is uncertainty regarding the safety-relevant effects of particular arrangements at pedestrian crossings in the field of tramways and city railways. It is not known what kind of arrangements are necessary and sufficient under safety aspects.

Aims:
Proceeding from the actual behaviour at differently organized crossings there shall be attempted by the means of theoretically structured designs and methods to systematize the behaviour of the passers-by and to relate it to the arrangements on the scene. Therefrom, recommendations for a safety-relevant organization of pedestrian crossings shall be derived. Proposals for improvements shall be elaborated.

Procedure:
By interviewing experts, tramway conductors and pedestrians as well as by analysing accident data, problematic crossings and situations are identified.On the basis of these results particular crossings are selected for a comparative behaviour observation. The analysis of the observation data should lead to conclusions concerning the behaviour at differently organized crossings as well as in specific situations.

In this report the problem as well as the selection and the combination of the methods will be demonstrated and explained. The methods will be presented and discussed one by one.

The paper which is to be presented is a thesis in the subject of psychology, more exactly in the optional subject of ecological psychology at the university of T_bingen. The thesis is supervised by Prof. Kaminski. The project is carried out in the field of the surface rail traffic of the "Stuttgarter Straßenbahnen (SSB) AG", the local traffic company of Stuttgart mainly operating busses, tramways and city railways, and supported by the SSB.

The aim of this project is to systematize the behaviour of pedestrians at rail crossings by the means of theoretically structured methods and to relate it to the arrangements on the scene. Proceeding from this, assessments of the traffic safety of these crossings shall be elaborated and recommendations for a safety relevant organization of crossings shall be derived.

The purpose of this report is not merely to present results, rather I would like to describe a definition of the problem as well as my approach to the subject, as the project is not completed yet and as presently, this working group is concerned with methodical questions. At present I am occupied with the elaboration of accident analyses (see below).

1. Definition of the problem

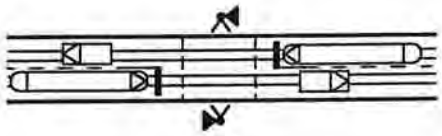
In 1990, there was a series of serious accidents in Stuttgart involving tramways respectively city railways and pedestrians at rail crossings. The Press adopted the subject, which was also discussed by the political committees of the city. The local Press was talking of "killer crossings". In the subsequent years, especially the municipal commission concentrating on accidents dealt with the subject. Within the SSB it was decided to build so-called z-crossings (see below) on condition that the space needed is available and that new construction measures are under consideration. Nevertheless, there is still uncertainty concerning the safety relevance of the various existing arrangements.

At present, there are numerous differently organized crossings according to historical and spatial aspects. The most important variants can be seen in picture 1.

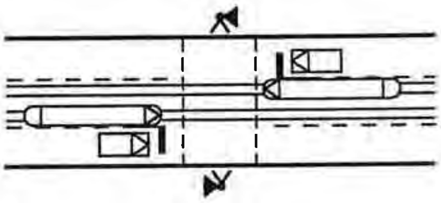
Picture 1: Basic models of the most important crossing-types

The most important kinds of pedestrian crossings

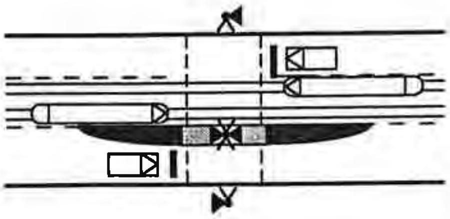
Alternative 1
Tram on grooved rail.
The rails of the tramway are imbetted in the lanes of traffic.
Traffic lights aim at tramway, car traffic and pedestrian.



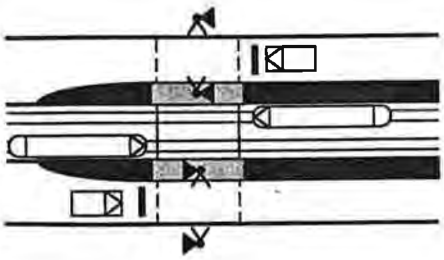
Alternative 2
Tram on grooved rail.
Tracks between car traffic lanes.
Traffic lights aim at tramway, car traffic and pedestrian.



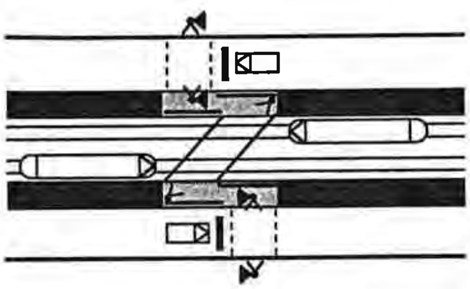
Alternative 3
Tram on grooved rail or right of way (tracks seperated from car traffic by kerbs, green lanes ... .)
Pedestrian crossing with separate traffic lights for the lanes.
Traffic light aim at tramway, car traffic and pedestrian



Alternative 4
Right of way.
Pedestrian crossing with separate traffic lights for the car lanes.
Traffic lights do not aim at tramway.
In some case pedestrian crossing on the tracks with yellow flashing light.



Alternative 5
Pedestrian crossing with Z-shape
Right of way.
Pedestrian crossing with separate traffic lights for the car lanes.
Traffic lights do not aim at tramway.
Pedestrian crossing on the tracks with Z-shape, yellow flashing light or alternating light.



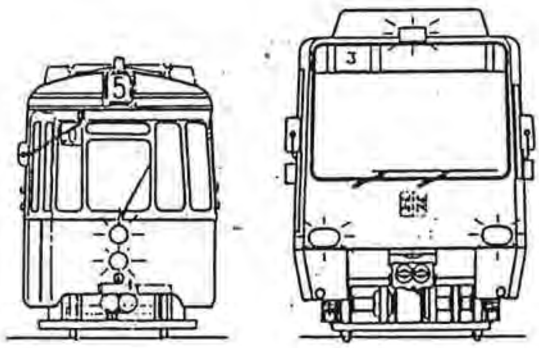
Apart from the differences in the spatial arrangement there are several variants concerning signposting and flash-signals. Almost all the crossings (with the exception of the first two crossing variants in pict. 1) are equipped with warning signals indicating the rail crossing. Again, there are several different signs. Both, the flash signals as well as the signs are in different positions at the crossings.

As for the flash-signal installations at particular tracks the following variants can be listed:

* Single red light (pedestrian symbol)
* Double red light (one pedestrian symbol on top of the other)
* One yellow flashing light, partly with tramway symbol
* Two yellow flashing lights next to each other (blinking in different intervals)
* Two yellow flashing lights, one on top of the other (blinking in different intervals)

The flashing installations and the red light are in operation when a train is approaching the pedestrian crossing. At the z-crossing the signals are screwed in so that the tramway driver can see whether these are in operation.

One further complication results from the mixed operating system operating two different car types. According to public opinion the new, large city-railway car is partly considered as the cause of the accidents and is felt to be more dangerous than the smaller variant of city-railway cars. Picture 2 shows the front side of both car-types in the form of a graphic representation.



Picture 2: The two car-types of the SSB in Stuttgart. (Source: Stuttgarter Straßenbahnen AG.)

Compared with the conventional city-railway-car, the new car is a lot more quiet, it runs more smoothly (with fewer rocking motions) and reaches a higher maximal speed (80 km/h instead of 60 km/h). The new car (width: 2,65 m) runs in standard-gauge tracks whereas the conventional type (width: 2,20 m) has to be operated in a one-meter-gauge system. In other words, within the area of the mixed operating system there are three rails per track, which have to be crossed by the pedestrian. As can be seen in picture 2, the new car has a totally differently shaped front-side and designing, which leads to totally different bound and rebound processes in the case of collision. Probably, a different driving style as well as a different perception on the part of the pedestrians has to be considered with both car-types.

The aim of this study is to determine the most effective kind of crossing for traffic handling and traffic safety (taking into account as many arrangement details as possible, as well as spatially defined particularities) or at least, to reach relative conclusions concerning safety on the basis of a comparison with existing crossings.

In the following I would like to describe the methods I selected for that purpose.

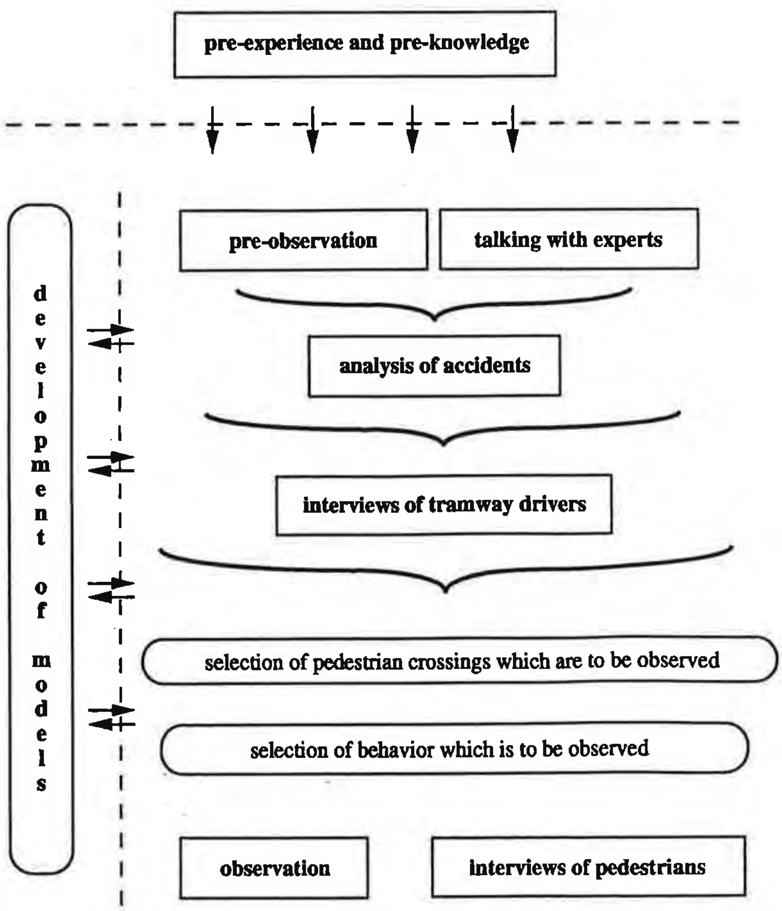
2. Methodical procedure

The multitude of variables that have to be considered as well as the rarity of accidents prevented a systematical-statistical procedure according to an experimental or a quasi-experimental design, at least within the limits of a conventional thesis. The theoretical approach, however, that I would like to pursue does not necessarily require such a design. Accidents are regarded as the final stage of a complex course of action which is preceded by cognitions, preliminary regulations, etc. Similar to the analysis of the problem in Hacker (e.g. Hacker, W. 1986), the problem of the safety of pedestrian crossings requires the assumption of relatively constant and systematic behaviour or action patterns respectively action demands, the identification of which requires a rather explorative procedure.

By explorative methods of this kind I attempted to approach the subject from different angles in order to penetrate it subsequently by the means of observations and interviews.

Picture 3 shows the individual phases in a chronological order from top to bottom. The brackets should symbolize the course of action but also the widened base of knowledge influencing each of the subsequent phases. In the following, the methods to be seen in picture 3 will be discussed and explained separately, including a description of the logical procedure of this study.

Investigation design



2.1. Model design

In parallel to the empirical parts, model considerations will be made with regard to the illustration of the action patterns mentioned. These models will be tested in existing reality and revised. They serve to systematize the observed behaviour but also as "a pair of spectacles" in the course of the ongoing study.

The model propounded raises questions like:

* What pre-conditions make the riskless crossing of rails possible?
* How can a risk potential be identified?

The model design serves as a "pair of spectacles" in a more comprehensive sense, as it introduces the theoretical terms applied in the study.These terms serve to describe the sector of reality observed as well as the theoretical implications, on the basis of which the study is carried out.

The model design also conforms to Kaminskis conception of a transactionalist theory of action, which aims at the registration of actions in dynamic environments in dependence on these environments (Kaminski, in preparation).

2.2. Previous experience and previous knowledge

First of all, picture 3 describes previous experiences and previous knowledge. Normally, this item is not mentioned, however, it seems to be essential in this paper. (Presumably, it can be said that as this item is always important it should be explained more frequently.)

On the one hand, previous knowledge refers to the study of ecological psychology, which teaches how to connect spatial environment to the behaviour observed in this environment. In this respect Barkers Behaviour-Setting-Analysis (e.g. Barker, R. G. 1978 & Ass.) should be mentioned as an example. Barker identified spatial-temporal behaviour settings, which are characterized by determined rules of behaviour. He proceeded on the assumption that these rules are in a way naturally linked to the corresponding spatial settings. A bakery or an intersection may be regarded as such settings. Kruse, Graumann, Lantermann (Hg., 1990) give a general view of the comprehensive field of ecological psychology.

On the other hand, a real-life reference to the subject is important. This is the case in road traffic studies, in so far as the analysts know the field from an interior view as car drivers and pedestrians. Of course, this is hardly the case with rail-borne vehicles.

Nevertheless, in this case there is a certain familiarity with the partial system, rail-bound local traffic. My father was a tramway-conductor in Stuttgart, so for me, it was a matter of course to use the tramway as a preferable means of transportation. Thus, from the beginning, there existed familiarity with the locality as well as a certain knowledge about the means of transportation and the transportation company concerned.

Explanations like that also involve a biassed position, so that I, for example, do not call in question that the flow of rail traffic should be quite fast and that this transport system should take precedence over other motorized means of transport.

2.3. Preliminary Observation

Preliminary observations are held in everyday-life as well as in target-specific ways. Thus, since I started planning and carrying out this study, I have chosen the seat behind the driver when using the railway in order to dispose of a similar field of vision. In addition, I come to a stop at pedestrian crossings time and again in order to observe the people using them. Another important point is the observation of oneself during the everyday-use of crossings in order to answer questions like:

* Which aim of action controls my behaviour in dependence on the location?
* When do changes in behaviour settings take place?
* Where and when do orientations take place?
* How do different signals influence the courses of action?
* Which role does acoustic information play in orientation?

...

Furthermore, I visit specific locations, e.g. with a particular regulation system in order to observe its influence, first of all informally.

Apart from the observation of the courses of action, preliminary observations of this kind lead to an increased familiarity with the locality.

2.4. Interviews with experts

This part of the study especially refers to interviews with staff members of the different departments within the transportation company who have to deal with the subject (law, traffic, public relations, management, planning, construction) as well as with agents of the traffic police of the respective city.

These interviews are rather informal and unstructured, only the items to be discussed are defined in advance. Interviews with experts serve to become familiar with the different experiences and opinions of experts as well as with the legal,planning and "informal" background of the subject, e.g. in order to be able to assess which alterations are actually possible.

The term "informal" means that we need answers to questions like:

* Where can the different kinds of information be obtained?
* What are the interrelations of forces and the actual streams of communication like in the transportation company?
* How does the co-operation among transportation company, police and municipality work?
* Who pursues what kind of interests?
* Which hypotheses exist about the causes of accidents?

2.5. Accident analysis

The analysis of accidents was only planned to a very limited extent. While examining the different accidents, however, I became convinced that a statistical analysis of existing accident data would also be advantageous with a relatively small number of accident situations and that this could supply a series of information. In this case, I drew upon accidents happening at crossings from July 1990 to June 1993. The files of the legal branch of the SSB served as a data basis, the amount and the quality of the data varies according to the different accidents. Partly, there existed investigation files of the police to rely on, partly only internal records of the SSB.

On the base of these documents I selected all the relevant data which could serve to illuminate the details of the incident as well as the course of action.

This included not only collisions involving pedestrians and cyclists at crossings but also situations where, although a collision was avoided, the driver carried out a so-called danger-braking at the crossing because of a pedestrian or a cyclist. Frequently it is the case that a passenger on the train was hurt in consequence of the braking. So far, accidents of this kind have not been observed at crossings. Whether a danger-braking involving no injured parties is reported to the transportation company or not is entirely up to the driver. The number of all the accidents and near-accidents recorded within the three years of the study is of the order of about one hundred.

Apart from the analysis of the marginal conditions often to be found in accident statistics (e. g. month, time of the day, sex, age, etc.), typical courses of action are identified and described before finding out to what extent these courses of action accumulate.

A relatively frequent pattern, which was also found by Brändli and Kobi (1989), is for example:

> A pedestrian pursues the aim of action to catch the tramway in time. At the same time, he pursues the secondary aim of crossing the rails safely only unsufficiently or incorrectly.

Furthermore, the accident analysis serves the identification of problematic crossings and types of crossing as well as that of problematic situations and their marginal conditions (time of the day, etc.), which shall be observed later on.

2.6. Interviews with conductors

On the one hand, conductors are informants as observers, on the other hand they are themselves involved in the traffic and accident happenings at the crossing as interacting participants. Both aspects are considered in the semi-standardized interviews based on a prepared interview guide.

First of all, the conductors are asked about their general experiences, opinions and attitudes concerning the subject. In that way it should be found out what importance the subject has among them, how they think about it, etc. First, explorative questions are used for this purpose. Finally, more and more specific questions are asked, the conductor is confronted with the results of the accident analysis and asked to comment on particular types of crossings, problematic crossings and situations. He is shown pictures for that purpose.

These interviews are carried out only with 6 to 10 conductors, as this number can probably cover the principal aspects and as a higher number would require more time than is available.

2.7. Observation

On the basis of the results of the existing interviews, inquiries and analyses the observation method is specified (video, direct observation or both), the relevant situations and locations are selected. In the case of a thorough observation and analysis of the resulting data, only few locations can be observed; however, on the basis of the preliminary studies carried out a small number of locations might also be sufficient to obtain results.

The point of the observation is to find out,

* which paths are actually used at the particular crossings
* which typical courses of action can be observed
* which danger avoiding and danger increasing actions respectively partial actions are performed
* and where and how the danger orientation takes place

2.8. Interviews with pedestrians

Actions always include unobservable components, too (perceptions, cognitions, etc.). By the means of interviews with pedestrians these gaps in the field of the observation shall be filled, as far as this is possible. For that purpose, the pedestrians are interviewed directly after crossing the rails about the installation and about their behaviour. They should in a way comment on their behaviour. In this case it will also be important, to what extent the pedestrians realize the purpose of the crossing facility respectively which hypotheses they have about them.

The data resulting from the three kinds of interrogations (with experts, conductors, and pedestrians) as well as from the preliminary observations and observations, have to be related to the spatial conditions by the aid of the model considerations, in addition, safety assessments concerning these spatial conditions have to be elaborated. Therefrom, recommendations for the future organization of crossings will be derived.

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TRAFFIC CALMING MEASURES AND INFORMATION SUPPORT

In accordance with the role of too high and nonadjusted speed of vehicles in endangering of road traffic safety, traffic calming concept is one of the leading one in safety work here now, particularly in urban areas.

In that field some of the measures are not the legal ones and there is a big variety of shapes, dimensions and signing of them, partly due to ununified practice in widen relations.

There is a big interest here for standards, recommendations and common practice, not only in the field of traffic calming solutions and measures.

Procedures that are practiced in solving of safety problems in urban areas by the using of traffic calming measures are considerably based on computer programme package "Integral Information System of Traffic Safety on Road Network", prepared for our own usage.

Some results and experience with the using of mentioned procedures as well as the problem of standardisation would be the matter of my contribution at the Congress.

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OCCURENCE AND CONTROL OF MOTORING OFFENCES EVALUATION OF THE PREVENTIVE SYSTEM OF REGULATION

This paper presents an alternative approach to the traditional evaluation of the regulatory prevention based on the linear linkage between a countermeasure and its impact on risk. Focused on the violation of the rule as a key criterium (risk predictor, observable and measurable behavioral fact, educative response) of the regulatory action, the approach develops new conceptions and methods turned towards a more comprehensive knowledge of the complex process of regulation.

The regulatory action process is viewed as an interactive system and a multi-criteria process involving different actors (drivers, control officers, judges and administrative officers) and covering the three usual areas of traffic safety studies: motoring and driver behaviour, control of motoring offences, road accidents. The evaluation based on this approach consists in developing the study of the correspondances between patterns of common variables observed in every mentioned area: behavior, control offence and accidents. The main common variables cover the classical categories of risk analysis (type of road, time and type of day, type of vehicle and categories of trips, sex, age, occupation, ...) and describe the main road offences (drinking and driving, speed, seat-belt, ...).

This methodology of evaluation has been applied at a local level in France by the mean of coordinated surveys carried out in 1991-92. The ongoing development of the experimental tool of evaluation will be presented including some resuls.

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TRAFFIC CONFLICT TECHNIQUE AS A MEASURE FOR SAFETY EVALUATION

Report - working group F

General comments

The group session included four papers. Two of the papers dealt with "traditional" conflict studies involving field studies with observers on site. These Austrian papers had an emphasis on discussing the role of traffic conflict studies and techniques in general safety analysis.

The other two papers had as their starting point one of the most crucial disadvantages of the traditional conflict techniques - their high costs due to its manpower requirement. The approaches, however, were totally different. One aimed at saving costs by making the observation and conflict scoring processes automatic with the help of image processing. The other used simulation of conflicts as a means of producing large quantities of conflict data for studying the effects of traffic engineering and road design measures.

The main differences between the papers can be summarized in the following way:

	Austrian studies	Canadian study	Swedish study
Data collection	On-site field observation	Simulation	Automatic Image processing
Role of conflicts	Complement to accidents	Risk indicators	Surrogate to acc.
Emphasis of use	Product evaluation	Product (and Process) eval.	Process evaluation

Much of the discussion circled around the central issue of the relationship between accidents and conflicts, and the validity of the conflict techniques. The needs for broadening the scope of traffic conflict techniques in the directions suggested i.e. automatization and simulation were accepted, and the attempts to do so were encouraged.

It was a pity that the paper of conflict studies in Indonesia was not presented, as it would have shown the value of the traffic conflicts technique in developing countries. In developing countries accident analyses are difficult to undertake due to poor accident statistics. The need for quick evaluation of safety evaluation of new measures, however, is very pressing.

Gerald Brown & Tarek Sayed: Time proximity measures for traffic conflicts simulation

The paper gave a rough outline of the factors behind the decision of developing a conflict simulation model, the simulation model, and its structure. The foundation of the model lies in the gap acceptance process based on existing knowledge (Highway Capacity Manual). The model classifies situations as conflicts on the basis of Time-To-Collision (TTC) values. Situations with a TTC value of 1.5 seconds or less are classified as conflicts.

The model has for now been tested at four junctions, and the comparisons give quite promising results. The further development of the model considers aspects of stopping distances and visual perception. The authors also aim at performing a large inventory of traffic conflict studies in order to develop the model further.

In the discussion, Brown explained the gap acceptance model in more detail. A truncated normal distributions are used. It was doubted whether the model could ass such be used to study design measures aimed at changing gap acceptance behaviour. Brown also clarified that conflicts are close enough to accidents to be used in safety evaluation even though they can not always be used in predicting the number of accidents. David Lee's model of visual perception will be used in further model development work.

The model does not utilize motivational aspects of driving behaviour in an explicit manner, although these might be included in e.g. gap acceptance submodel in an implicit way (the number of cars behind the first car waiting for a gap affects the gap acceptance behaviour of the first car).

In the end, it was concluded that a model has not to be accurate and complete in order for it to be useful in helping us to understand driving behaviour. In fact, modelling work will usually reveal very efficiently our lack of knowledge and point out the most relevant areas of further research.

Åse Svensson & Klas Odelid: A more automatic conflict technique with image processing.

The image processing approach chosen by the authors has produced a semi-manual prototype. This prototype has been used for testing purposes, and for further development of the idea of automatic conflict observation. The prototype has shown that it is necessary to smoothen the speed and TTC curves, and that a real-time system requires the prediction of vehicle routes on the basis of present situation, etc.

The development of the system is proceeding in cooperation with the image processing industry. The system is being developed in steps, starting with a road user tracking system, automatic selection of potential conflicts, and ending in automatic conflict analysis.

An example of an actual conflict situation stirred an interesting discussion on the interpretation of the TTC curve. The conclusion was that it is very important to study the whole curve and interaction process, because in that way it will be easier to understand road user behaviour. The use of the already validated traditional Swedish traffic conflict technique as the basis for the automatic system was regarded as a good starting point.

Rudolf Fruhmann: Traffic conflict technique for local accident forecast

A standardised Austrian traffic conflicts technique has been defined by the common guidelines. The guidelines classify the conflicts into 10 main groups, within which there are several conflict types. The classification resembles that normally used for road accidents.

The paper compared the conflicts observed within three hours to the accidents of 1 - 5 years at the same junctions. There were a lot of differences between the accident type and conflict type distributions, especially at signal-controlled junctions. On the other hand, the aggregated distributions on the basis of 10 main groups were much more similar. The conclusion of the study was that conflicts are not sufficient in themselves in assessing the safety of the junctions, but they are their value in complementing the accident data, and in studying specific safety problems on a short-term basis.

The validity of the traffic conflicts technique was one of the topics of the discussion following the paper. The problem of signal-controlled junctions was brought up as well as similar experiences in Canada. On the other hand, the speaker told that this study had only been a preliminary test with short observation periods.

Ernst Pfleger & Wolf Dietrich Zuzan: RVS1.22 Guidelines for traffic conflict technique of the austrian research society for traffic and road systems.

The speakers presented the new guidelines for the traffic conflict technique and its use in detail. The traffic conflicts technique is regarded as the most important safety research tool for complementing accident analyses in local road safety work. The definition of the conflict also includes potential collisions into steady obstacles as well as situations with close proximity even without a collision course. Lots of emphasis is laid upon the information collection and processes of individual road users.

The following means of conducting conflict analyses are described in detail with specific datasheets:
- conflict tables
- conflict diagrams
- structural analyses
- before and after studies

Also here, the conclusion was to promote the traffic conflicts technique as a complementary method to support accident studies so that a more complete picture of the traffic safety picture can be achieved.

In the discussion, it was pointed out that the Austrian guidelines attempt to structurize the conflict studies in the same format as accident studies. The manner of classifying driver behaviour on the basis of whether it was intentional (aggressive, submissive etc.) or not also caused discussion. The intentional aspects are judged by the conflict observers on site. This has proved also to be useful at least for diagnostic purposes. An example of not complying with traffic signals was brought forward.

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TIME PROXIMITY MEASURES FOR TRAFFIC CONFLICTS SIMULATION

ABSTRACT

This paper uses time proximity to hazard as driver perceived measures of safety to simulate traffic conflicts when defined by time-to-collision. A traffic conflicts observation technique has been developed to determine time-to-collision behavioral responses. Statistics and experimental research have provided insights for reasonable threshold times to use in traffic conflict definition based on driver hazard perception and behavioral response.

In order to extend the research potential, a traffic conflicts computer simulation model, TSC-Sim, and attached graphics display for tee and 4-legged intersections was developed and used to study traffic conflicts, with time-to-collision as the critical traffic event in driver behaviour simulation. Some aspects of gap acceptance criteria and differential effects of driver parameters including age, sex and waiting time tolerance are investigated. The simulation was validated against previous work in the literature and actual conflicts at several intersections with, so far, quite good results.

INTRODUCTION

Traffic crashes are serious road system failures, yet our understanding of the failure mechanism is poor; in particular, we know little about the conceptual linkage between human factors and road safety. More specifically, good design, for both conventional roadways and future "intelligent" vehicle and highway systems requires an intimate knowledge of the relationship between road user risk and road and traffic design criteria. The purpose of this research report is to examine how the time space between the driver and roadway hazard, presumed to be perceived visually, may be used in a simulation model to allow further insights into this relationship.

In past investigations of human behaviour and road safety in the past the time space between a vehicle operator and road hazards has been articulated as gap acceptance in taking action to proceed safely and more recently as the concept of time-to-collision in taking action to avoid collision. In this present research the literature on gap acceptance (see for example, Darzentas, 1981) provides the means for a simulation model of vehicle movement, while the concept of time-to-collision, as a quantitative definition of the severity of traffic conflicts, provides the means to evaluate safety with the simulation model.

Traffic conflicts, defined by time-to-collision measures, may well prove useful to examine the road system failure mechanism, and may provide a measure of driver risk that can be related to roadway and traffic parameters for safe design. But programs to collect traffic conflict data are few because of difficult and costly observational techniques with trained observers. It therefore appears useful to attempt to simulate traffic conflicts for both research and professional objectives.

CONCEPT OF TIME SPACE

The concept presumes that driver perception of hazard and subsequent behavioural response is an automatic control process with little or no cognitive content, and can be explained by visual parameters. First proposed as a theory of visual perception, a moving observer picks up properties of the environment in the form of ambient optical array of visual information which is processed as an optic flow field. Lee (1976) first applied this concept to driver braking responses in which he postulated that a driver does not simply depend upon his spatial proximity to hazard, nor simply on the closing velocity and deceleration, but on some relationship (or synthesis) of these variables which he called temporal proximity, or more specifically time-to-collision (TTC). Lee postulated that visual information alone, in the form of the changing optical array at the driver's eye, is used to register the hazard, when to start braking and how to control the ongoing braking process. Lee specifies the time-to-collision by the visual variable $\alpha/\dot{\alpha}$ in which α is the angle subtended at the eye by two elemental points on the surface of the hazard and $\dot{\alpha}$ is the rate of separation of the image points.

The concept can be extended to the case in which two vehicles approach an intersection on a converging course. In this case the time-to-collision is defined by the remaining time space between the converging vehicle and the trajectory of the subject vehicle on a collision course. If the angle subtended by the remaining time space is Θ, the time-to-collision as a visual perception concept can be described in terms of the visual image of the closing angle Θ. For a vehicle at rest at an intersection waiting to proceed Θ is subtended by the time lag as defined in the literature on gap acceptance.

Several braking and simulated braking experiments appear to support the validity of this concept: Schiff and Detwiler (1979); McLeod and Ross (1983); Carvallo et al. (1986).

The time-to-collision measure is used here as an indicator of the danger or the risk of a collision. In principle, the lower the TTC value during the approach, the higher the risk of a collision. In practice it is defined as the time required for two vehicles to collide if they were to continue at their speed and were to remain on the same path. As long as a collision course is present, TTC is a continuous function of time. If two vehicles are not on a collision course, the value of TTC is infinite. The function is linear when both speed and heading-angle of the two vehicles remain constant. If none of the vehicles changes its speed and/or course, a collision will result and TTC goes to zero. A "near miss" may be described by a minimum value, TTC_{min}, after which TTC increases.

To illustrate, Figure 1 shows what happens when a car approaches a fixed object. Point A indicates TTC when the evasive action is started, t_c, representing the available manoeuvring space at the moment of braking. Point B gives TTC_{min}, reached during the approach.

VALUE OF CRITICAL TTC, t_c

For simulation the value of the critical TTC, referred to here as t_c, needs to be defined. The driver decision rule assumed in collision avoidance is that, if TTC is less than or equal to t_c begin and continue evasive action, but after the point at which TTC is greater than t_{min} revert to normal driving behaviour. If x is the distance between a subject vehicle and a potential point of contact and v is the velocity at the point where evasive action is taken, and if the road users are treated as point sources for simplicity, the time-to-collision is x/v. Assuming that the velocity and heading angle are constant, the critical event will be taken to be the point of evasive action, or $t_c = x_c/v$, with x_c the critical distance. The t_{min} measure presumes the driver adjusts acceleration rates to maintain a critical time space such that $d_{tc}/d_t = 0$. While this describes the rule on which to value t_c, for simulation evasive action is not possible to replicate and t_c is simply taken as the minimum time space calculated for two vehicles on a collision course.

A number of field and experimental studies using time-based measures of driver risk indicate a desirable time-based driver safety space of 1.5 seconds and a minimum space of 1.0 seconds (Godthelp, 1984; van der Horst, 1990). Van der Horst (1990) has also examined by video analysis the distribution of critical events from two major conflict calibration studies. In these studies conflicts were defined, not by time-to-collision measures but by a combination of objective and subjective indices used by observer teams from several countries. When converted to time measure the mean is very close to 1.5 seconds, as shown in Fig. 2.

To test the t_c and t_{min} values of 1.5 seconds and 1.0 seconds used in this research a field experiment for braking was conducted (van der Horst and Brown, 1989). Twelve student subjects were instructed to drive an instrumented car at various given speeds toward a styrofoam model of a stationary car, and to apply the brakes at the last possible moment to avoid a collision with the styrofoam "car". Driver vision was partially obstructed for some experimental runs. The experimental site was an abandoned airport providing an asphalt test track of 544 metres. Data was logged and downloaded to Toshiba T1100 plus computer. A pulsed infra red detector on the vehicle fired on passing a track side reflector pole 107m from the collision point (that is, the styrofoam "car"). There were 216 experimental runs in all; 18 for each subject at 3 speeds, 2 braking strategies and 3 vision scenarios. The experimental apparatus allowed the following data to be recorded and downloaded; distance with time, longitudinal speed with time, moment of braking action, and moment of passing the reflector. Summary results as shown on Figure 3 give a mean t_c of 1.6 seconds and a mean t_{min} of 1.1 second for the "hard" (emergency) braking instruction.

The field experiment was also designed to test the visual perception hypothesis of driver braking behaviour. For this experiment the 12 male students were instructed to approach the styrofoam mock-up of the rear of the vehicle at different approach velocities and to brake at the last possible moment to avoid a collision with the "car". Stroboscopic visual occlusion, by means of specially designed electronic liquid crystal glasses, was used to monitor braking performance in the absence of continuous visual clues which would normally be available to judge distance and speed. Three levels of occlusion were used; (a) no visual occlusion, (b) 25 Hertz, or where vision was unrestricted for 10 ms periods at a frequency of twenty five openings per second, and (c) 5 Hertz, or where vision was unrestricted for 10ms periods at a frequency of 5 openings per second. These tests provide scenarios of 100%, 25%, and 5% of the flow of optic information to the driver in braking manoeuvres. Figure 3 shows summary results, indicating deterioration of braking performance with visual occlusion with less deterioration at high speed than at low or moderate speed. What is not shown by the figure is the large variation observed across individual drivers, indicating a tendency toward individualization of driving strategies in braking. However with this caveat, the experiment appears to suggest that the subjects' braking strategy could match the safe visual time space, independent speed hypothesis, as shown by Figure 4(b), as opposed to the conventional assumption of uniform deceleration as shown by Figure 4(a).

THE TRAFFIC CONFLICTS SIMULATION MODEL

The model simulates individual vehicles as they approach, proceed through and depart an intersection. This process is quantified as a driver accepting a "gap" or a "lag" in which gap is defined as the time headway between two successive vehicles in the major road traffic stream and a lag is defined as the time remaining between a vehicle on the major road and a vehicle entering the major road from a minor road. The simulation is meant to emulate this traffic process at unsignalized intersections as follows; (a) vehicles with a random set of characteristics are generated on the approaches; (b) on arriving at the intersection a gap (lag) acceptance criterion is determined based on, a priori, realistic assumptions; (c) a "consistent" behaviour model assumes a minimum gap (lag) which is acceptable to each driver at all times, with variation across drivers based on the type of traffic control, approach speed, driver age and sex, and stopped delay. A traffic conflict is recorded by the simulation when a gap (lag) is accepted by a driver, which given the closing speed of the conflicting vehicles, puts him/her at risk of collision with the other vehicle, using the critical conflict time space criterion t_c. It is assumed that traffic conflicts have the same stochastic event characteristics as vehicle arrivals.

The model uses a micro computer version of the discrete event simulation language, General Purpose Simulation System or GPSS/H, a specialized language described by Schriber, 1974. The simulation model also has some features not normally part of GPSS/H and therefore has been labelled "TSC-Sim," for Traffic Systems Conflict Simulation. (For a full description and results of TSC-Sim, see Sayed, Brown and Navin, forthcoming.)

Actions for vehicles in the model include vehicle generation, approach to the intersection, choosing a gap (lag) and proceeding to depart. The input parameters to the model include: (a) traffic volumes of all traffic streams, (b) percentage of heavy vehicle traffic to the total traffic volume, (c) type of the intersection control (yield or stop), (d) speed limit on the major road, (e) percentage of each driver type in the driver population, (f) number of lanes for both major and minor roads, and (g) total default simulation time. Several other parameters such as: move-up time, minimum allowable headway, turning speed of vehicles, and maximum queue lengths are given as constants to the model. It is possible to change the values of these parameters between simulation runs.

The Gap Acceptance Process

This process takes places when a vehicle has to cross or merge with other traffic streams where different traffic streams have different priority levels according to the rules of the road. Each vehicle is assigned a primary critical gap value by testing the gap acceptance function according to the driver type and the intersection type of control. The primary critical gap value is modified according to the vehicle type and the number of lanes to be crossed. Vehicles trying to cross or merge wait for a gap in the conflicting traffic stream (streams) greater than or equal to their critical gap. The critical gap value is obtained by multiplying the primary critical gap with a delay modification factor. The delay modification factor has an initial value of 1.5 when the vehicle faces no delay and this value decreases as the vehicle's stopped delay increases with a minimum theoretical value of 0.5 when the vehicle faces infinite delay. The model assumes that no driver will accept a gap that he/she thinks will certainly lead to a collision. Therefore, a minimum acceptable gap is used, with a value of 2.0 seconds as a minimum allowable critical gap, based on data provided by Wennel et al. (1981). If the critical gap value is less than the minimum acceptable gap, it is set to the minimum.

Vehicle drivers who decide to enter the intersection are assigned a single lane manoeuvre time. This time is sampled from a truncated normal distribution function. The mean and standard deviation of the function depend on the driver type (Darzentas et al., 1980). The sampled manoeuvre time is then corrected according to the number of lanes to be crossed and the vehicle type.

Traffic Conflict Simulation

A traffic conflict occurs when a driver decides to execute a manoeuvre which puts him/her at risk of collision with another vehicle. Conflicts are classified into six types, as visualized from one approach: left turn opposing (LT/O) ; left turn crossing (LT/C) ; crossing (C) ; right turn (RT) ; rear end ; and weaving (W) . The time-to-collision for the simulation process is taken to be the minimum time space between two converging vehicles during these conflict incidences. The model first estimates whether or not the vehicles are on a collision course. If the vehicles are on a collision course, the TTC value is calculated and compared with the threshold value of t_c. If the TTC is less than or equal to the threshold value the model records the conflict, its type, location, and the TTC value. For this study the threshold value of t_c is 1.5 seconds.

VALIDATION

Validity of the simulation was tested by comparing traffic conflicts observed at four unsignalized intersections with traffic conflicts predicted by the simulation model for these intersections for the same period of time. The validation data base came from studies of traffic conflicts at several intersections in the Greater Vancouver, Canada, area. Although several more intersection studies were reviewed, the majority of the unsignalized intersections covered by the conflict studies were complex layouts, beyond the simple T and four way intersections selected for this analysis. All selected intersections were 4-leg intersections with negligible grades, good visibility and simple layout. Table 1 is a summary of the intersection characteristics.

Table 1. Study Intersections for Simulation Validation

Intersection Type	Lanes	Turn Restrictions	Minor	Peak Hour Traffic
#1 4 approaches	1+1 2+2	none	stop signs	120 vph/80 vph
#2 4 approaches (1+2 lane ramps on major approaches)	2+1	high type	stop signs	500 vph/300 vph
#3 4 approaches	1+1	none	stop signs	460 vph/110 vph
#4 4 approaches	1+1	none	stop signs	360 vph/140 vph

Conflict Observation Method

For 4 legged intersections there are 44 conflicting movements. The observation method used here collapses these movements into the six categories described above. The observer positions himself about 2 seconds from the centre of the intersection so as to be able to observe brake lights or the beginning of evasive action. The method sets up hypothetical TTC zones according to the average approach speed to facilitate accurate recording.

Traffic conflicts were recorded at the study intersections by trained observers. The observation and recording method is an on-site, on-line record of the incidence and severity of traffic conflicts. Observations were made for two days at each intersection. Two observers were used each day for an 8-hour observation period, giving a total of 32 man-hours/intersection. The severity of traffic conflicts is determined by the sum of two scores: the TTC score and A "Risk of Collision" or ROC score. The ROC score is a subjective measure of the risk of collision and is dependent on the perceived control that the driver has over the conflict situation. The TTC and ROC scales were given equal weighting and combined into a 5-point Likert type scale. The summation of the TTC and ROC scores gives the overall severity score which range between two and six. An overall severity score of two signifies a low risk conflict situation and a score of six is a high risk conflict situation (Table 2). The mid-point of the composite scale registers the critical event, corresponding to a TTC of 1.5 seconds or less with a "moderate" ROC.

Table 2. Time-to-collision and Risk of Collision Scores

TTC and ROC Scores	Time-to-collision (TTC)	Risk Of Collision (ROC)
1	1.6 - 2.0 seconds	Low Risk
2	1.0 - 1.5 seconds	Moderate Risk
3	0.0 - 0.9 seconds	High Risk

Source: Brown, G.R. (1991)

Reliability tests of the observation method gave 77% accuracy with 95% confidence, with a high of 85% accuracy for assessing the correct TTC. In addition, in a study of 13 intersections to test the validity of a TTC = 1.5 seconds or less for a measure of safety as defined by the number of accidents, it was found that at 8 of 11 intersections conflicts are significantly correlated with accidents at 95% confidence with $R^2 \geq .64$ with 3 intersections having $R^2 \geq .81$ (Brown, 1994).

Validation Results

Conflict simulation was based on legal speed limits of 50 km/hr, but it was observed that vehicle speeds were by and large higher, so runs were made at 70 km/hr and 60 km/hr depending on estimated actual traffic speed. The model was modified for traffic volume changes for morning, noon and afternoon peaks, and further adjusted to allow the exclusion of a left turn restricted movement from 7-9 a.m. at intersection #2. The overall results are given in Table 3 which shows encouraging results, particularly in the distribution of conflicts by movement type.

Table 3. Observed Versus Predicted Conflicts by Movement Category

	Observed Conflicts*	Predicted Conflicts* @ 50 km/hr	Predicted Conflicts* @ __ km/hr
	O	P_{50}	P_{70}
RE Crossing LT/C	4+1 1+0 2	2+0 1+1 1	4+1 1+2 2
	8	5	10
	O	P_{50}	P_{60}
RE Crossing LT/C LT/O RT	0 2+2 10 1+2 2	0 3+3 7 2+1 1	1 3+4 9 2+1 1
	19	17	21
	O	P_{50}	P_{60}
RE Crossing LT/C LT/O RT	2+1 0 3+2 1 1	1+0 0 2+1 1 1	2+1 0 2+1 1 1
	10	6	8
	O	P_{50}	P_{70}
RE Crossing LT/C	1 8+4+1 1	0 4+3+1 1	1 6+3+1 1
	15	9	12

* by approach

CONCLUSIONS AND FURTHER RESEARCH

To gain credibility for application traffic conflicts need to provide a quantitative, observable measure of the systematic variability of road safety, and combined with random effects serve to describe road user risk. In this study the systematic component of risk is described by the traffic process critical event, t_c. The notion of driver risk intended here follows Zeidel's ergonomic model of the driver as a self-paced vehicle operator in a complex and multi-dimensional environment, dependent upon his abilities and limitations to control the vehicle and on the information and uncertainty about what lies ahead (Zeidel, 1985). A traffic conflict is viewed as a unique, independent critical event in the traffic process which signals a hazard, and combined with a severity level of the conflict event represents some discrete risk. Thus defined, the traffic conflict meets at least one definition of risk in a driver behaviour context; the probability and consequences of a hazardous event (Kalbfleisch, Lawless and MacKay, 1988).

The research attempts to contribute to road safety studies in two ways. The measure used to delineate the conflict has been quantified as a time proximity value, allowing road safety to be studied in the context of gap acceptance research; and the resultant simulation model using this measure appears to replicate, with some degree of accuracy, field observations of traffic conflict behaviour. However, the study has pointed to several areas of further research. Firstly, the severity definition used is specific to the field procedure, and this constrains the wider evaluation of the model. A larger inventory of conflict studies, using the time proximity definition, is needed. Secondly, more research is needed to confirm the conceptual linkage of traffic conflicts to safety and risk. The model simulates conflicts (as defined here) and cannot be evaluated against accident statistics. The authors are reasonably confident that the time proximity definition of traffic conflict will prove to be a measure of driver risk, but to date, this contention is still tentative. Lastly, simulation has been suggested as a tool to study road safety. Until the road safety problem can be described unambiguously, and the complex relationship between driver behaviour and roadway and traffic parameters delineating driver risk is known, perhaps computer simulation will prove useful for road safety evaluation.

ACKNOWLEDGEMENT

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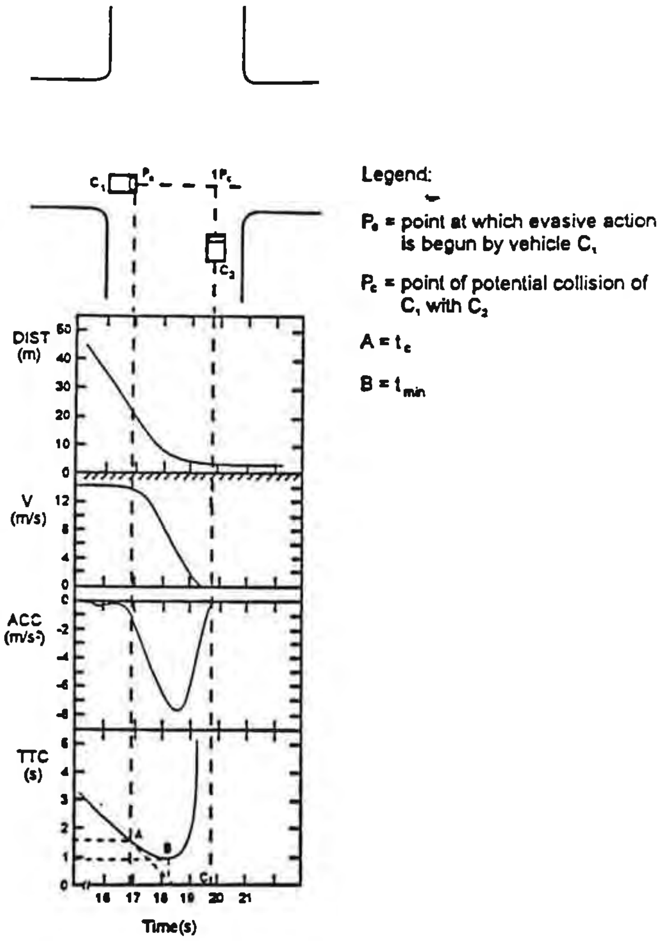

Figure 1. Concept of Traffic Conflict, Showing Time-to-collision (TTC), Critical Event (t_c) and Minimum Time-to-collision (t_{min}).

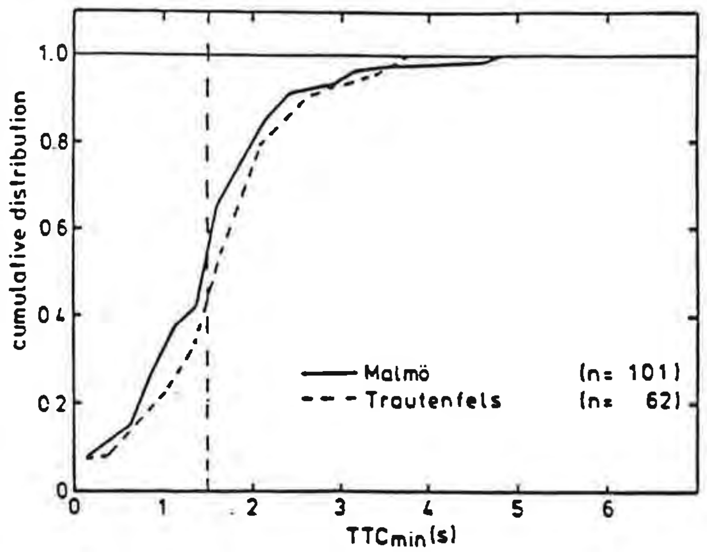

Figure 2. TTC_{min} Distributions of Conflicts from the Malmö and the Trautenfels Calibration Studies.

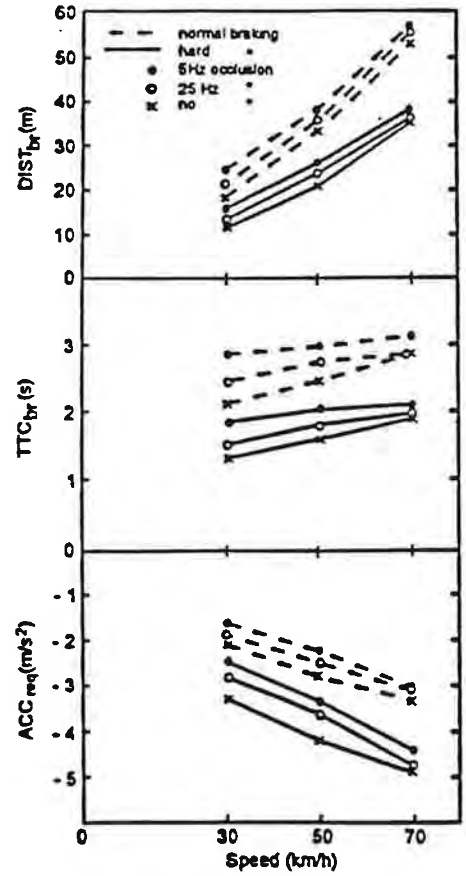

Figure 3. Braking Strategy for 12 Male Subjects in Closed Course Experimental Conditions (Source: van der Horst and Brown, 1989).

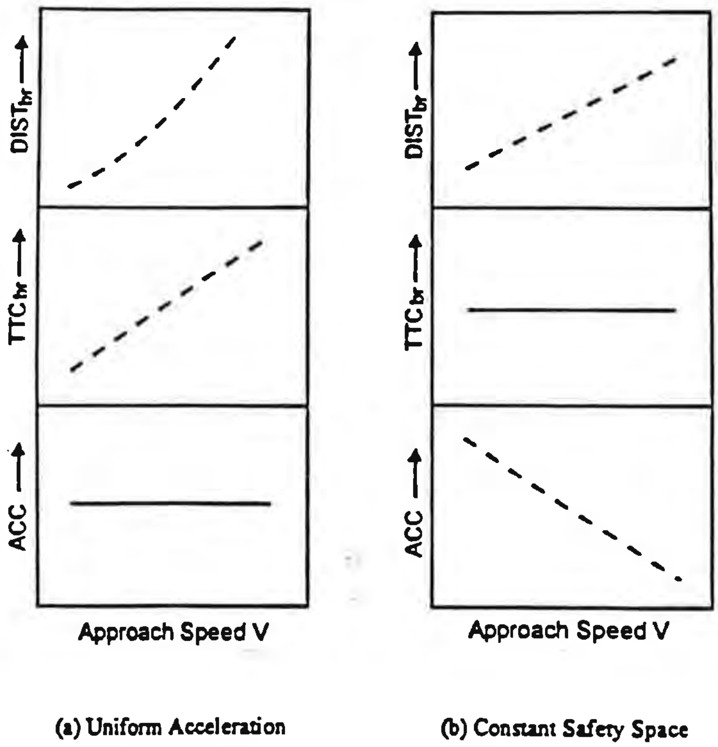

Figure 4. Two Hypotheses of Driver Braking Strategy (Source: van der Horst and Brown, 1989).

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THE APPLICABILITY OF ROAD TRAFFIC CONFLICT STUDIES IN INDONESIA

Driver behaviour in Indonesian cities is fundamentally different from that in Europe, particularly at intersections. At signalised intersections, for example, violation of the red signal is more common and priorities for conflicting movements are neither clearly stated, nor observed by drivers. At unsignalised intersections normal priority rules based on gap-acceptance generally do not apply to traffic on the "minor road" approaches and vehicles force their way into or across the "major road" flow whether or not a sufficient gap or lag exists. Though vehicle speeds are generally low, these behavioural characteristics appear to increase the probability of accidents occuring. This apparent risk is heightened by the variation in speed and performance between vehicles, which include human-powered trishaws and push-carts as well as motorised modes. Undisciplined stopping by small public transport vehicles adds further complications.

Such conditions give rise to conflicts and it can be expected that studies of these conflicts could help traffic engineers improve junction design and encourage legislators to modify and enforce traffic rules. The potential value of conlict studies is further increased because of the general lack of reliable information on accidents.

A traffic conflict study was carried out in 1990 in Bandung, an Indonesian provincial capital city with a population of around 2 million. The aim of the study was to identify a suitably simple definition of a traffic conflict and to apply it in field surveys to determine the extent to which it was both reliable and repeatable. Reliablity was defined as being good agreement between different independent simultaneous observers as to the numbers and types of conflict. Repeatability was defined as agreement between two viewings, separated by several weeks, of the same traffic events, by individual observers: video recordings were used for this. For conflict studies to be a useful tool for traffic engineers, it was consiedered that the method should be both reliable and repeatable. Four technicians who had received simultaneous and equal training, counted and classified traffic conflicts in the field at two signalised and two unsignalised intersections. The generally good agreement between them and the fact that they were able to reproduce their individual results after a period of time, indicated that conflict studies can be successfully applied in Indonesian conditions.

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A MORE AUTOMATIC CONFLICT TECHNIQUE WITH IMAGE PROCESSING

Background

The Swedish Traffic Conflict Technique (TCT) has been developed at the Department of Traffic Planning and Engineering in Lund. Our work with the Swedish TCT has shown that it is often preferable to use conflict data instead of accident data as a measure of traffic safety. The Swedish TCT is a quick and valid method to estimate and prognosticate accident risks in traffic. Our validation studies confirm the existence of a valid relationship between conflicts and injury accidents. There is for instance striking resemblance between the processes preceding both accidents and conflicts. We have also produced results showing that the TCT is more useful than available accident data in estimating expected number of accidents, at intersections with low accident frequencies.

Historically measuring traffic safety has been equal to making accident analyses. The information that can be extracted from accident data has however some evident weaknesses. It is very hard to find out anything about the processes preceding the accident - what caused the accident - to be able to imply the correct measures. If then only a fraction of all accidents is included in the accident data material, that is if we only investigate the police reported accidents, then several other biases like different degree of reporting for different types of accidents arise.

Our research in the TCT area has been and is still very extensive. Today we have a technique based on solid theoretical and practical knowledge about risky behaviour in traffic. The development and the validation work have attracted nationally as well as internationally attention. The work has brought about that we now have access to a very effective method to describe (qualitative and quantitative) traffic safety problems at intersections.

Over the years we have used the TCT in many of our projects as a method for safety evaluation. We have had staff from municipalities and the Swedish Road Administration (SNRA) at our training courses for conflict observers. So the interest for the TCT is big among those working with traffic but the technique is unfortunately very seldom used in their everyday work. The reason is that the TCT is very resource demanding - each location has to be observed during three to five days by one conflict observer. This is now why the SNRA and the Swedish Transportation & Communication Research Board financially support this project, which this paper will focus on, which aims at making the TCT more cost-effective by using image processing.

In this project we have continued the research and development concerning the TCT. Our main aim is to start out from the present TCT, automatize certain parts as the data collection and some steps in the analyses with help of image processing, to bring about a more cost-effective technique. In a futures time-scale our ambition is to further develop and adapt today's TCT towards a completely new TCT that more comprehensively uses the possibilities that image processing and computer science can offer.

Definition of a conflict

The very first definition of a conflict that was agreed upon in Oslo 1977 (1), had the following wording;
"A traffic conflict is an observable situation in which two or more road users approach each other in space and time to such an extent that there is a risk of collision if their movements remain unchanged."

Since then different groups of researchers in Europe and North America have continued to further develop their own TCT's, which has lead to that we today have a handful of partly different TCT's. In the Swedish TCT we are principally only interested in the serious conflicts and their relationship to injury accidents. We say that a serious conflict is a situation which nobody puts him/herself deliberately into. A serious conflict is therefore sometimes referred to as 'almost an accident'. It is a situation that includes an evasive action, otherwise would the road users have collided within a certain time-interval.

At the time for the evasive action the conflict observer estimates the distance remaining to the collision spot and the speed of the road user. Time-to-accident, the TA-value, is then calculated as the time remaining to the spot of collision if the road users had continued with unchanged speed and direction. The combination of speed and TA-value then determines the severity of the conflict. With a TCT based on image processing it is quite easy to estimate speed and distance. It is considerably more difficult to find the exact spot of the evasive action (due to insufficient resolution), that is, to estimate the TA-value. We have solved this by calculating continuous TA-values as the road users approach each other.

In the Swedish TCT the conflict observer also makes a subjective score of the likelihood that this situation could have ended as an injury accident. One result from the Malmö calibration study in 1984, organised by ICTCT (2), was the finding of a common understanding among trained observers about conflict severity. This makes it even more interesting to try to preserve this subjective information as the TCT becomes more automatic. The question is however if the subjective severity can be measured by physical parameters.

System available today

During the project we have cooperated with some different hardware developers aiming at producing a PC-card for collection of coordinate data from a video recorded sequence. We count upon being able to test a prototype card within a year. In the mean time we have developed a semi-manual system that gives us possibilities to collect coordinates in a small scale. In today's system we have put the video image on the computer screen. We are using a video recorder with time codes and a serial interface to the computer so we are able to control the video recorder from the computer. By overlaying the video image with a graphical footprint, figure 1, on the computer screen controlled by the mouse we can do a quite easy data collection.

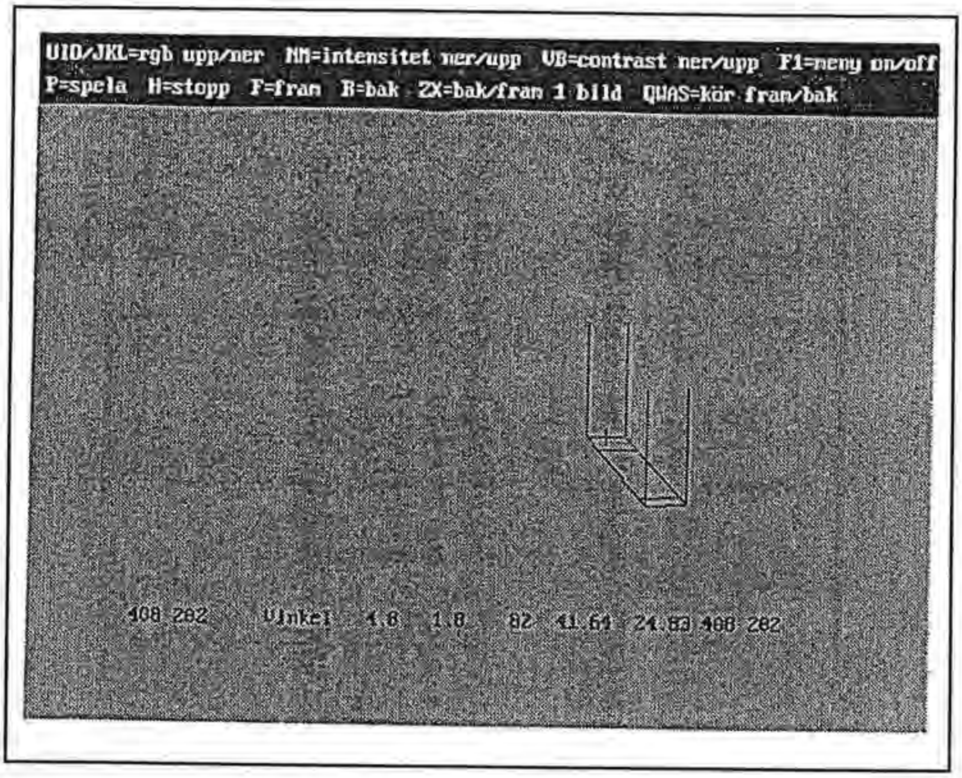

Figure 1 Footprint image for the coordinate picking program.

With the knowledge of real coordinates and image coordinates for four reference points, figure 2, we can transform all image coordinates into real coordinates. We also use these transformation equations to alter the size of the footprint so it always has the same size of a specific road user wherever it is in the analysed sequence.

During the data collection phase we go through every second image in a sequence and mark all the involved road users' positions. The output is a data file with real coordinates and belonging time codes. After this we use a PC program designed so that it for each time-step projects the future positions, up to 2.5 seconds in the future, using the existing direction and speed of all road users and estimates hypothetic collisions.

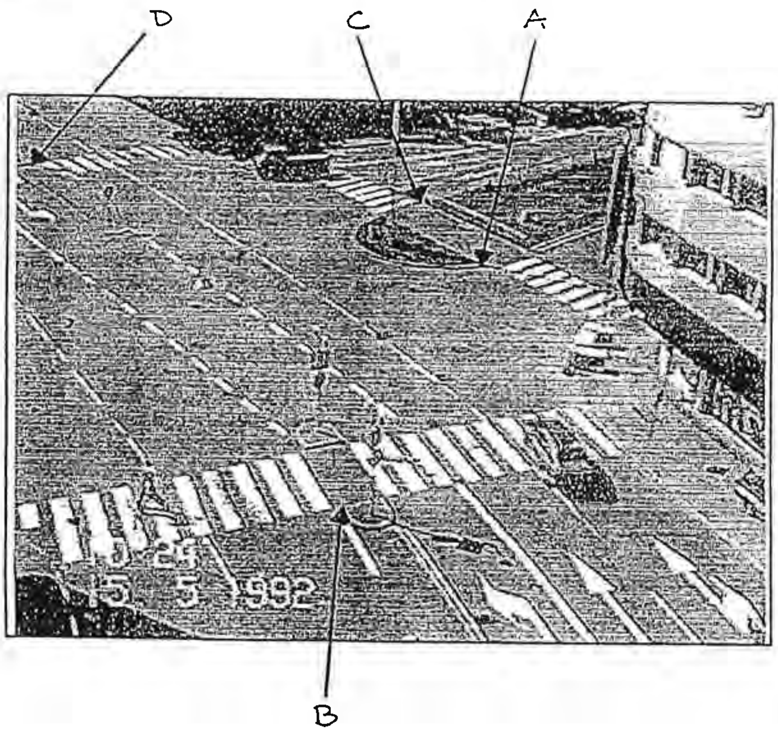

Figure 2: Reference points for the coordinate picking program.

Results of analyses - one example

Figure 3 below is an illustrative example of how the information from the conflict detection program can be analysed and presented. This particular situation is a conflict between a car and a bicyclist. The bicyclist is exiting a minor road to cross the major road. The car is driving along the major road. The bicyclist does not seem to detect the approaching car and continues, quite unaware of the dangerous situation, the crossing. The car discovers the bicyclist very late and is forced to brake and swerve to avoid an accident.

The figure shows the behaviour of the car throughout the conflict. The thin line represents the speed of the car estimated in every second image, which is the reason for the heavy fluctuation. The thicker line is also the speed but here it has been smoothed with regard to the four previous positions. The dotted line is the estimate of the TA-value as the car is approaching the bicycle. The car has an approaching speed of 55 to 60 km/h. This continuity breaks at real-time 2.6 seconds and the speed starts suddenly to decrease. At this time the car starts the evasive action and on the right Y-axis the TA-value 1.5 seconds can be read.

In figure 4 the action of the car is illustrated in an ordinary TA-Speed diagram. One should start reading this diagram from the top right part. This is where the car is approaching the bicycle with unchanged speed and steadily decreasing TA-value. When the TA-value has dropped to 1.5 seconds, the situation has turned into a serious conflict and the car starts to decelerate. The rest of the course of events nicely follows a parallel path to the line that describes the border between serious and not serious conflicts.

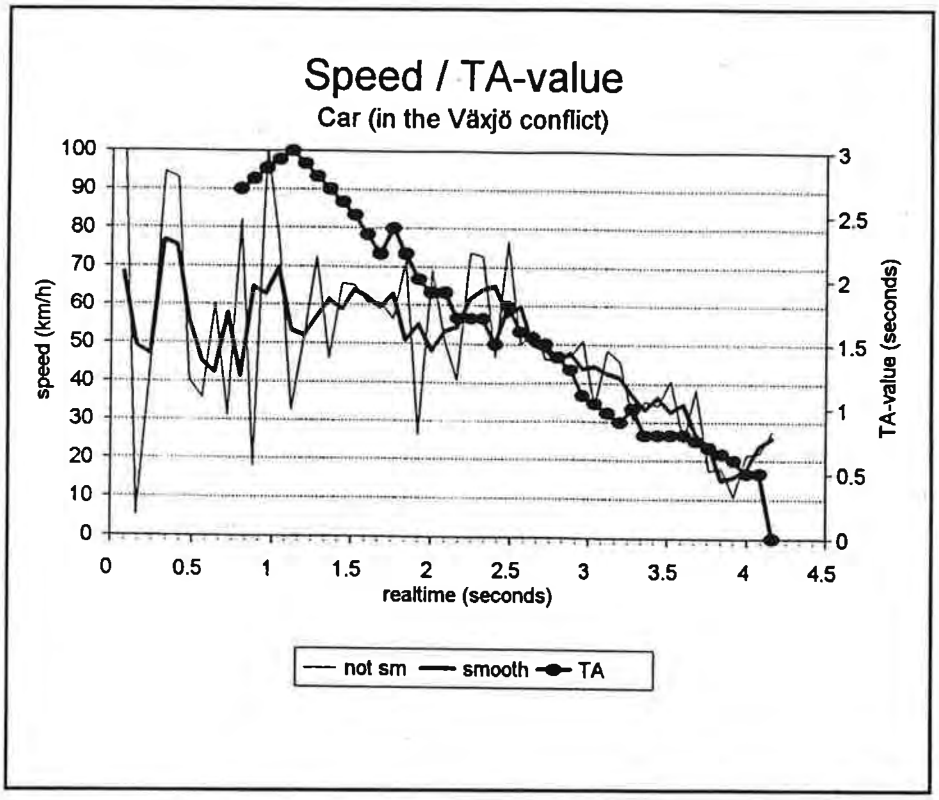

Figure 3: Conflict between a car and a bicycle. Analyze of the approaching car. Speed and TA-value with respect to real time.

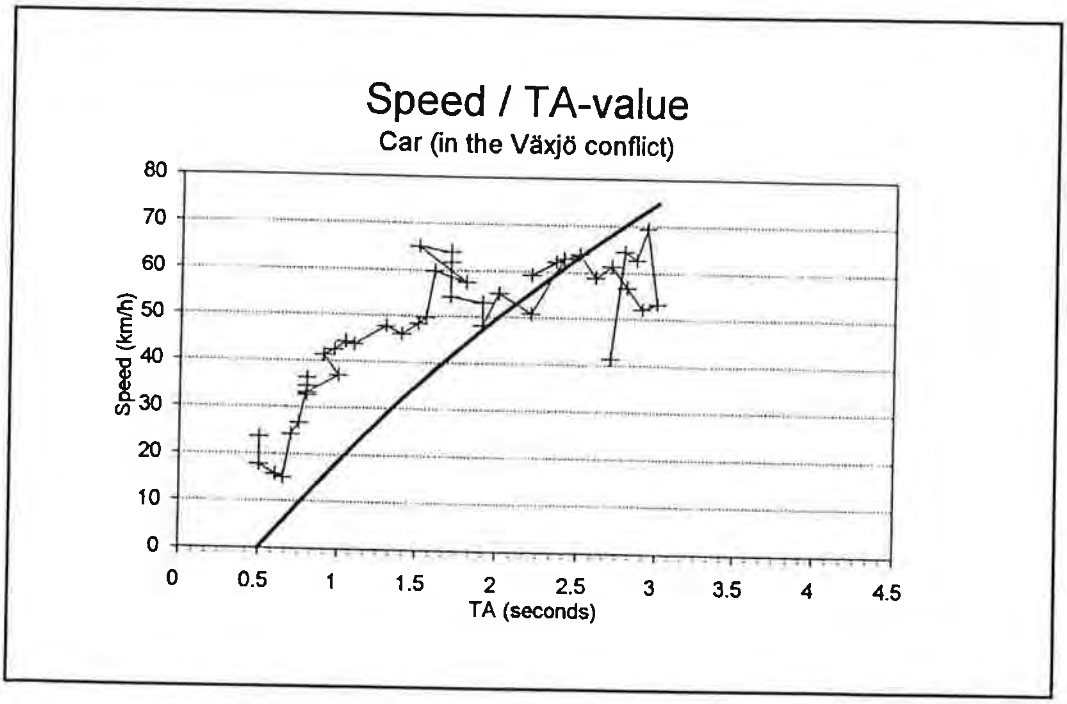

Figure 4: The same conflict as figure 3. Distribution of speed/TA-value for the car.

A future system

Here we will try to describe how a future image based conflict system may look like. We have chosen to point out the different phases of development that we think must be passed on the way towards a system suitable for practitioners. First a system for automatic conflict studies can be divided into different parts concerning various degrees of automation:

* tracking, identification and continues registration of the road users position from a video recorded sequence
* preliminary conflict analysis and selection of potential conflicts
* detailed analysis of selected conflicts

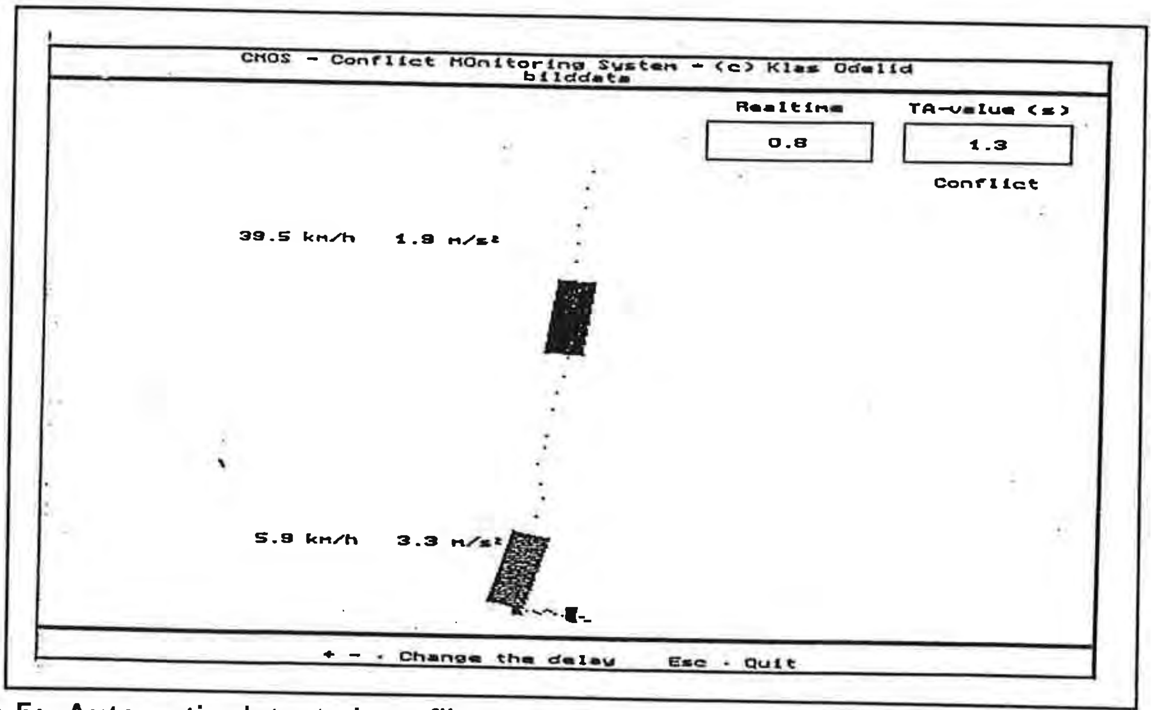

Figure 5: Automatic detected conflict.

We assume that a prototype of a PC-card will be available in half a year. This card will be able to analyse a videotape and produce results that contain vehicle identity and coordinates for a fix point on the vehicle. With this set of data it will be possible to use our Conflict MOnitoring System (CMOS) to select potential conflicts. The quality of the data produced by the prototype card will probably be inferior to the data produced by our semi automatic system described above. But the resolution will hopefully be good enough to suit the first selection phase. Due to the lower quality of the recorded coordinates, the selected conflicts will be analysed in aä second step. We will both use our semi-manual system, figure 5, and make manual observations direct from the videotape. In a little longer perspective, this second phase of coordinate picking will be possible with a PC-card, where the operator initialises the detection phase and manually points out the involved road users and adjusts their sizes in the first picture of the selected sequence.

The future system can consequently be divided in the following functional parts:

1 trackingsystem, PC-card and software to identify and record the road users' positions

2 PC-software for selection of potential conflicts

3 PC-card and software for a second registration of the road users positions with a better resolution

4 PC-software and manual analysis of the selected potential conflicts

The possibility to combine all these parts in one automatic system lies far in the future. In the short run we can see a great potential in combining part 1 and 2 and this would be a feasible development of the prototype card that we are aiming at.

By adding the first selection phase into part 1 in the real time system, we will benefit a lot during the actual recording. We can then design a system that onlyä records the potential conflicts. This makes longer studies possible since there is no longer any need for switching tape every three or four hours.

With a system as described above, we think we have a tool that will not only be useful for our research studies but it will also be possible to put it in the hands of practitioners. It could be a very feasible and fruitful tool for traffic safety analysis in a big scale.

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TRAFFIC CONFLICT TECHNIQUE

Evaluation Methods and the Possibilities of Local Accident Prognoses

The guideline of the research department for road and traffic systems (RVS 1.22), which will be published soon in Austria, standardizes traffic conflict studies. The standardized registration and evaluation of data will make it possible to draw comparisons between traffic conflict data and traffic accident data. The registration of the conflict data ist exactly defined in the guideline and has to be carried out by the means of a standardized conflict-investigation questionnaire. This ensures the equal value of all data. Conflict data investigated in this way can easily be registered on computer and can be processed and evaluated more efficiently.

EVALUATION METHODS ACCORDING TO RVS 1.22

RVS 1.22 distinguishes four groups of evaluation methods. These are very similar to those of the accident analysis.

The evaluation methods consist of:

* conflict table
* conflict diagram
* structural analyses
* before-after-studies

All the conflict-related data are summarized in the conflict table, which serves as a basis for structural analyses and for the representation of the conflict diagram. Structural analyses are evaluations according to particular examination aspects, as for example time of the day, days of the week, etc. The conflict diagram is the graphical representation of the traffic conflicts in the form of a situation sketch. By that means accumulations of similar conflicts can better be illustrated. By the means of before-after-studies chronologically different conflict registrations are compared in order to examine changes in the conflict happening of a location.

TYPES OF CONFLICTS

Owing to the standarization of traffic conflict studies and their adjustment to accident studies according to RVS 1.21, traffic conflicts and traffic accidents can be contrasted.

By adjusting types of conflict to types of accident direct comparisons are possible. There are 10 main groups of conflict types including altogether 112 subordinate types.

* Main conflict-type group 0: Conflicts involving only one person conflicts based on agreement, etc.)
* Main conflict-type group 1: Conflicts in the respective direction of traffic (conflicts involving change of lane, front-end collision, passing, etc.)
* Main conflict-type group 2: Conflicts concerning on-coming traffic (involving front collision)
* Main conflict-type group 3: Conflicts at turning - same direction (traffic turning right, traffic turning left)
* Main conflict-type group 4: Conflicts at turning - opposite direction (conflicts concerning left-turning vehicles, etc.)
* Main conflict-type group 5: Rectangular conflicts at intersections while crossing (straight-running vehicles)
* Main conflict-type group 6: Rectangular conflicts at intersections while turning-in
* Main conflict-type group 7: Conflicts involving stopping or parking vehicles
* Main conflict-type group 8: Conflicts involving pedestrians (from the right and the left, at intersections, in street blocks, etc.)
* Main conflict-type group 9: Conflicts on exit/entrance roads from/to parking lots, petrolstations, houses or plots.

LOCAL ACCIDENT PROGNOSES

Possible connections between the conflict and accident happenings were examined at altogether nine intersections (7 in Vienna, 1 in Graz and 1 in Leoben). During the first phase of registration three-hour conflict observations were carried out at each intersection. The timing of the observation was determined by the hours when most accidents could be expected. Table 1 shows a comparison between the accident and conflict happenings.
The intersections printed in italic letters are equipped with flash signal installations. The remaining intersections are regulated by right-of-way determinations.
At those intersections regulated by right-of-way rules, 5 - 7 conflicts per intersection were registered during the three-hour observations. During the same observation period 1 - 5 traffic conflicts were recorded at those intersections regulated by flash signals. Consequently, there occur fewer conflicts at intersections regulated by signals than at those not regulated at all. This can be explained by the limited number of interactions, as the individual traffic flows at signal-regulated intersections are directed temporally separate, which leads to the reduction of conflict aspects.

Tab.1: Comparison: accident and conflict happening

KREUZUNG	UNFÄLLE			KONFLIKTE	
	Zeitraum Monate	Anzahl PSU	Unfälle pro Jahr	Zeitraum (Stunden)	Anzahl
Wien: Vorgartenstraße/Stromstraße	42	18	5,14	3	5
Wien: Brigittenauer L./Friedensbr./Wallensteinstr.	48	27	6,75	3	1
Wien: Peter Jordan-Straße/Cottagegasse	48	9	2,25	3	6
Wien: Lidlg./Richthausenstr./Roggendorfg./Wattg.	48	16	4,00	3	5
Wien: Hofferplatz/Kirchstetterng./Thaliastr.	48	12	3,00	3	3
Wien: Alserbachstr./Spittelauer Lände/Friedensbr.	60	36	7,20	3	3
Wien: Gumpendorferstr./Mariahilfer Gürtel	48	39	9,75	3	4
Graz: Alte Poststr./Köflacher Gasse/Eckertstr.	36	14	4,66	3	7
Leoben: Tivolikreuzung	36	34	11,3	3	2

Furthermore, the frequencies of conflict types and accident types were considered separately according to signal-regulated and non-signal-regulated intersections.As for the three non-signal-regulated intersections of the study, a positive accordance between the frequency of conflict types and that of accident types could be observed. In spite of the short observation period and the resulting small spot-test, the frequencies of traffic conflicts are seen to be similar to the frequencies of accident types in the respective collision diagrams (Fig.1 and Fig.2). The traffic conflicts registered as well as the occurring accidents fall almost exclusively into the main conflict-type groups 5 and 6, i. e. rectangular conflicts respectively collisions at intersections. Thus, the conflict happening corresponds relatively well to that of accidents at the three intersections regulated by right-of-way rules.

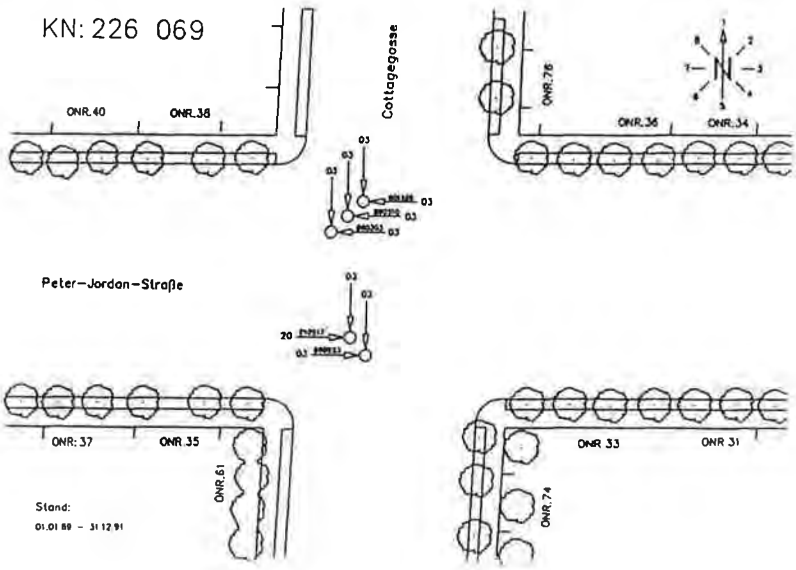

Fig.1: Collision diagram: Peter Jordan-Straße/Cottagegasse, 1989/01/01 to 1991/12/31.

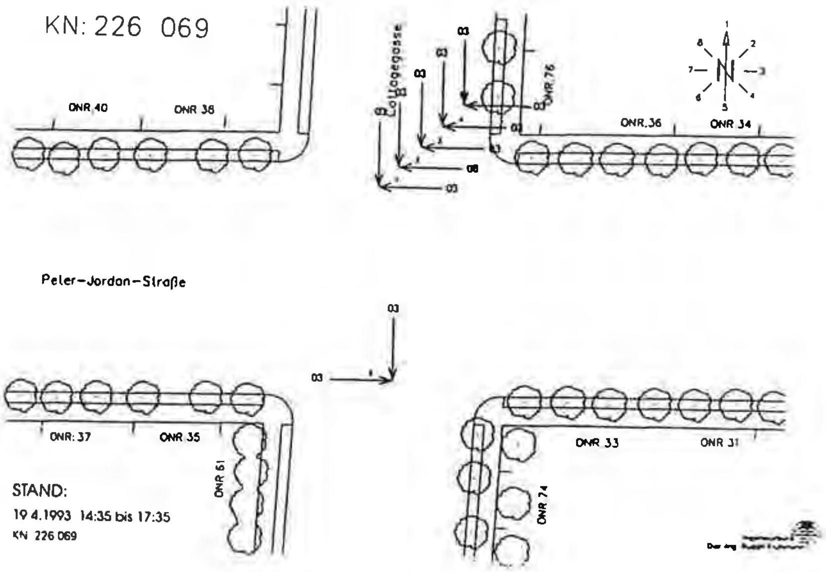

Fig.2: Conflict diagram: Peter-Jordan-Straße/Cottagegasse, on April 19th, 1993, 14.35 - 17.35h.

At intersections regulated by signals, however, the results are different. At several intersections similar conflicts are observed, which also occur as accidents and accumulations of accident types. Other locations, however, show no corresponding tendency between the conflict and the accident happenings (Fig.3 and Fig.4).

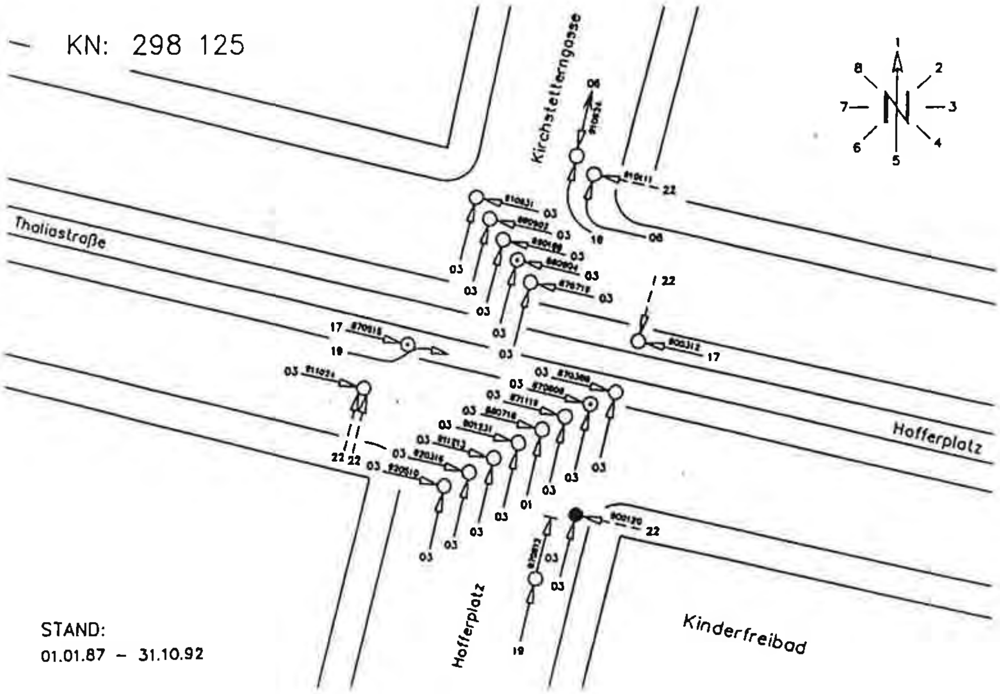

Fig.3: Collision diagram - Hofferpl.Thaliastr./Kirchstetterng., 1987/01/01 - 1992/10/31

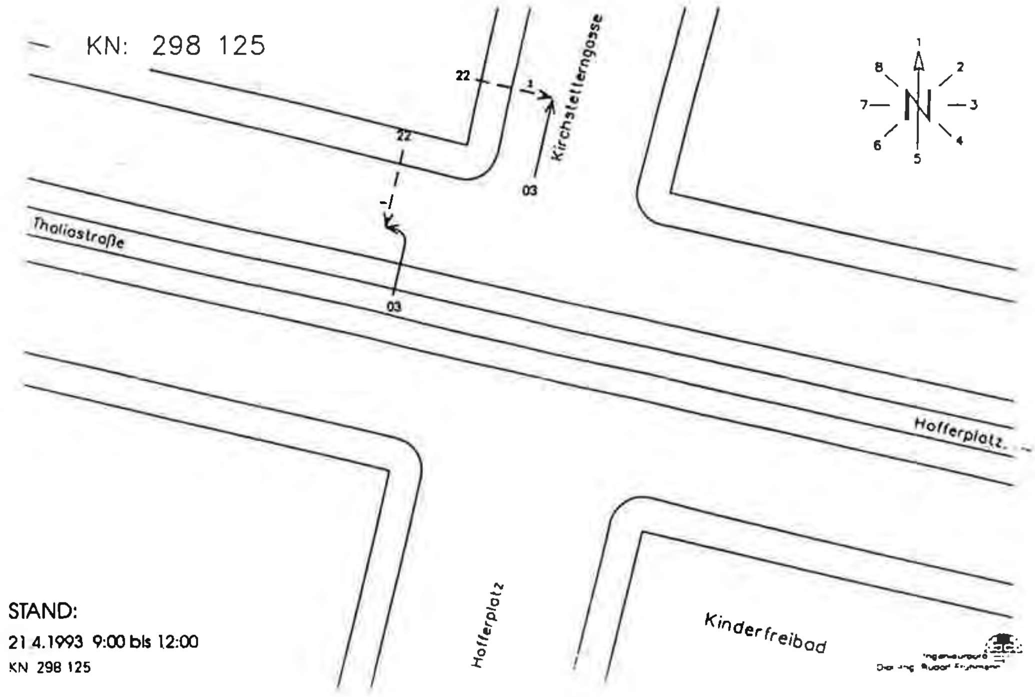

Fig.4: Conflict diagram: Hofferpl.Thaliastr./Kirchstetterng. on April 4th, 1993, 19.00 - 12.00h

As these examples show, the traffic conflict types observed at one location need not necessarily be identical with the accident types. This leads to the following application areas for traffic conflict studies:

* Complement applicable to locations showing frequent accidents
* Application at risk-locations (accidents have not been registered)
* Assessment of the safety quality of traffic installations
* Verification of the effectiveness according to measures taken
* Assessment of the safety quality for particular road users

On the one hand, the possibility of accident prognostication on the basis of traffic conflicts observed depends on local marginal conditions, on the other hand, it depends on the probability of the occurrence of particular accident and conflict types. An analysis of the main groups of accident types of the year 1992, including the totality of accidents involving personal injury (in Vienna and Graz), clearly shows that the main groups 1, 5, 6, and 8 constitute more than 70% of the overall accident happening. The remaining accident types can be observed rather rarely (Fig.5). The intersections examined in this study also show a similar distribution of accidents as well as of the traffic conflicts registered. It is only main group 4 which stands out more prominently (Fig.6).

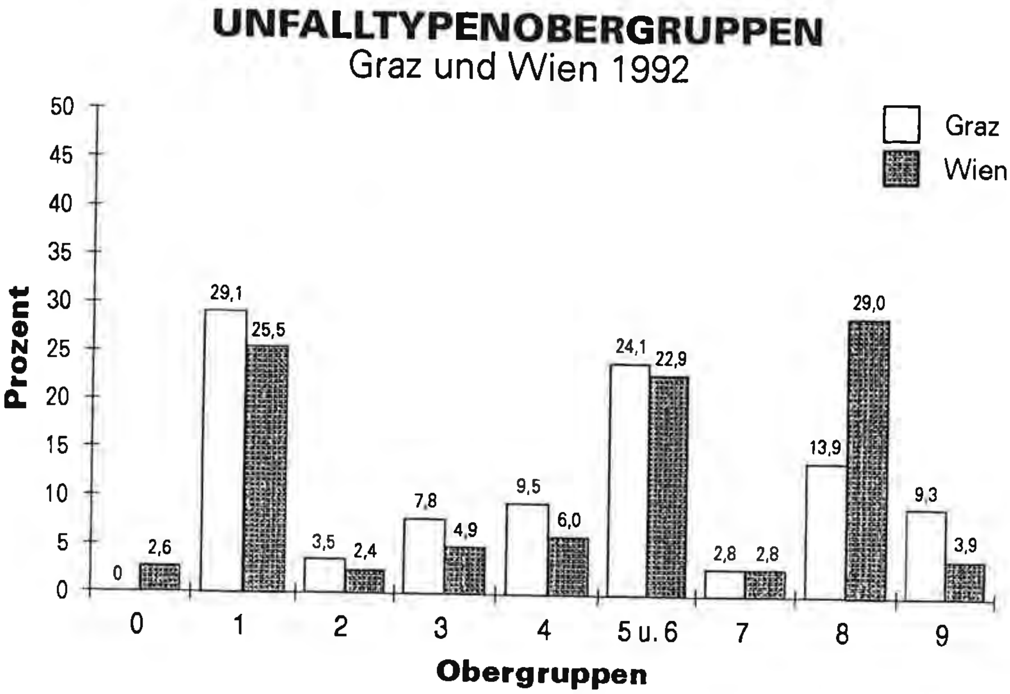

Fig.5: Main accident-type groups: Graz and Vienna 1992

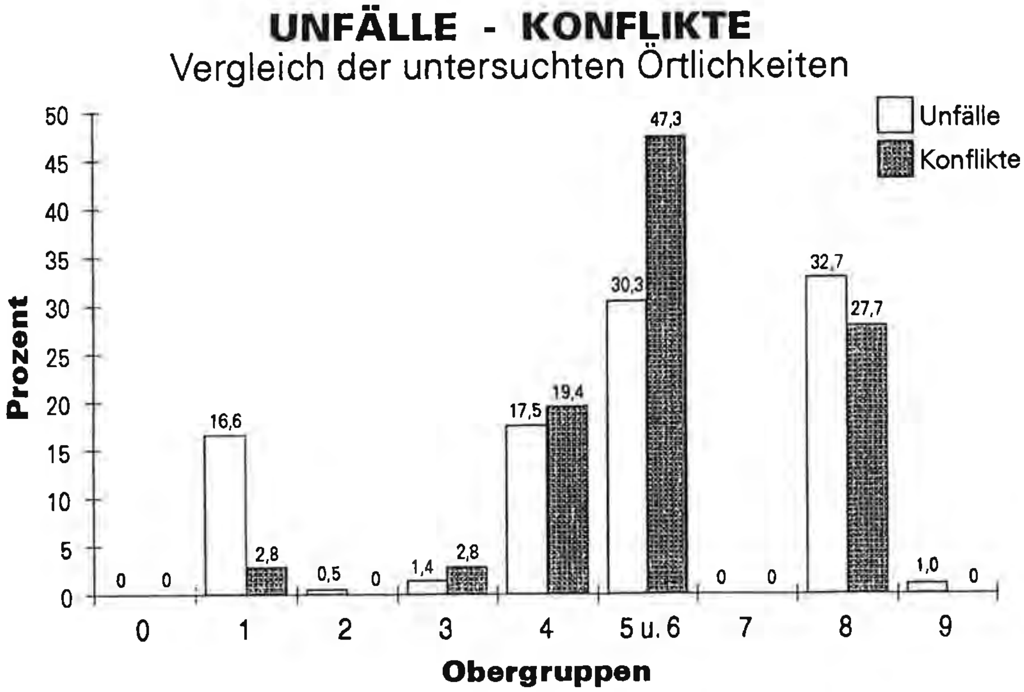

Fig.6: Main accident and conflict-type groups of the intersections studied

Although no significant spot-test was available in this first examination phase, it can be supposed that generally, it will not be possible to draw conclusions with regard to the accident happening, respectively even to predict accidents generally on the basis of conflict observations. For particular applications, however, the conflict technique must be preferred to the accident analysis on grounds of the short observation periods; but as not necessarily all the typical safety-shortcomings leading to accidents can be registered for a location, conflict techniques will never be a general replacement for accident analyses.

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RVS 1.22 -GUIDING RULES FOR TRAFFIC CONFLICT TECHNIQUE OF THE (AUSTRIAN) RESEARCH SOCIETY FOR TRAFFIC AND ROAD SYSTEMS

Several years ago the Austrian Research Association of Road - and Traffic Management established guidelines for road safety studies in Austria for the first time. These guidelines provide exact instructions on how to keep records of accidents, analyze accidents and also on the redevelopment of scenes of accidents for a systematic accident research. In addition to that a seperate chapter contains a check list for the systematic examination of road projects. This check list is designed to make a considerable contribution to the reduction of accidents on a medium - term basis by means of conducting correct road safety studies.

Generally, the scientific basis of the so-called research of accident types with special emphasis on local accident research has advanced far. However, it was unsatisfying, that until now safety experts did not attribute enough importance to accidents which almost happened and to road conflicts in general.

The RVS 1.22, whose draft is now available for Austria, presents the latest guideline on the organisation of road safety studies.

It is of particular importance that the facts presented in the guideline are expert opinions agreed upon by road safety experts, road safety engineers and psychologists. The guideline was established in cooperation with representatives of various universities, experts of the Federal Ministry, psychologists, road accident experts, and civil engineers.

Analogous to the guideline for road safety studies the guideline in front of you also follows the principle of presentation of expert opinions. Therefore, a widespread and intensified effect can be expected for road safety management by means of road conflict studies conducted by professionals.

The guideline on road conflict studies is to be applied to the entire road system. This means that the guideline is intended to be used in urban traffic as well as on country roads.

The basis for road conflict research is very similar to the basis for accident research. It distinguishes among several conflict types of the same kind, featuring ten different groups of conflict types.

Group 0: Conflicts with only one participant (single conflict)

Group 1: Conflicts associated with flow of traffic in one direction (passing manoeuvre, rear-end collision)

Group 2: Conflicts associated with oncoming traffic (head - on collision, leaving the road)

Group 3: Conflicts associated with making turns and turning around in one direction (right - turn, left - turn, U-turn)

Group 4: Conflicts associated with making turns and turning around in the opposite direction (left - turn conflict)

Group 5: Right - angled conflicts associated with crossing intersections

Group 6: Right - angled conflicts associated with turns at intersections (right - turn, left - turn)

Group 7: Conflicts associated with stopping or parking vehicles (opening doors

Group 8: Conflicts with pedestrians (pedestrians from the right, pedestrians from the left, pedestrians moving in the direction of the vehicle)

Group 9: Conflicts associated with acces and exit roads of parking lots, gas stations, private property, and driveways.

Like the recording of road accidents the recording of road conflicts also allows the conclusion that within the flow of traffic human and technical limits are undoubtedly reached and exceeded.

Therefore, traffic conflict studies reveal an important part of local lack of safety. By combining road conflict studies with road accident studies relevant insufficiencies and causes connected with the construction of roads and the way of driving can be pointed out. Road conflict engineering is therefore an important additional research method for local accident research.

In general, the following areas of use are planned:

1. Additional information on road segments with increased frequency of accidents
2. Use in danger zones (areas of increased risk of accidents)
3. Analysis of the quality of safety of a road system
4. Examination of effectiveness of a taken measure
5. Analysis of the quality of safety for selected road - users

To resolve these conflicts the same measures as in the reconstruction of scenes of accidents are to be taken. A reduction of road conflicts can be achieved by taking road engineering and road constructing measures as well as traffic controlling measures according to the particular road conflict.

Basically the following types of conduct and their consequences can be identified:

1. *Normal conduct*

Normal conduct can be defined as a problem-free sequence of movements without any road-user being restricted, as well as a conflict-free interaction between road-users approaching each other, which requires a coordination of actions to ensure safety. Every situation can be mastered without any danger and/or conflict.

2. *Incorrect conduct*

Here a distinction must be made between incorrect conduct without any concrete danger, dangerous incorrect conduct and unclear problematic interactions. Traffic - regulations are disregarded by road - users, which may lead to dangerous actions and/or other critical interactions between the road - users (such as discrepancies etc.).

3. *Road conflicts*

Road conflicts are defined as situations in which it is either absolutely necessary to make abrupt changes of motion to avoid accidents or in which a slight variation of the sequence of movements would have led to a collision.

4. *Accidents*

An accident is the result of a conflict situation in which a collision can not be avoided because one or more road-user(s) react too late or do not react at all.

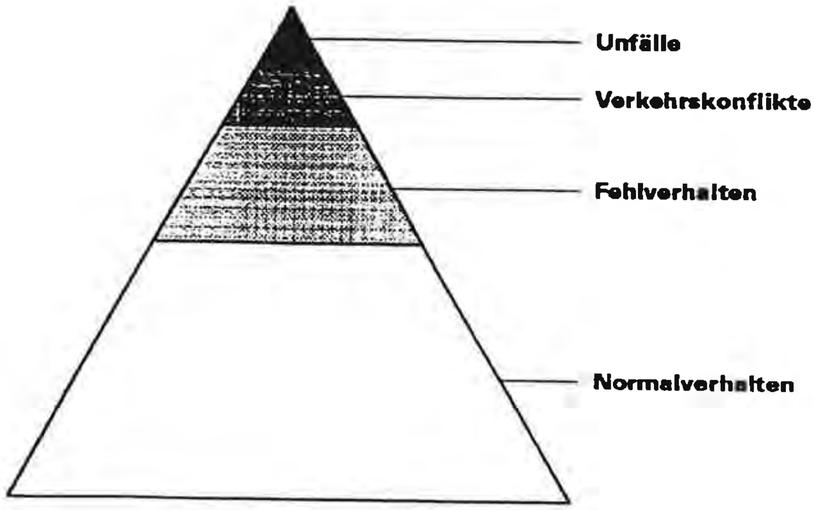

Diagram 1: General diagram of conduct and consequences in traffic

Therefore, road conflicts are situations in which road-users approach each other or traffic obstuctions in a way that requires an abrupt change of the original sequence of movements (direction of speed, slowing down, accelerating) in order to avoid a probable collision. Furthermore, road conflicts are situations in which no one of the road-users reacted, but in which a slight variation of the movements would have resulted in a collision. Such a situation can be identified by an observer as an "almost - accident".

The road conflict management described in the RVS 1.22 is to be used in connection with correct conduct with resulting conflicts as well as in connection with the violation of traffic regulations without resulting conflicts.

Observable characteristics of conflicts are direction and changes of direction (abrupt change of direction, abrupt deviation, abrupt correcting manoeuvre, abrupt getting into lane, etc.), speed and changes of speed (changes of the way of driving by strong deceleration or acceleration, abrupt breaking, increasing acceleration, etc.) as well as movements of pedestrians and changes of movements (traffic- related abrupt change of movement or direction, sudden stopping or running of pedestrians, etc.).

Causes of road conflicts

The following causes of road conflicts can be identified:

Lack of relevant information, relevant information that was recognized too late or not at all, incorrectly interpreted information, lack of abilities, incorrect expectations concerning the conduct of others, misguidance or deception, intentional actions and technical insufficiencies.

The selection of relevant information depends upon the objective offer of information, the selected subjective information and on the individual's ability to translate the given information into action.

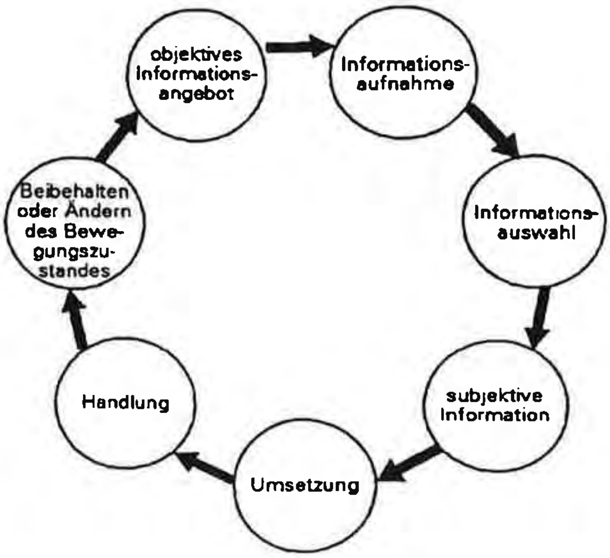

Diagram 2: Sequence of information

The objective offer of information is influenced by the traffic area and the surroundings, the individual state of motion, other road - users and additional factors such as brightness, weather conditions and environmental influences.

Conflict observation

Conflict observations are conducted to establish conflict analyses based on the recording of conflicts. The collected data distinguishes between general data and conflict-related data, which - after an exact definition of the area of observation and data collection - reveals comprehensible information on road conflicts.

Therefore, the RVS 1.22 includes exact samples of data collection sheets, which provide the basis for the corresponding analysis. Important additional information related to the description of the individual conflict such as incorrect conduct which was objectively observable (violation of traffic regulations etc.), subjective interpretations of uncertainty, lack of information and observable additional action intended as a warning or hint using acoustic or optical signals is recorded.

Road conflict statistics, analyses and evaluation

The RVS 1.22 provides standardized analyses in the form of a conflict table, that gives exact information on time, type of conflict, state of the road, road-users, circumstances, additional criteria, complementary actions and directions. The graphic form of the conflict table is the so-called conflict diagram, which shows the road conflicts according to conflict types in a clearly designed diagram.

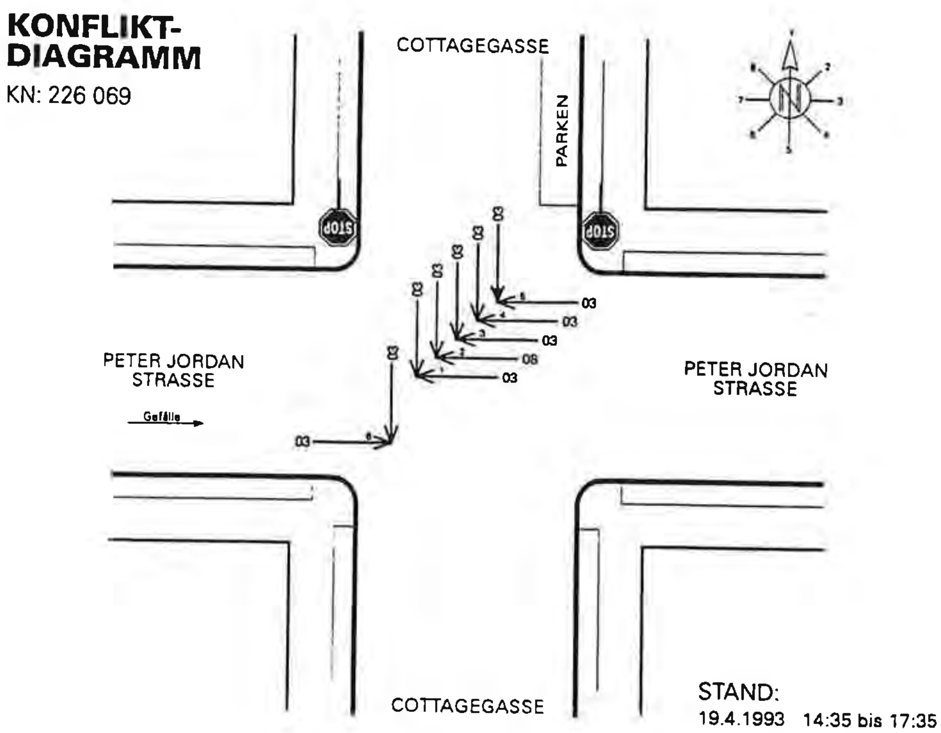

Diagram 3: Conflict diagram

With regard to the conduct of the individual road-user a distinction must be drawn between obvious agressiveness, intentional action, lack of information (uncertainty) and unobtrusive relatable behaviour.

A structural analysis provides a detailed listing and order according to defined study goals. This form of classification allows a detailed analysis of problem areas at particular times and with particular traffic circumstances (cf. studies concerning safety on the way to school, pedestrian crossings after a theatre-performance, etc.).

The RVS 1.22 also provides for a comparison of road conflict observations under similar conditions with regard to previous and later studies. This includes a comparison of respective road conflicts with each other - in a general sense and according to the distinction of groups - for the entire period of observation, but also for the limited period of one hour.

Road conflict studies

Road conflict studies can be conducted by taking into account traffic-relevant data such as traffic types and composition of traffic, relevance of traffic, counting of traffic, mearuring of time-gaps, speed measuring, information on traffic regulation and many other aspects. In this context the entire data concerning the surroundings of a road segment including the course of a road, the marking, the roadway, the lighting, and the arrangement of road signs is of great importance to road conflict studies.
The organization of a road conflict study is based on a sequence of events: presentation of the study object, definition of the subject and goal, presentation of the entire basis of road conflict management, conflict statistics and analysing methods, traffic-relevant data and recordings concerning the road surroundings. Based on this data, conclusions can be drawn from the entire road conflict study.

The road conflict study is part of a result within the structural analysis of a road safety study. All the conclusions drawn from the road conflict study are included in the road safety report.

The road conflict study reveals part of the lack of safety on a local scale, which makes it possible to point out insufficiencies in road engineering, road construction and in the way of driving. According to the RVS 1.21 it is possible to reveal considerable insufficiencies and their causes based on the road conflict study combined with other records and analyses in accordance with the road conflict study. The results of the road conflict study have to be included as a basis for redevelopment suggestions into the report on road safety study as stated in RVS 1.21.

Other aspects related to road conflict studies

Time of recording data and duration as an important criterion of reliability

Based on previous studies it can be assumed that the reliability of the results of a total recording period of eight hours is generally sufficient. The total duration of data recording needs to be seen in direct connection with the local situation, the frequency and the kind of accident types in the volume of traffic etc. If necessary the time span of data recording can be prolonged and/or it can be reduced if conflicts of the same type occur in short periods of time. However, there is a general minimum time limit of two hours for data recording.

Additional technical information on road conflicts

By using video recording and other technical supplies in road conflict management, additional details on road conflicts can be collected.
Based on the information concerning avoided collisions, changes in speed or direction as well as the actual moment of reaction can be defined by time-way-analyses. This method observes the speed of vehicles and pedestrians within a measured road segment for a defined period of time. Random speed checks support the method and help verify the results.
By reconstructing the road conflict - especially the moment of reaction - it is possible to define the incorrect conduct of road - users and to point out definitive insufficiencies of the road construction and the way of driving.

Summary

In the RVS 1.22 the entire field of road conflict study is exactly defined and standardized. The RVS 1.22 is therefore an important device for the description of lack of road safety. It also provides the possibility to quantify the risk of accidents in danger zones, where an increased risk can be proved without actual accidents occuring.

All future concepts concerning road management have to take into account accident studies and - especially for areas of increased risk of accident - a road conflict study must be conducted. Only after the elimination of possible lack of road safety in the concept it can be assumed that the new concept avoids previous insufficiencies of road construction and provides actual improvement for the flow of traffic.

Therefore, the road conflict study RVS 1.22 provides an extraordinarily important basis for the prevention of road accidents and lack of safety on the road.
Accident — studies and - especially for areas of increased risk of accident - a road conflict study must be conducted. Only after the elimination of possible lack of road safety in the concept it can be assumed that the new concept avoids previous insufficiencies of road construction and provides actual improvement for the flow of traffic.

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Mr.Chairman, Ladies and Gentlemen,

It is a great pleasure to attend this conference on behalf of the Preparatory Committee of the Chinese Road Safety Academy. Please allow me to give our compliments to the organizers of the conference, the host, and the delegates from various countries. At this time, we would like to take the time to introduce you to the special characteristics of road accidents in China.

1. A brief survey of road accidents in China in recent years

In China the work of preventing and decreasing traffic accidents has always had a great deal of importance attached to it by the government. The government has formulated a general policy of "Safety first, prevention first" and has outlined a series of specific policies. The traffic administration departments of the public security organs have always put the prevention of traffic accidents as a priority of their work. In recent years, in pace with the rapid development of the socialist modernization, the number of motor vehicles has been increasing by 15% or so every year and the volume of traffic has increased proportionately. Not surprisingly, road accidents have been increasing as well.

In 1990, there were more than 250.000 road accidents throughout China, and nearly 50.000 people died in traffic accidents in that same year, and more than 155.000 injuries were reported. In 1991, there were nearly 265.000 road accidents which resulted in more than 53.000 deaths and 162.000 injuries. These figures reflect a 5,8% increase in accidents, an 8,16% increase in fatalities, and a 4,7% increase in injuries from 1990 to 1991. In 1992, although the numbers of accidents and injuries decreased somewhat, the fatality rate went up again by 10,2%. The fatality is still increasing.

2. The main pecularities of Chinese road accidents

Because regional differences are very great in China, and due to the sheer size of the country and the complex mixed traffic situation, merely looking at the fatality numbers and rates does not accurately reflect the whole picture of Chinese traffic safety. In recent years, deaths caused by road accidents have exceeded 50.000 year and this number is higher than that of other countries. However, the death rate per 10.000 vehicles is in the middle to low range in comparison with other countries, standing at 31.3. Within China, there are dramatic regional differences in the death rate. Beijing at 8,6 deaths per 10.000 vehicles, and Inner Mongolia at 9,7 stand at the low end of the spectrum, while Jiangxi Province has 78 per 10.000. Guangdong Province, with 178.000 square km, 55.000 km of roads, and more than 2,43 million vehicles, had 5.509 deaths and a death rate of 22,63 per 10.000 vehicles. Ningxia Huizu Antonomous Region, on the other hand, has 66.000 square km of land, 8.000 km of roads, and 160.000 vehicles, had 412 fatalities for a mortality rate per 10.000 of 24,7. Inner Mongolia and Shanghai have seen a continous decrease in the absolute number of deaths over the last five years, despite the numbers rising in all other parts of the country. The reasons for these differences are as follows:

A. There are large differences in the vehicles, traffic volume, and road grade throughout the country, causing great disparities in the number and type of accidents. China has a land area of 9,6 million square kilometers, and the total road mileage is 1,05 million kilometers among which expressways and fist and second class highways only represent 5,58% of the total, while fourth class and off class highways represent nearly 80%. But also China's highways, irrespective of class, are universally lacking in safety measures.

In 1992, there were 160 deaths due to road factors, an increase of 25% over 1991.

To summarize, there are few highways, the classes of those that do exist are low, and safety measures are lacking in all of them.

B. The second reason for the great regional disparities in road accidents, death and injury numbers and rates is the unique mixture of traffic on China's roads today. Non-motor vehicle traffic rates are very high, and these vehicles create serious interference with motor vehicle traffic, producing high accident rates.

At the end of 1992, there were almost 20 million vehicles in China, which included only 6,9 million automobiles, 5,3 million transportation tractors, and 1,2 million motorcycles and other form of motor-driven vehicles. Travelling with these vehicles on China's urban and rural roads are more than 400 million bicycles.

The combination of poor road conditions and mixed traffic including automobiles, tractors, motorcycles, bicycles, animal-drawn vehicle and on many roads pedestrians results in a serious disturbance of automobile safety. This situation is reflected in the statistics. In 1992, deaths caused by accidents which were the responsibility and fault of bicycle riders and pedestrians were more than 13.000, represanting 22,4% of the total number of road accident deaths that year.

C. A third reason for regional differences is the high percent-age of mountainous areas in China. In addition, mountain ranges are crisscrossed with more hills than plains. Road conditions in some regions of precipitous topography are extremely poor, and accidents caused by passenger automobiles in these areas are, not surprisingly, increasing.

Roads in these mountainous regions of China are also unsuitable for long-distance passenger transport vehicles. In addition, the technical condition of many long-distance buses and vehicles is inferior. Accidents are increasing, with one accident killing ten to thirty people at a time, and in some cases as many as fifty to sixty people. In remote regions, these numbers are shown a tendency to rise.

D. The fourth characteristic of the traffic and safety situation in China relates to the drivers themselves. There is a low consciousness of abiding by the law, professional ethics are inferior, and driving skills are below par. As a result, accidents related to driver negligence make up a large proportion of all accidents in China.

In recent years, driver training has progressively become more standardized in driving schools in China. But because the demand for drivers has been rising rapidly, there are still some trained drivers whose performance, sense of legality, and technical ability are inferior. These drivers often ignore safety and create accidents. In 1992, there were more than 33.000 cases of accidents directly related to driver fault which caused more than 38.000 fatalities. This figure represents more than 65% of the total fatality rate on China's roads.

3. Some maine countermeasures

By analyzing the characteristics of road accidents in China, and by taking note of the continuously rising rates of accidents in the country, we have developed a series of countermeasures. These countermeasures are designed to keep pace with the quickening of the reform and the rapid development of economic construction in China, and we are in the process of perfection them step by step.

A. As the mixed traffic situation cannot be changed in a short time, we have decided to attack the problem macroscopically through various means. One side of this approach is increasing the building and development of common-use highways in order to ease the tense traffic situation. The other side is to construct high-class highways in a planned way and to transform and administer the highways which are prone to accidents, as well as improving traffic safety facilities. Mobilization of enthusiasm for these projects in various regions on China is essential for these projects.

B. It is also necessary to strengthen the administration of the vehicles, and to manage the drivers, especially passenger vehicle drivers, strictly.

One aspect of vehicle administration is to try to furnish the bicycles with separate roads isolated from motor vehicle traffic. In addition, non-motor vehicles must be strictly administered. A second aspect is to perfect standardized training for drivers, and to launch research into the psychological and physiological qualities needed to make good drivers. We are also focussing on raising the technical skill, the professional ethics, and the sense of legality of Chinese drivers. Lastly, passenger vehicles will be administered even more strictly, and annual and quarterly inspections are being maintained as preventative measures against unsafe vehicles being on the roads.

C. A third contermeasure being instituted against road accidents in China is the introduction of a safety responsibility system. Traffic safety is a complex social work which relates to all trades and every family, and it is only under the leadership of the governments at different levels that the work of accident prevention can become a reality. Comprehensive administration with Chinese characteristics, and full cooperation from the whole of society is being promoted in order to put the responsibilities and obligations of safeguarding traffic order and safety first in China, and to focus on preventative measures.

D. The final countermeasure being introduced is strengthening the legal system with respect to traffic, propagande, and education. In order to prevent and decrease traffic accidents, we must normalize the traffic behaviour of the people by sientific and unified traffic rules. We intend to achieve compliance with the slogan "There are laws to abide, so the laws must be abided; Enforce law strictly, and punish unlawful practice". In the meantime, it is necessary to favorably influence public opinion and public consciousness on the importance of complying with traffic rules, and on their ability to provide their own selfdefense.

Mr.Chairman of the Congress, ladies and gentlemen, China is a developing country. The increase of road accidents has become of greater and greater importance to the government. In order to prevent and decrease road accidents, we will make unremitting efforts to find countermeasures and to try to decrease fatalities and injuries on China's roads, in order to helpserve the establishment and development of China's socialist market economy. In the meantime, we are open to learn from the experience, advanced technology, and safety measures of all the countries represented here today. We look forward to receiving the expert opinions and comments which you may have on our work.

Thank you.

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INTERNATIONALER KONGRESS FÜR DIE SICHERHEITSEVALUIERUNG VON VERKEHRSSYSTEMEN: VERKEHRSKONFLIKTE UND ANDERE MASSE

Einleitung

Wie jedes Jahr hat ICTCT auch 1993 - diesmal unter der Regie des Kuratorium für Verkehrssicherheit, Landesstelle Salzburg - einen jährlichen Workshop abgehalten. "Workshop" stimmt für dieses Jahr aber nicht ganz, denn es war ein Kongreß, im Rahmen dessen mehrere Workshops (=Arbeitsgruppen) stattfanden. Die Ausdehnung auf Kongreßgröße hatte zwei Ziele: Kollegen aus Wissenschaft und Forschung, die nicht Mitglieder von ICTCT sind und Beamte - hauptsächlich aus Österreich - auf Landes- und Bundesebene sollten zur Teilnahme eingeladen werden. Mit der üblichen Workshopgröße von 30-40 Personen konnte man daher nicht mehr das Auslangen finden.

Für die ICTCT-Workshops hat bisher generell gegolten: Die Präsentationen sind sehr heterogen. Die Klammer, die die Beiträge umfaßt wird durch die Diskussion geschaffen, welche traditionell einen vorrangigen Platz einnimmt. Diesmal - 1993 in Salzburg - waren die Beiträge weniger heterogen, obwohl die Zahl der Beiträge größer als üblich war. Während normalerweise mit einem eher allgemein gehaltenen Thema das Auslangen gefunden wurde, war diesmal für vier Hauptreferate eine gewisse "Linie" von vornherein geplant und wird von den Beiträgen auch wiedergespiegelt:

In den Hauptreferaten sollte einerseits ein gesellschaftlicher Hintergrund dafür gegeben werden, wie man denn einen Verkehr mit wünschenswerten Eigenschaften beschreiben kann. Unter dem Schlagwort "social sustainability" (was ich gerne mit "Sozialverträglichkeit" übersetzen möchte) zeigte Joop KRAAY vom niederländischen Verkehrsministerium auf, welche Kriterien man auf staatlicher Ebene anlegen kann, sprich: welche gesetzlichen und formalen Randbedingungen zu schaffen sind, um einen Verkehr zu schaffen, der bezüglich der Interessensgegensätze zwischen unterschiedlichen Gruppierungen in der Gesellschaft den bestmöglichen Ausgleich schafft, und der generell auf grundlegende menschliche Bedürfnisse Rücksicht nimmt.

Beim Zuhören war es schon möglich, sich Gedanken darüber zu machen, wie wohl neue technologiebasierte Ausrüstung im Straßenverkehr sich bezüglich der obgenannten Aspekte auswirken würde. Im ersten Hauptreferat hatte nämlich Christer HYDÉN vom Institut für Verkehrstechnik der Technischen Universität Lund einen Überblick darüber gegeben, welche unterschiedlichen Arten von Ausrüstung sich derzeit in welchem Stadium der Entwicklung und/bzw. Implementation befinden.

Der Aspekt der Verkehrssicherheit wurde in weiterer Folge unter den vielen Anforderungen, die Verkehr erfüllen soll, speziell hervorgehoben. Dies nicht zuletzt deshalb, weil viele der Methoden, mit denen sich die Mitglieder von ICTCT befassen, an Sicherheitsfragestellungen orientiert sind. Das dritte Hauptreferat befaßte sich folgerichtig auch mit Möglichkeiten und Begrenzungen der Unfallanalyse: Siem OPPE vom niederländischen Institut für die wissenschaftliche Untersuchung der Verkehrssicherheit (SWOV) gab dazu einen ausführlichen Überblick.

Und schließlich befaßte sich Farida SAAD von der französischen Verkehrssicherheitsorganisation INRETS mit Verkehrskonflikten und anderen Formen der Verhaltensanalyse. Sie stützte sich dabei auf eigene Überlegungen und auf ein Papier von Nicole MUHLRAD (ebenfalls INRETS), die am Kongreß nicht teilnehmen konnte. Verkehrskonflikte und Verhaltensanalysen zur Bewertung der Verkehrssicherheit werden gerne als Komplemente zur Unfallanalyse angesehen.

Hier sei noch erwähnt, daß viele Experten dazu neigen, Verkehrskonfliktanalysen als Verhaltensanalysen anzusehen: Wenn auch technisch definierte Aspekte im Mittelpunkt der Erhebungen stehen (TTC, evasive action, usw.) so ist es doch bereits Standard, daß bei Verkehrskonflikterhebungen beschrieben wird - frei, mit eigenen Worten - was denn dem Verkehrskonflikt an Verhalten bzw. an Interaktion vorausgegangen sei. Diese Erhebungen fließen in die Berichtlegung nach Verkehrskonfliktanalysen immer mit ein. Die Verkehrskonflikttechnik wird daher im folgenden auch ab und zu unter dem Begriff der Verhaltensanalyse (zumindest im weiteren Sinn) subsumiert werden.

Verhaltensanalysen sind Methoden, die einen besseren Einblick in Verhalten und Interaktion der Verkehrsteilnehmer zulassen, als Unfallanalysen. Und wenn auch der, oft verlangte, rechnerische Bezug zu Unfallanalysedaten - im Sinne einer Validität - fehlt, so stellen sie doch die Methoden der Zukunft dar: Weil sie eher Schritte in die Richtung der Definition eines wünschenswerten Verkehrs zulassen, als Unfalldaten. Letztere sind nicht reliabel (die Erhebung vor allem leichterer Unfälle funktioniert nicht verläßlich), sie informieren über die Faktizität von etwas, was man eigentlich hätte verhindern wollen, und sie geben zu wenig Auskunft über die menschlichen Ursachen der Verkehrsunfälle.

Damit soll keineswegs gesagt werden, daß Unfallanalysen nutzlos sind. Vielmehr soll unterstrichen werden, daß Verkehrssicherheitsarbeit darin bestehen sollte, herauszufinden, wie man Unfälle vermeiden kann. Und dazu braucht man - neben dem Widerspruch, daß man das zu vermeidende Ereignis in Datenbänken als Analysematerial sammelt - mehr Information darüber, was die Verkehrsteilnehmer denken, was sie tun, wie sie miteinander umgehen etc. Mehr über die letztgenannten Aspekte zu lernen ist zuletzt immer häufiger das Ziel von Verkehrssicherheitsfachleuten. In Österreich wird dieses Streben u.a. durch neuere Arbeiten des Kuratorium für Verkehrssicherheit reflektiert - z.B. in der Kooperation mit der Forschungsgesellschaft für das Verkehrs- und Straßenwesen bei der Entwicklung neuer RVS (Richtlinien und Vorschriften für den Straßenbau).

Die Gruppenarbeiten sollten den Leitgedanken aus den Hauptreferaten folgen, wobei der Aspekt "(neuere) Verkehrssysteme" als horizontales Thema geplant war: als eines, welches in allen Arbeitsgruppen sozusagen "auftaucht". Die Referate für die Arbeitsgruppen nahmen dann darauf doch weniger Bezug: Die Arbeiten waren fast ausschließlich eher grundsätzlicher Natur. Das widerspricht aber nicht dem Gedanken, daß man das hier zusammengetragene Know-how mit wenigen Problemen auch für die Evaluierung neuer Ausrüstung im Straßenverkehr einsetzen kann - halt in seinen prospektiven Formen: Denn auf der Basis von Unfallanalysen kann man schwerlich Vorhersagen treffen, vor allem dann, wenn sich das Verkehrssystem grundlegend verändert. Letzteres ist, angesichts des derzeit vor sich gehenden Technologieschubs, aber sehr wahrscheinlich.

Die Themen "Sozialverträglichkeit" und "Verkehrssicherheit" sowie die ausführlichen Überlegungen zu zwei Methodengruppen - Unfallanalysen einerseits und Verhaltensanalysen andererseits - wurden in mehreren Arbeitsgruppen gezielt als Arbeitsthema gewählt:

In der Arbeitsgruppe A wurde dargestellt und diskutiert, wie man denn zu Kriterien für einen an gesellschaftlich akzeptierten Werten und an sozialer Verträglichkeit orientierten Verkehr gelangen könnte. Der "westlichen" Sichtweise allen Verkehrs mit dem Kfz im Zentrum sollten Perspektiven aus Afrika entgegengestellt werden: Der größte Teil des Transportes erfolgt z.B. in Nairobi/Kenya zu Fuß. Dort wird es besonders deutlich sichtbar, wie sehr autoorientierte Strukturen - und solche zu entwickeln hat man auch dort versucht - sowohl den Komfort und die Leichtigkeit des Gehens, als auch die Sicherheit der Gehenden nachhaltig beeinträchtigen. Das kann man jedenfalls aus den gelieferten Abstracts schließen. (Die Kollegen aus Afrika konnten die Anreise nicht selber bezahlen und in Österreich konnten dafür keine Sponsoren gefunden werden.)

In der Gruppe D wurden verschiedene Möglichkeiten für die Anwendungen verschiedener Formen der Verhaltensanalyse präsentiert und diskutiert. Als sehr wichtiger Aspekt kam die Bedeutung verschiedener Betrachtungsweisen der Exposure zur Sprache. Es gibt offenbar nicht "eine" linear in ihrer Bedeutung zu- oder abnehmende Exposure. Verkehrsmengen/Verkehrsleistungen, auf die man Unfallmengen bezieht, variieren in ihrer Bedeutung nach Situation, nach Kombination (verschiedener Fortbewegungsarten) und nach der Größenordnung. Ein interessanter Gesichtspunkt wurde in der Diskussion anschließend an eine Präsentation aus den Niederlanden (Piet NOORDZIJ, SWOV) angesprochen: Nach Expertenmeinung würde eine rechtliche Gleichstellung bezüglich der Vorrangregelungen (derzeit gilt lt. NOORDZIJ in den Niederlanden der Rechtsvorrang nicht für Fahrradfahrer) zu vielen Toten und Verletzten führen - zumindest während einer Übergangsfrist. Man erinnerte sich daran, schon längere Zeit keine intelligenten Diskussionen über Gesetzeswerdung, Rechtsprechung, hinter ihnen stehende Philosophien (ohne und mit Anführungszeichen) und ihre Konsequenzen für die Verkehrspraxis gehört zu haben.

Die Arbeitsgruppen B, C und E befaßten sich ausführlich mit Theorien und Methoden von auf Verhaltens- und Interaktionsstudien basierenden Sicherheitsanalysen. Viele interessante Probleme sind an Verhaltensanalysen geknüpft. Zwei davon, die in den Diskussionen auftauchten, möchte ich kurz ansprechend:

1) Man versucht, zu einer objektiven Definition (und daraus folgender Identifikation) von Fehlern im Fahrverhalten zu gelangen. Dabei übersieht man jedoch, daß ein gewaltiger Teil des Verhaltens der Verkehrsteilnehmer aus Überlegungen, Konzepten, Motiven und Einstellungen besteht. Sie alle können z.B. die Aufmerksamkeit beeinflussen, mit der man an eine Sache herangeht. Sie alle können auch damit einhergehen, daß der Verkehrsteilnehmer gewisse Details in einer Situation diskriminativ erfaßt, die das Gesamtverhalten im Endeffekt zu einem sicheren Verhalten machen. Sie alle entziehen sich aber auch einer objektiven Analyse, genauso wie die Gesamtmenge aller diskriminativen Stimuli die man sich im Straßenverkehr vorstellen kann (man denke z.B. an den Aspekt, daß ein Verkehrsteilnehmer andere Verkehrsteilnehmer sieht/beobachtet und aus ihren Blickverhalten, Bewegungen etc. Schlüsse zieht). Das Verhalten der Verkehrsteilnehmer im qualitativen Sinn besser zu verstehen wäre wichtig. Solches Bemühen wird aber häufig als "nicht objektiv" abgetan. Letzteres leitet über zum zweiten ausgewählten "interessanten Problem" (s.o.):

2) Ergebnissen von Untersuchungen auf der Basis von Verhaltensanalysen wird abverlangt, sie müßten - am Unfallkriterium - valide sein. Will man aber rechnerisch Validität nachweisen, so muß die Kriteriumsvariable in reliabler Form erfaßbar sein. Diese Anforderung ist für Unfalldaten sehr oft nicht erfüllt (s.o.). Und will man "Validität" als Übereinstimmung von Prozessen verstehen, dann müßte man aber besser über das Unfallkriterium Bescheid wissen, als wir das tun: Wir wissen, mit unterschiedlichsten Unfalldaten in der Hand, daß etwas passiert ist. Aber wir wissen nicht, was in den Verkehrsteilnehmern vor dem Unfall vorgegangen ist, allenfalls als

Rekonstruktion der Aussagen Beteiligter und Zeugen. Die rein mechanischen Schwächen solcher Rekonstruktionen sind bekannt (z.B.: das Gedächtnis funktioniert nicht wie ein Videogerät). Gleichzeitig landet man wieder bei den unter 1) angesprochenen Problemen der Subjektivität. Eine sinnvolle Auswertung von Unfalldaten wird damit zu einem qualitativen Prozeß.

Somit hat man also größte Schwierigkeiten, wenn man mit Hilfe von Beobachtungen von Verhalten und Interaktionen Phänomene (seien es Einzelereignisse, seien es Prozesse) identifizieren will, die objektiv (im Sinn von korrelativ) zu Unfällen führen. Und man befindet sich mit diesem Bemühen möglicherweise auf dem Holzweg.

Eine Arbeitsgruppe - die Gruppe E - befaßte sich mit der Erhebung von Verkehrskonflikten. Der vielversprechendste Ansatz ist hier die Videoanalyse: Interaktionsprozesse an definierten Stellen können auf Video eingespielt werden. Ein einprogrammierter Algorithmus auf Basis von Raum-Zeit-Relationen von Verkehrsteilnehmern zueinander unterscheidet Ereignisse, die der Definition eines Verkehrskonfliktes genügen (siehe die diesbezüglichen Artikel in diesem Band) von anderen. Damit wird ein Kritikpunkt gegenüber der Verkehrskonflikttechnik entschärft: nämlich der, daß menschliche Beobachter Zeiten und Geschwindigkeiten nicht ausreichend genug einschätzen, und damit nicht wirklich beurteilen könnten, wann ein Ereignis "knapp", "gerade noch gutgegangen", gefährlich oder ähnliches sei.

Auch im Zusammenhang mit der Verkehrskonflikttechnik gilt aber, daß die Ereignisse als Teil von Handlungskonzepten der Verkehrsteilnehmer auf strategischer, taktischer und operationaler Ebene zu sehen sind. Diese Konzepte verständlich zu machen ist auch hier das Problem. Solange man "naturwissenschaftliche" Nachweise der Validität beobachteter/registrierter Prozesse - auch auf Video raum-zeitlich exakt registrierter Prozesse - verlangt, verstellt man sich den Weg für intensiveres Arbeiten in Richtung Verständnis der Verkehrsprozesse unter größtmöglicher Berücksichtigung der Eigenheiten menschlichen Denkens und Handelns.