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International Workshop 'Recent Developments in Road Safety Research'

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INTRODUCTION BY THE CHAIRMAN

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International contacts are a kind of elixir for those engaged in research: finding out about the work of fellow researchers improves the quality of one's own work, encourages reflection and suggests new ideas. Many find that personal contacts are an essential part of the exchange of ideas. It is not enough to note the contents of books and specialist journals: these merely indicate something of what is going on in the research world, and often long after it has happened. Personal contacts provide admission to the "back-rooms", they make it easier to find the right man or woman, especially in large organizations.

In the field of road safety research there is, unfortunately, nowhere one can buy admission tickets to the backrooms. Every so often a "ticket window" is opened: an international conference or working party, for instance. Other opportunities, such as study visits, international projects, exchange agreements between research organizations or an international journal of road safety research in Europe, are almost if not entirely absent. The needs of researchers for more international exchange of information, more personal contacts (including informal ones), are at present met on an ad hoc basis - and therefore inefficiently. Our field, which has developed in the wake of mass car ownership, may be relatively young, but it is already too old for these needs not to be met in an organized fashion.

By organizing an international workshop on Recent Developments in Road Safety Research, SWOV has tried to make a first, cautious step in this direction. We believe that informal gatherings, with properly prepared material, which provide adequate opportunities for researchers to talk to one another, bring together the right people (in terms of material and quality) around the table, avoid any undesirable exclusiveness, are held regularly and are organized on a permanent international basis are the most promising form.

We have tried to bring together researchers solely to exchange research experience. It is not our aim to organize a forum for researchers to meet their customers (politicians, policy makers, people working in the field, road users): there are enough such forums already. Our motto is "Show your weakness to your colleagues and let them say what is your strength".

Lastly, we have tried to emphasize the multidisciplinary nature of road safety research in the subject matter chosen: a wide variety of topics, examined from different angles by different researchers. SWOV is delighted that so many excellent researchers from so many countries have accepted our invitation. The organizers, Joop Kraay and Els Geljon, have don a marvellous job in organizing a forum which meets many of the conditions I outlined earlier. We shall certainly learn from our experience, but I think we can say we are on the right track.

BEHAVIOURAL RESEARCH

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Introduction

The title 'behavioural research' might seem to suggest that this discussion will be concerned with only a subdivision of safety activities, or with an area of specialist interest. This would be far from the truth, for it is a contention of this paper that behavioural research is fundamental to making significant progress in safety research in the future. This is not to deny that impressive achievements have been made in the past. However, there is these days a growing recognition that it is becoming increasingly difficult to make advances in road safety without a deeper knowledge of the operations involved. The researcher therefore needs to seek for an understanding of the complex interactions that are involved in the safety system, the processes at work within the system, and in particular, the reasons for breakdowns in these processes. In short, the key task of the researcher in the future might be described as being to establish the causes of safety, or more properly, of unsafety.

Why behaviour?

Once it is accepted that safety research should be concerned with gaining understanding, then the contribution of behavioural studies is clear. Accident statisics alone have little explanatory value; they can only describe situations and go some way to identifying problems. They provide a framework or a skeleton that needs to be complemented by behavioural flesh if safety problems are to be tackled in an efficient and effective way. This behavioural flesh can be of many different forms, with varying relationships to the framework of accident data that lies beneath it.

At the simplest level there is the collection of normative data on behaviour. To some, this barely counts as a 'real' research activity, but in practice its contribution can be a very valuable one. For example, in developing countries where accident data is incomplete or unreliable, normative studies can provide a clear and simple picture of the nature of safety problems in either absolute or comparative terms (eg Jacobs, Sayer and Downing, 1981). Even in the so-called developed countries, much safety work is hindered by stereotypes and conventional wisdom that often exert an undue influence on the nature of remedial measures. In these circumstances the provision of objective value-free data can be of great benefit. Until fairly recently, the prevailing view of pedestrians in England was that, compared with the 'normal' adult, the behaviour of children and the elderly was characterised by carelessness and irresponsibility. Support for this view was obtained by invoking the 'faculties' theory, ie that faculties are undeveloped in one group and declining in the other. So prevalent were these views that they acted as a positive disincentive to empirical work. However, when normative studies were carried out (Grayson, 1975; Wilson and Grayson, 1979) they showed that the traditional beliefs were very largely unfounded, and that the problem groups deserved more thought than they had been given in the past.

A second type of behaviour study is that which relates specific aspects of behaviour to accident data in order to obtain estimates of accident risk. These are effectively exposure studies, but can prove to be extremely powerful tools if they are able to assess the risks associated with alternative courses of action. The implication should be clear: accident data can only tell people what not to do, but behaviour data can make it possible to give advice on how to substitute low risk actions for high risk ones.

The third type of behavioural study has perhaps the widest range of application, for it is the evaluation study. The case for behavioural evaluation is a very strong one, evaluation in this context being taken to include the diagnosis of the problem as well as the assessment of the remedy. The majority of safety measures are based on explicit or implicit assumptions about road user behaviour, and so the examination of behavioural change is not just a logical part of the evaluation process, but an essential one if some understanding of the method of operation of the measure is to be obtained. This, of course, is the so-called 'process' evaluation, whose virtues were extolled at length at a recent conference (Oppe, 1985; Grayson, 1985), and need not be repeated here.

Finally, there is the 'pure' behaviour study which can be quite divorced from accident data and which sets out simply to understand more about the behaviour of road users. A wide variety of investigations fall into this category, ranging from the specific hypothesis-testing or problem-solving study to the broad naturalistic study that is often modelled directly on ethology.

What behaviour?

While the case for using behavioural research techniques can readily be established, agreement on what to study is less easily reached. Selecting items of behaviour to record and measure must inevitably involve some element of theoretical preconception. For example, many behavioural studies have been undertaken on the assumption that there exists a relationship between behaviour and accidents, often conceptualised as a continuum. Demonstrating the existence of such a continuum in empirical terms has proved to be a slow and difficult process, and many workers have been tempted into an alternative approach, that of categorising and classifying behaviour. There are many examples in the literature of behaviour being classed as safe/unsafe, good/bad, cautious/heedless, etc, either subjectively, or on the basis of so-called operational definitions. Attempts to develop criteria for 'safe' behaviour have led in the past to the construction of task analyses of sometimes amazing complexity (and doubtful value). When such notions have been transferred into practical application, as with the American experience with Defensive Driving Courses, the results have not been an unqualified success

(Lund and Williams, 1985). On logical grounds, it would seem more sensible to concentrate on 'unsafe' behaviour, ie behaviour that contributes to unsafety. Here it is possible to argue that certain actions can be deemed unsafe on a priori grounds, but the more justifiable approach is to attempt to identify hazardous behaviour, where it can be demonstrated empirically that certain behaviours or combinations of behaviours occur more frequently in accident situations than in non-accident situations. This calls for the collection of detailed information on both accidents and 'normal' behaviour. The quality of accident data will be a constraining factor in many cases, and the whole process will inevitably be a long and laborious one.

Behavioural research at TRRL

To give some idea of how the problems outlined above are being tackled, four examples of recent behavioural research at TRRL will be described briefly. The order of presentation reflects how closely the studies are associated with accident data in the design and execution of the work.

The first study is a highly specific one that set out to relate pedestrian road crossing behaviour to pedestrian road crossing accidents in order to estimate the risks faced by different groups of pedestrians at different parts of the road network. The procedure used was simple; lengths of road were divided into different types of section depending on the presence of crossing facilities and of junctions, teams of observers recorded the numbers of pedestrians crossing the road in each section, and pedestrian accident records for the roads in question were examined in order to allocate road crossing accidents to the appropriate section types. Estimates of pedestrian risk were derived by relating accidents to flows for each section type and subgroup of the pedestrian population.

Although the technique may be regarded by some as being rather 'low-tech', the results obtained enabled clear statements to be made about, for example, the relative risks of crossing on as opposed to near crossing facilities, or for men as opposed to women when crossing at junctions. Here, behavioural data has been used in close association with accident data in order to achieve a clearly defined objective that increases our understanding of a small but important part of the safety system. A further point of interest is that this study is one of the few instances of replication in the safety literature, having used the same methods at exactly the same locations as did the investigation reported more than twenty years ago by Mackie and Older (1965).

The second example is also of interest in that it is concerned with the behavioural evaluation of a feature that is believed to be so effective that it has never been evaluated, and further is held to be so essential to safety that it is now not possible to carry out any 'conventional' evaluation, ie long term analysis of accident statistics. The feature is known as speed discrimination, which is a system used at traffic signals on high speed roads. It acts by sensing vehicles approaching at high speeds when the green signal phase is about to change, and by extending this phase if any vehicle is likely to be unable to clear the signals before the onset of the red phase. Because of the widespread belief in the necessity of this system, the authorities were only prepared to disconnect the system for research purposes for short periods of time; thus behavioural evaluation was the only form of assessment possible.

The TRRL study was a before-and-after one, based on the use of the traffic conflicts technique. In addition to conflicts, two other types of 'critical incident' were recorded: heavy braking, and violations of the red signal (for fuller details of the procedures see Baguley, 1986). The study is still in progress, and so results are not yet available. However, these are less important to the present discussion than is the philosophy of the study design. The data for the before period (ie before the system was temporarily disconnected) consist of the sites' long term accident record, plus the behavioural data collected over a limited period. For the after period (ie the short time during which the system was disconnected), only behavioural data is available. Thus, behaviour and accidents can only be compared for the before period. If this relationship is seen as credible, then the behavioural data from the after period can be accepted as being relevant to or indicative of the level of safety (or unsafety) if the feature being studied were not present. For traffic conflicts this is not too difficult, since conflicts are widely accepted as being closely related to accidents (although there is still much debate over the use of the term 'validity'). For the other behavioural measures, the situation is not so clear. It might be argued that going through signals against a red light is an unsafe act, since it must almost by definition increase the probability of an accident. However, there is the opposing argument that, if there is a four second delay before the cross flow of traffic starts to move, then a driver who violates the initial part of the red phase is in practice using his knowledge of the road system to the full in order to minimise his journey time - and also reducing the level of congestion at the traffic signals. Thus, while accident statistics are important to this study, there is also a discernable move towards the less well charted areas of behavioural research.

In the third study this move is taken further, for accident statistics are used only to identify the problem, while conflicts are used as the sole indicator of unsafety. The problem is that of the emerging driver at T-junctions, a situation that has long been known to be associated with large numbers of accidents. What is not known is the extent to which such accidents are the result of, for example, inadequate looking behaviour, poor judgement, or some personal characteristics of the drivers involved. To investigate this problem, video films have been taken at a number of T-junctions. Two cameras were used at each site; one was situated at the mouth of the junction to give a close-up view of drivers stopped in the minor road, and the second was located so as to give an overall view of the junction. Traffic speeds and flows were recorded automatically through loop installations linked to microprocessors, and in addition, teams of observers recorded details of all conflicts that occurred, using the standard British traffic conflict technique (Baguley, 1984).

Analysis was carried out on two samples of drivers; the involved sample, which was made up of all drivers who were recorded as having been involved in a conflict with the major road traffic, and a control sample of non-involved drivers which was made up of the driver who arrived at the junction immediately before each involved driver, together with the driver arriving immediately after. The aim of the analysis was essentially to see how these two samples differed. Again, the study is still in progress, and full results are not yet available. What is emerging is a complex picture of interacting variables as far as the driver is concerned, but a clearer one regarding the traffic variables. Vehicles involved in conflicts were found to be travelling significantly faster than the overall mean, suggesting that underestimation of approach speed may well be a factor that increases the probability of a conflict.

There are two points of methodological interest about this study. The first is that it explicitly accepts the validity of the traffic conflict as an index of unsafety, and concentrates its attention on the antecedent events. Thus the conflict is being studied rather than just counted, and it is an understanding of the nature of the errors that lead to conflicts that is the real objective of the study. The second point is rather more cautionary. With modern technology, it is now very easy to amass large amounts of data in short periods of time. It is not so easy to analyse the data, and it is still less easy to interpret the results. Techniques of data analysis have not kept pace with developments in data capture. The transition from clipboard to microchip calls for more care in providing effective means of data handling and analysis - as well as for more discrimination in what data is collected in the first place.

The final example shows a complete break with accident data, since it is a 'pure' behaviour study, concerned with age and sex differences in driver behaviour. The unit of study is the driver error, which, though assumed to be on the continuum linking normal behaviour and accidents, is readily admitted as being some distance from accidents, and where the question of validity has rarely arisen. The technique used was very different from the other three studies in that it investigated subjects under controlled test drive conditions. A sample of young, middle aged, and old drivers of both sexes were taken on a test drive, during which the driving errors they made were recorded by an observer seated in the subject's car. A roof mounted video camera coupled to a radar speed gun was used to obtain continuous speed readings over the test route. When the drive was completed, subjects were tested in a hazard perception simulator and were also given some standard personality tests. Thus, for each subject there were available his or her biographical details, scores on the personality inventories, scores in the simulator, the number and type of driver errors made on the test route, and the speed data from the drive.

The study produced a wealth of inter-correlated data that showed how age in particular was an important factor influencing the number and type of errors made during the test. The other results were rather less easy to interpret, partly because it was difficult to assess the generality and applicability of the findings. The investigation can be seen as demonstrating both the strengths and the weaknesses of this particular approach. On the positive side, it comes closest to adopting the principles of experimental method. It embodies a high level of control over external variables, it collects data under clearly defined conditions, and full information is available about the subjects who participate. On the negative side, it is the in depth nature of the investigation that is its major weakness, for collecting data in depth from subjects necessarily means that only small sample sizes can be studied with normal resources. Further, the element of experimental control is itself a double edged weapon. All the subjects may have carried out exactly the same manoeuvres while driving over an identical test route, but it is not easy to say how representative that route was of normal everyday driving. Finally, a study of this type produces both too much and too little data. It produces too much as a result of the natural tendency to make the most of valuable subject time by collecting all possible information, while it produces too little because the sample sizes involved are usually too small to provide sufficient power for statistical tests.

Methodological problems

The four studies described in the preceding section have each been associated with particular problems of methodology, and only general issues will be discussed here briefly. These can be grouped under three headings: reliability, interpretation, and validity.

The issue of reliability does not get enough attention in behavioural research. In the more sophisticated behavioural studies investigators may devote much time to establishing reliability scores within and among their observers, but pay no regard to the stability or repeatability of the behaviour their observers are recording. Most behaviour studies are cross-sectional in nature rather than longitudinal, and the results are only rarely re-examined for consistency. Some attempt has been made to do this in the traffic conflict field (eg Hauer, 1978), but in general this issue represents a serious weakness in this area, particularly when claims are being made for behaviour to play a greater role in evaluation work. It is not unlikely that this situation has arisen because the process of assessing reliability and repeatability is a time consuming and unglamorous one.

The question of interpretation is perhaps more subtle, but no less important, for it asks how to ascribe meaning to the behaviour that is observed or measured. This is not always easy, as was pointed out earlier when discussing the traffic signal study. There it was suggested that running a red light should not automatically be seen as unsafe, and other examples can be brought to mind. One is gap acceptance, where it is far from clear whether small accepted gaps should be regarded as indications of skilled or of incompetent behaviour. The study of driver head movements will also need to tackle the problem of whether small numbers of head movements before emerging on to the main road reflect high levels of skill or limited abilty to cope with the task. The lesson here is that, taken in isolation, many items of behaviour are far from unambiguous.

Finally, there is the question of validity. This has been discussed at such length on so many occasions that there would seem to be little that can be usefully added here. It is worth noting, though, that this debate has been very restrictive in scope. A recently published dictionary of psychology includes entries on twenty-four types of validity; in the safety field the discussion has largely been about just one - predictive validity. However defined, it is generally accepted that validity remains the central problem faced by behavioural research. Acts of faith on this issue are not enough, and the collection of empirical data over long periods of time is unavoidable. The debate at present tends to be focused on the traffic conflicts technique. Outsiders to that subject should however note that it is the conflict technique that at present provides the strongest evidence for a meaningful and orderly relationship between behaviour and accidents, and that in effect conflicts will lead the way for other behavioural measures.

There is, however, one aspect of the conflicts debate that is particularly worrying. This is the move towards using conflicts (and by implication other behavioural measures) as surrogate measures for accidents. Establishing validity is a necessary first step, but after this nothing could be more calculated to diminish the potential contribution of behaviour measures than to simply feed them into the black box of assessment procedures, and thereby ignore the way in which they can lead to a better understanding of the operation of the safety system. Attempting to find substitutes for accidents is not the way to gain insight.

The future of behavioural research

Up to this point, the case has been argued that behaviour provides the best means of achieving a better understanding of the reasons for safety - and unsafety. However, the argument can be taken a stage further to point to the need for an understanding of behaviour itself. The best way to avoid the dangers of surrogacy is to study not just what road users do, but also why they do it. Only in this way can a properly integrated approach to safety research be achieved.

We at TRRL have been concerned with these problems for some time, and earlier this year organised a seminar of human factors specialists to discuss the issue. One result of this has been a decision to set up a Behavioural Studies Unit within the Laboratory which will be concerned with developing new initiatives in this field in conjunction with universities and other research organisations. The area is a complex and difficult one, where progress will be greatly assisted by co-operation at a national level and, it is to be hoped, at an international one.

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ROAD USER BEHAVIOUR

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Introduction

Road user behavior is very complex and has been studied in different ways, starting from different scientific backgrounds. But the goal of all these studies has been more or less the same: understanding road user behavior in order to explain accident patterns and to design and evaluate countermeasures.

This paper is a personal reflection on models, theories and research on road user behavior and presents illustrations of the complexity of this behavior and of the selective attention by researchers to elements or aspects of this behavior. The last paragraph gives the characteristics of a conceptual framework for road user behavior. In no way is this paper a documented review of past and current efforts in this field.

Complexity of road user behavior

The term road user behavior as used in this paper refers to observable behavior as well as to mental processes that are not directly observable but can be inferred from observations.

In its simplest form road user behavior can be described as a combination of the tasks of maintaining speed and lane keeping. In the case of a driver of a vehicle this means controlling the vehicle.

For various reasons the speed and path of a vehicle will be disturbed and the driver has to make corrections. If the sideway disturbances cannot be tolerated, the driver has to slow down.

The driver has to follow the road, avoid obstacles and other road users as well. This involves predicting the future position of the vehicle in relation to the roadprofile, the position of obstacles and the future position of other road users. Preventive action has to be taken if this results in the prediction of leaving the road or colliding with an obstacle or road user. There are physical limits to acceleration and deceleration (both ahead and sideways), which determine the freedom in obtaining a future position. The task of the driver is to select the present speed and path, giving enough freedom to take a future position without leaving the road or colliding. This further limits the selection of speed and path at any time.

The prediction of future position, the potential acceleration or deceleration cannot be perceived directly from the situation but are dependent on knowledge, experience and training. Perceptions of road profile, presence of obstacles and other road users may be replaced or complemented by knowledge or expectation. And legal regulations have to be recalled from memory insofar as they relate to the selection of speed, path or action with regard to other road users.

Thus far the description of road user behavior has gone from simple to complex but is still far from complete. There is no account of the diversity of conditions (concerning e.g. other traffic, road layout, lighting and weather conditions) and of the diversity of road users (concerning capabilities, motivation etc.). It is a description of behavior as it could or should be, rather than of behavior as it is in reality. There is no specification of the cues or search patterns that are used to get information, of the time pattern of tasks or the role of present experience in future behavior. But even more important is that there is no description of the translation of information into action plans. In other words there is no explanation why road users select their speed and path, action with respect to other road users, trip destination, route, time of trip and transport mode.

Models, theories and research

As a consequence of the complexity of road user behavior many models or theories have been developed and applied to road user behavior. They all have in common that they pay selective attention to elements or aspects of this behavior, ignoring others.
It is obvious for example that studies on control tasks, such as tracking or car following, are restricted to elementary tasks of on road behavior. Other approaches of the past, looking at road user behavior as information processing (with accidents resulting from informational overload) are restricted to on road user behavior also. This seems to be a characteristic of studies on accident proneness of the past as well. The idea was to identify individual differences in order to predict unsafe behavior on the road which is reflected in accident rates. At present there is evidence from a number of studies that groups of drivers are different with respect to the acceptance of risk at the level of trip planning and preparation as well as of on road behavior. Another current trend in research seems to be the attention to risk acceptance or avoidance as the motivating factor for road user behavior. The work of Wilde on Risk Homeostasis Theory is well known and has raised a lot of controversy.

The theory states that a road user has a target level of risk wich is compared to the actual level of risk. Risk is defined as probability times cost of having an accident per time unit. If the experienced level gets lower, for instance as a consequence of safety measures, the road user changes behavior to return to the same target level of risk. This implies, among other things, that the road user has enough freedom to select other behavior with more benefit per time unit as compared to the original behavior but with the same level of risk.
The theory seems to apply to the level of on road behavior as well as of trip planning. But there is no specification of the feedback of changes in level of risk at the two levels of behavior, no specification of the selection of compensatory behavior and no explanation for differences in target level of risk between or within individual road users. It must be acknowledged, however, that this theory has stimulated more interest in the motivational aspects of behavior and more attention to the possibilities of migration of accidents or unsafe behavior.
Since the introduction of RiskHomeostasisTheory there are at least three of four more models on the role of risk in road user behavior.

Conceptual framework
Looking at the different conceptualisations of road user behavior there seems to be recognition of a conceptual framework with a number of characteristics. None of these characteristics is new but can be found in the literature as long as twentyfive years ago. The behavior can be described as an ordering of tasks on a number of levels, with the higher level tasks setting the goals for lower level tasks. Tasks at the operational level (speed maintenance, lane keeping) form the execution of tasks at the tactical level (taking a curve, overtaking, giving way) which form the execution of tasks at the strategic level (trip planning). The goal setting of each task is the result of a process of weighing and comparing the costs and benefits of a number of behavioral options. Information for this process comes from memory or perception. This process may be deliberate or automated, depending on past experience and training. All these tasks are partly performed parallel in time and partly in succession.

The ideal model or theory of road user behavior should incorporate all three levels of tasks with, at each level, details of the search and selection of information, of the process of selecting behavioral goals and of the timing of tasks. As with all ideals, this one seems to be far away.

In this situation priority could be given to behavior at the tactical level for a number of reasons. This kind of road user behavior is neither completely deliberate problem

solving, nor automatic control activity. It is also interesting because at this level behavior seems to be highly interactive with the situation. The study of tactical behavior will provide opportunities to study the time sequencing of behavior at this level as well as between this and the other levels (operational and strategic).
In the past work on task analysis of road users has resulted in a very long list of tasks which are identified as an intention by the driver in relation to a specific situation. The tasks themselves were described as a number of successive mental/motor actions. Early work on computor simulation of road user behavior has shown that even a simple task such as crossing in the presence of a traffic light requires very complex programming.
What seems to be needed is empirical evidence to test or further develop theoretical models of tactical road user behavior.

CHOOSING AVOIDANCE MANEUVERS IN EMERGENCY SITUATIONS

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ABSTRACT

In-depth analyses of real accidents carried out at Salon de Provence have shown that lateral avoidance is under-used, considering the gains to be derived if performed properly. We describe here the results of two accident studies dealing with emergency situations, and two experimental research projects which try to shed light on the excessive use of braking.

The problem of emergency situations is not a simple one. Their relative scarcity makes them difficult to observe. Althought conflict technics exist in many countries, it has never been possible to establish identical situations whose conflicts resolved or culminate in accidents. To put it another way, we don't know whether the difference between a resolved conflict and an accident is a matter of degree (a little less space, a slightly higher speed) or is essentially due to the way one of the two drivers involved behaved. This paper tries to summarize several pieces of research carried out in this field at INRETS, most of which have not yet been published.

THE FACTS : THE MANEUVERS PERFORMED BY USERS INVOLVED IN ACCIDENTS : A TYPOLOGICAL APPROACH.

The first study made at Salon de Provence deals with 72 real accidents studied on the spot (FERRANDEZ, FLEURY, LEPESANT 1984) which involved 126 road-users.

The maneuvers attempted : There are the ones actually performed and which, by definition, all failed. In some cases, though, they may have been the best course available for trying to avoid the accident.

The feasible maneuvers : There are the ones that would have prevented the accident, if properly executed and initiated at the same moment as the attempted maneuvers.

Of the 72 accidents, 31 could have been avoided if a feasible maneuver had been made by at least one road user. Braking constituded 23% of the feasible maneuvers, the others being a slight prompting (43%) or a hard one (27 %).

<table>
<tr><th></th><th>ATTEMPTED</th><th>FEASIBLE</th></tr>
<tr><td>Nothing</td><td>35 %</td><td>1 %</td></tr>
<tr><td>Braking</td><td>21 %</td><td rowspan="2">8 %</td></tr>
<tr><td>Braking
+ sideway movement</td><td>24 %</td></tr>
<tr><td>Slight lateral prompting</td><td>6 %</td><td>15 %</td></tr>
<tr><td>Hard lateral prompting</td><td>13 %</td><td>10 %</td></tr>
<tr><td>Others</td><td>1 %</td><td>2 %</td></tr>
<tr><td>TOTAL</td><td>100 %</td><td>35 %</td></tr>
</table>

TABLE 1 : Comparison between attempted and feasible maneuvers.

The main maneuver actually performed is braking (70 %), either alone or combined. In many cases a slight sideways movement would have been appropriate but the driver reacted too late or too violently, or tried to combine braking and sideways avoidance, which often results in loss of control.

At junctions, a leftwards avoidance maneuver is very seldom attempted, except when the obstacle is coming from the right.

A second study dealt with 82 accidents, at junctions involving 164 people. (FERRANDEZ, FLEURY, 1986). In 45 % of the accidents, a feasible maneuver existed.

Scope for evasive action is very limited for road users travelling on the secondary road who are responsible for the conflict. Conversely, on the main road, there is a feasible maneuver and in 50 % of cases if the obstacle is coming from the right, in 25 % of cases if the obstacle is coming from the left. In the latter case, the intruder is generally recognized as an obstacle later, which explains the lower percentage of feasible maneuvers. The maneuver attempted is generally braking, but if a sideways movement is made, it is almost always in the same direction as the intruder is moving.

It is clear that the major possible gains are to be found more in an improvement of the driver's response time than in vehicle performances (See Lechner 1983) or even in the appropriateness of the driver's choice of maneuver. Earlier identification of the danger is the most sensitive factor but we did not vary it in the different scenarios of accident reconstructions.

- WHY IS THERE A DISCREPANCY BETWEEN FEASIBLE AND ATTEMTED MANEUVERS ?

When a feasible maneuver was available, why did the driver make the wrong choice ? Did he behave stupidly, differently from other drivers (the good ones, those who resolve the conflicts they are involved in) or did he behave like any ordinary driver ? Why is the use of sideways avoidance so rare and so badly executed ? The reasons are manifold and one cannot give a simple answer. Nevertheless, several approaches seem possible.

- In depth analysis of real accidents (this work is in progress)
- Experiments on a circuit or a driving simulator
- Surveys of driver attitudes and their knowledge concerning avoidance maneuvers.

DO DRIVERS PERCEIVE THAT A SIDEWAYS MOVEMENT REMAINS POSSIBLE CLOSER TO THE OBSTACLE THAN EMERGENCY BRAKING ?

This research (Malaterre, 1986), the results of which have not been published yet, was carried out on a racing circuit. Twelve people (7 males and 5 females), having clocked up more than 150 000 kms, were used for the experiment and carried 64 trials each. The subjects didn't actually make the maneuver but signaled by pressing a switch the last moments beyond which it would be too late for initiating the braking or the sideways avoidance of an imaginary stationary obstacle. The results showed that nine persons perceived the advantages of sideways avoidance, two thought there was no difference and the 12th person behave in a way opposite to the hypothesis. (This woman was recently involved in a fatal accident in which she ran over a moped when attempting sideways avoidance). So it doesn't seem sensible to try and explain the under-use of lateral avoidance by a non-perception of its associated gains.

Nevertheless, its perceptive and cognitive cost has not yet been assessed. Reality is of course much more complex. Drivers are seldom prepared to cope with an emergency situation. The greatest part of the response time variance is ascribable to central mechanisms. Triggs and Harris (1982) put it this way : "When a completely unexpected signal occurs on the road, the driver may have to change mental set to the new situation before being able to prepare and to make his response". We also find in the literature the notion of "violation of expectancies" (THOMSON and KAMMANN, 1979) to explain observed time-lags in urgent situations, or persistence in an erroneous response mode. It still remains that in an emergency situation, the driver can't analyze all the parameters in terms of probabilities and the losses or gains negative or positive values of each solution. More probably he acts :

. On the basis of a stereotyped strategy, which he thinks to be generally the most efficient. Prentice (1974) sees intersection conflicts as a game with a non-zero sum, the minimax of which is braking.

. On the strenght of only part of the available information, according to priorities that remain to be investigated further.

Seeing the complexity of the problem, it is necessary to tackle separately the different stages of the final response. One of them relates to attitudes and knowledge concerning maneuvers considered feasible.

WHAT DO PEOPLE THINK ABOUT AVOIDING MANEUVERS ?

In intersection situations reconstructed in the laboratory, what choices do drivers make and what kind of arguments do they back them up with ? The aim of this experiment (MALATERRE 1986) was to investigate drivers'mental representations of appropriate solutions to intersection problems, without any time constraint and without taking into account perceptive judgements about physical parameters (i. e. speeds, distances). On the basis of the diagnosis made (I have enough space to brake or not), we took into consideration the descriptions of the maneuvers perceived as feasible or unfeasible, and the reasons given by the drivers. 24 drivers with various degrees of driving experience were presented 4 slides each, showing 4 intersection conflicts. The approach was filmed from the front seat of a vehicle on a video tape recorder, which could be stopped at 3 distances from the obstacle (10, 30 and 70 meters).

The speed of the car was approximately 25 m/S. We used slides instead of the video recorder for static pictures, because of their better image definition and stability. The intruding obstacle was a RENAULT van whose speed was adjusted to be on a collision course.

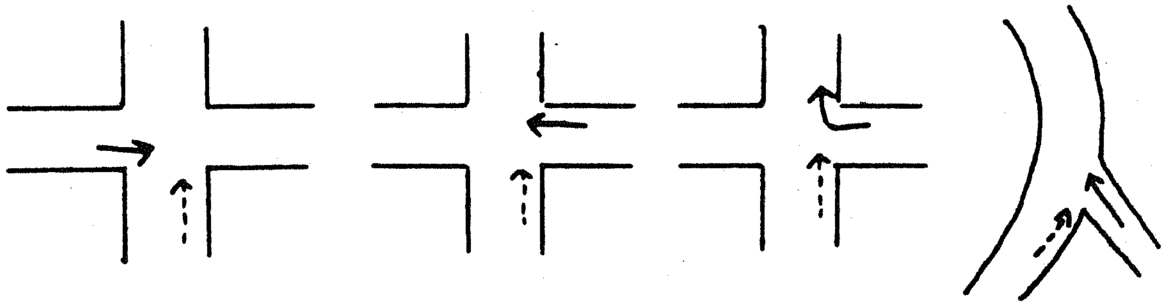

FIGURE 1 : The four intersection problems : the solid arrow represents the obstacle and the dotted one the subject's vehicle.

The instructions were these : "On this TV screen, you will see a road, as if you were driving. Next to a junction, the video recorder will stop and the same scene will appear on this other screen. You will have all the time you want to analyze the situation. You will have to tell me which maneuver would be appropriate to the situation and explain why". The answers were tape recorded.

Aggregating the answers of the 24 subjects for the 4 situations, we obtained the following distribution :

Braking	23 %
Sideways movement	19 %
Combined maneuver (1)	11 %
Conditional maneuver (2)	47 %

TABLE 1 : Total responses distribution.

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(1) Braking + sideways movement combined.

(2) Braking first and then sideways movement if necessary, according to the obstacle's movement.

We can see that lateral movement alone is rare, and that roughly 80 % of attempted maneuvers begin with braking, either on its own, combined, or prior to another maneuver.

More thorough analyses were carried out concerning the effect of different simulated variables.

. <u>Distance from the obstacle and direction of its movement</u> (situations 1 and 2).

	FAR	MEDIUM	NEAR	TOTAL
Braking	4	4	0	8
In front of movement	1	3	10	14
"Behind" movement	6	7	0	13
Conditional	1	10	2	13
TOTAL	12	24	12	48

<u>TABLE 2</u> : Direction of the obstacle and direction of the avoidance

It can be seen from this table that very close to the obstacle, drivers do not brake. They are aware of the inefficiency of this maneuver. The avoidance is elicited before the obstacle in the hope that it will stop. Otherwise no maneuver appears feasible. It's a last chance maneuver. Avoidance action behind the obstacle seems to be viewed different by. It is based on an estimate of speed and distance and is more logical than action taken on a reflex. Conditional responses correspond to the intermediate distance, where there is the greatest uncertainty (it was calculated for that purpose).

. Visibility

The movement of the obstacle was exactly the same for situations 3 and 4, but the visibility was very reduced by the bend in the latter case.

	Situation 3	Situation 4	TOTAL
Braking	3	11	14
Movement to the left	21	7(1)	28
Movement to the right	0	6(1)	6

TABLE 3 : Visibility and sideways movements.

For situation 3, where the visibility is good, avoidance to the left is almost systematic. On the contrary, responses are always conditional in situation 4 : braking first and then sideways movement depending on the visibility. All the subjects but one preferred a collision with the van to taking the risk of overtaking without any visibility.

. Justification

The most difficult part of the work consisted in classifying the reasons given to justify an action or non action. We can't examine this part of the study in detail, so we will just present a table which summarizes the results.

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(1) Conditional

	sit. 1	sit. 2	sit 3	sit. 4	TOTAL
Obstacle movement	63 %	67 %	42 %	8 %	45 %
Visibility	58 %	29 %	54 %	96 %	59 %
Space distance	63 %	50 %	46 %	38 %	49 %

TABLE 4 : Justifications by great categories.

This table reflects the perceived difficulties of each situation. It can be seen that negative evidence carries great weight (1) : in situation 4, the absence of visibility is mentioned by almost all the subjects. We asked the subjects to rank the degree of perceived difficulty for the four situations and we found it was in agreement with the absence of visibility mentioned.

. Comparison with accidents.

If we consider now the final response but the initial one, (the case of conditional maneuvers beginning by braking), we can describe the choice process this way.

- Enough distance	braking	15 %
- Uncertainty about the obstacle's movement	braking	13 %
- Poor visibility	braking	29 %
	other	5 %
- Good visibility	braking	17 %
	other	21 %
		100 %

(1) See Wright 1974, Zakay and Wooler 1984.

That is, to start a sideways movement as a primary response, three conditions are required :

+ Short distance
+ Certainty about the obstacle's movement
+ Good visibility

We see from these figures that 74 % of subjects decide firstly to brake . Knowing that in an emergency situation braking results generally in a locking of the wheels, we may imagine that braking is over-represented in accidents, since further maneuvers are rendered impossible. Despite the inherent limits of this expermiment (which is not representative of accident situations), we find a close correlation with the accident study. So the conclusion might be : people involved in accidents did not make stupid initial choices. Sitting in an armchair with their slippers on, they would have made the same decisions. That would appear a rather puzzling conclusion, without knowing the effects of time constraint and stress. Unfortunately, we know few things in this area. Many subjects said that braking to start with would not necessarily be the best thing to do but is the action they probably would take in an emergency situation.

This was associated in people's minds with a "reflex" notion, rapidity, simplified analysis of the visual scene, impossibility to do anything else. But the circumstances that trigger a "reflex" action are far from clear. The question is : is it possible to modify these so-called reflexes, and how ? But above all, is it desirable to modify natural strategies which in most regards proved to be efficient ?

We don't know how many accidents were avoided bu using these strategies, and how many would occur if drivers attempted more sideways movements. Prentice may be right when he refers to game theory for explaining the gains obteined from braking, assuming it was a step in the construction of the individual's rational response and not the outcome of on-line information processing. It is possible that initial braking may be a sub-optimal strategy which manages to cope with most conflict situations. The shorter response times for braking than for sharp sideways movements seem to back up this position (see Triggs and Harris 1982 or Malaterre 1986).

It is clear that further research is needed, particularly in more complex situations (higher degree of interactivity) and that the use of high performance simulators will be valuable.

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CHOOSING AVOIDANCE MANOEUVRES IN EMERGENCY SITUATIONS, SOME COMMENTS

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The problem that is discussed in this contribution is concerned with, what I lately call, the "missing link" in traffic safety.
We have a lot of information about accidents that did appear in the past. From this information hypotheses are deduced, that give an explanation of the appearence of the accidents or at least describe contributing factors. These hypotheses are in many cases based on accident reconstructions that are derived at using information available in the accident report. However, a lot of information that is needed to reconstruct the accident is missing. Additional information is sometimes collected as is the case here, where an in-depth study is carried out. If the information search is focussed on a particular problem, as seems to be the case here, one may expect an improvement of that reconstruction. To check the value of the additional information collected in such a specific type of in-depth study, we are carrying out a methodological study in the Netherlands on second-lane accidents at one intersection. One of the main issues in this study is an evaluation of the reliability of this kind of information that is collected afterwards.
This information is primarily based on reports of the road-users involved and eventually of witnesses and on damage reports of vehicles, silent witnesses such as braking marks etc.
To check the reliability of the verbal reports, a camera is installed at the location for continuous control. A comparison of reported (non-accident) behaviour with that behaviour itself, recorded just before the inquiry, showed very large discrepancies between actual behaviour and reported behaviour. This confirms previous findings about the reliability of this kind of information.
Accident reconstruction seems to be very difficult, primarily if detailed information is necessary, e.g. about attempted manoeuvres and feasible manoeuvres as is the case here.
The origin of the information in table 1 cannot be deduced from the

contribution itself. It is assumed that this information originates from the reports of the car-drivers involved. If this is true, then it is questionable whether we must not speak of an "armchair"-evaluation here also, as described at page 11 with regard to the experimental situation. The "missing link" then is the actual conflict situation under study, varied over the relevant aspects that are important for the evasive action, resulting in accidents and the comparative conflicts under the same conditions that do not result in accidents.
We are all interested in this kind of information, but we are not able to collect this kind of data, because accidents are rare events.
The study is restricted to one aspect of the process: the ultimate choice of an action and the effectiveness of the combination of actions.
It seems logical in an accident - reconstruction approach to stay as close as possible to the facts. The remote stages in the accident-process are the most difficult to reconstruct. On the other hand, if one tries to explain the existance of accidents against the background of the normal traffic process and the possibilities for failure in the system, one is tempted to include other factors also.
From the game-theoretic or decision-theoretic approach of risk control the following need for information about the process can be added.
- Are both participants aware of the possible conflict?
- Do they search for the relevant information in order to anticipate?
- Is the anticipatory behaviour adequate?
- Is it possible to give an operational definition of this concept, e.g. in terms of maximum speed such that detection at the first and last possible moment is within time-to-collision bounds that are acceptable?
- Are the participants aware of the alternative actions possible, are they skilled to use them?
In the study actions are implied.
However, it is not only relevant to compare all kind of manoeuvres that result or does not result in an accident. In many cases there is no evasive action at all for at least one of the participants because he is simply not aware of the other road-user. On the other hand, in some conflicts the manoeuvre has communicative aspects and can be regarded as bargaining if one uses a game-theoretic approach. In the cases described here, we assume that the situation is out of control for at least one participant. In such a case a number of remarks can be made.
- According to the example given by Prentice: in a particular situation,

the strategies may be optimal for each of the participants, given his uncertainty about the other participants strategy, but sub-optimal if communication between participants should have been possible, or if information about the other participants strategy is available.

- Not only the probability of a collision is minimized by the participants but also the severity of a collision once it takes place. So the expected loss cannot be defined with regard to the probabilities of an accident only.
- Also the responsibilities are of importance. A participant may prefer an almost certain loss without own responsibility against a more uncertain loss with own responsibility (e.g. by making an evasive manoeuvre instead of braking).

What people will do in such a situation where they have to decide in a split-second and why they do it is not easy to explain.

Turning back to the original problem that was stated: what similarities and dissimilarities exist between encounters or conflicts that result and do not result in accidents we may ask ourself, what the means are for collecting this information.

Accident studies are necessary, but the information we really want cannot be satisfactorily derived from in-depth studies.

Additional information is necessary about the actual behaviour just before tthe accident occurred and low-accidents are avoided.
From the systematic analysis of behaviour in critical situations theories about the appearance of accidents may be constructed. Accidente information is needed to check the validity of such theories.
This paper starts from the end: the product. The alternative approach mentioned here starts from the beginning: the process. May be we meet each other at the missing link.

DISTRIBUTION OF ACCIDENT DATA AND CRITICAL INTERACTIONS OF A STANDARDIZED ROUTE IN VIENNA

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Mainly for the purpose of describing and comparing driver performance we developed a test-route by means of pre-tests in 1981, which is representative for the characteristics of streets in eastern Austria (RISSER et al. 1982).

To be used on that test-route a technique of driver-observation was developed, which should supply the following data:

1. Critical actions (errors in driving behavior) and interactions (traffic conflicts, communication processes) of the observed subjects (observed by a so called "free observer").

   Standardized data on driving behavior (e.g. headway, speed, Overtaking, behavior in interactions with pedestrians, behavior in priority situations). By means of this standardized behavioral observation an index of erroneous behavior was assessed, too (observation by a "coding observer").

2. The data obtained by this procedure should allow a comparison of the observed subjects to each other by means of appropriate methods in order to classify their performance.

   On the other hand, relations between the driving behavior and the results of a diagnostical testing in the laboratory should be examined (= control of validity of diagnostical testing using driving behavior as a criterion; RISSER et al. 1983).

The behavioral errors assessed by the "free observer" and the index of erroneous behavior of the "coding observer" showed a correlation of r = 0,75. Differences can be explained by the fact, that several actions (e.g. moderate infringements of speed limits) classified as erroneous by the coding observer, were not recorded as erroneous by the free observer: The relation of driving behavior to the situation plays an important role for the assessments of the free observer.

Quite a different kind of analysis was included in the study, also using the above described observation data:

On several sections of the test-route a high frequency of erroneous behavior and critical interactions were observed; on other sections very few subjects showed erroneous behavior or got involved in critical interactions.

The question that interested us was, if a correlation between these indices and the frequences of accident at these street-sections could be found.

For a comparison of the two measures we were provided with the neccessary accident data by Vienna police.

We started from the assumption, that by that kind of screening we planned one could find out critical sections of the road network when no accident data are available yet: As soon as one detects accummulations of driving errors and critical interactions there is the hypothesis of higher accident risk. Thus, our kind of investigation may indicate, which sections need more detailed examination.

As a next step, frequency counts as well as the analysis of critical interactions - registered on the spot - will have to be done.

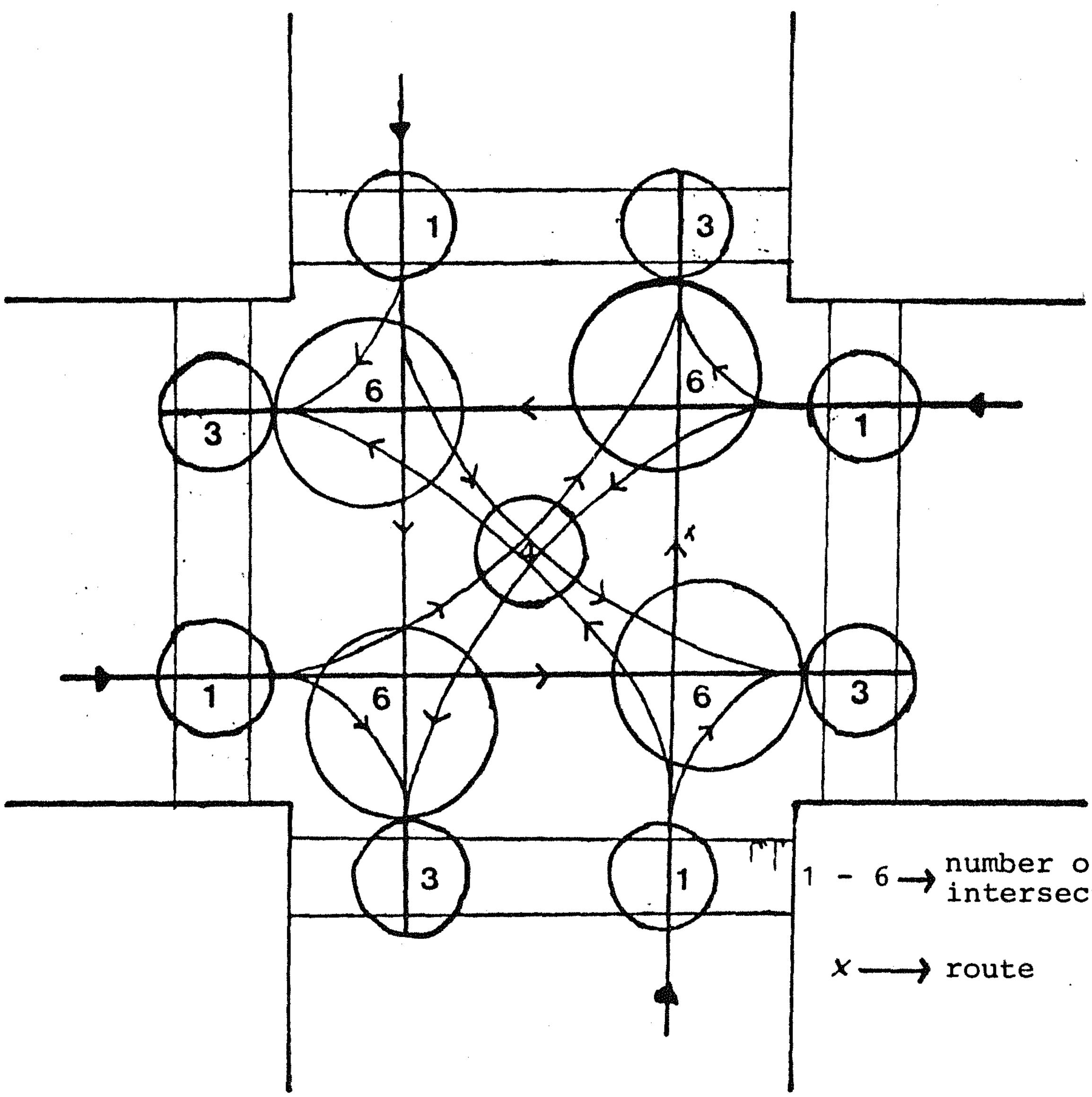
Before calculating correlations between observed behavior variables and the distribution of accidents a few restrictions had to be made:

- Long road sections including(two or more intersections of lower importance were excluded from the analysis (localisation-problems of accidents). Thus, the total number of compared road-sections was reduced.
- On the other hand there are sections consisting only of one well defined crossroads, but with several possibilities of interactions as well as accidents between traffic-participants not moving along the test-route. They were meant to be excluded from analysis, too.

Excluding these two types of sections 13 points remain for analysis. On those 13 points in almost all accidents and critical interactions taking place there is a vehicle moving along our test-route involved.

As 13 crossing roads seem to be quite a small number for comparing distributions of events, we thought of an estimation method for accident numbers concerning the traffic flow along our test-route by calculating all the intersecting-possibilities between traffic-participants not travelling along our test-route on those sections with several traffic streams not necessarily concerning the one along the test route (see RISSER 1985).

Figure 1: Number of possible intersectings in the area of a rectangular cross-road



The crossing shown in fig. 1 shows a total number of 44 intersecting-possibilities, but only 8 of them concern the traffic moving along our test-route, which is 20 % of all intersecting-possibilities: Following this reasoning, we divided the number of registered accidents by five and used the new number for our calculations. The intersection shown in fig. 1 shows the highest degree of complexity, we would feel able to accept for the topic of our investigation.

Using that estimation method 24 more sections of the test-route could be used for calculations additionally to the 13 sections where no transformations were necessary.

For those 37 sections (24 + 13) correlations between accident-distributions and distributions of behavioral variables were calculated.

Comparison of accidents and traffic-conflicts on 37 sections of the test-route

The following table shows correlations between accident- and traffic-conflict-numbers*) on 37 sections of our test-route, where accident-numbers in 24 cases are estimated.

Table 1: Correlations*) between accident- and traffic-conflict-numbers (n = 37)

	VK	UK	ΣK
VN 3	0,59	0,70	0,73
VN 4	0,46	0,50	0,55
VN 5	0,53	0,45	0,52
VN 6	0,45	0,61	0,57
VN 7	0,52	0,64	0,62
VN 8	0,52	0,39	0,49

*) $\alpha \leq 0{,}01$

VK = Conflicts caused or partly caused by the observed subjects.

UK = Conflicts without fault of the observed subjects.

ΣK = Total sum of conflicts the observed subjects got involved in on a certain section.

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*) For definition of conflicts see RISSER & SCHÜTZENHÖFER 1984.

Accident-variables were described as following:

VN 3: Accidents with severe injuries in 1981*)
VN 4: Total number of accidents with injuries in 1981
VN 5: Accidents with material damages only in 1981
VN 6: Accidents with severe injuries 1976 - 1980
VN 7: Total number of accidents with injuries 1976 - 1980
VN 8: Accidents with material damages only 1976 - 1980

The following conclusion can be made:

At places with a high frequency of accidents subjects driving along a test-route which of course includes those places with higher frequency of accidents get involved into traffic conflicts more often.

Table 2 shows the total number of conflicts and accidents occuring on the analyzed road-sections.

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*) 1981 was the year before the behavioral observations were done (n = 200).

Table 2: Total number of conflicts and accidents occuring on the analyzed road-sections

	accidents 81			accidents 1976-1980			ΣK	VK	UK
	VN3	VN4	VN5	VN6	VN7	VN8			
Weyringerstraße	3	9	4	9	31	26	22	7	15
Einb.Joh.Straußg.	0	1	1	2	5	7	2	1	1
Einb. Schelleingasse	0	0	1	1	2	1	0	0	0
Schelleingasse	0	0	0	0	0	1	1	0	1
Einb.Blechturmg.	0	0	14	0	0	43	2	2	0
Blechturmgasse	0	0	0	0	0	0	0	0	0
Einb.Gürtel-Nebenfb.	0	0	0	0	0	0	1	1	0
Gürtel-Nebenfahrbahn	0	1	1	0	3	6	0	0	0
Einb.Kliebergasse	0	8	12	10	35	36	2	1	1
Kliebergasse	0	0	3	3	17	7	6	3	3
Einb.Wiedner Hstr.	0	1	2	0	7	12	11	7	4
Wiedner Hauptstr.	0	1	3	4	9	7	5	3	2
Abb.Matzleinsd.Pl.	0	0	3	0	1	6	9	4	5
Einf.Triesterstr.	1	3	28	3	26	145	16	10	6
Triesterstr. (1)	6	44	42	36	121	159	10	6	4
Triesterstr. (2)	2	4	21	13	37	57	16	7	9
Triesterstr. (3)	2	5	2	6	14	6	11	6	5
Einb.Schönbr.Allee	0	0	0	0	0	0	2	0	2
Laxenburgerstr. (2)	2	6	5	5	12	21	1	0	1
Einb.Draschestr.	0	0	0	1	3	2	1	1	0
Draschestraße	3	7	8	7	29	19	6	5	1
Einb.Pfarrgasse	1	1	5	0	0	12	0	0	0
Einb.Sterngasse	0	0	2	0	2	2	1	1	0
Einb.Autobahnauff.	0	1	0	0	0	5	2	2	0
Schüttelstraße	0	3	4	4	15	14	7	4	3
Einb.Stadionbrücke	0	3	5	6	12	14	3	3	0
Kößlerplatz	0	0	1	1	1	5	4	3	1
Freuth/Erdbergestr.	1	2	3	1	8	8	6	2	4
Einb.Kard.Nagl-Pl.	1	1	1	0	5	1	3	2	1
Einb.Hainburgerstr.	0	0	2	0	0	3	2	2	0
Hainburgerstraße	1	5	6	3	10	22	16	8	8
Einb.Wassergasse	2	3	2	1	8	9	14	11	3
Wasser/Neulinggasse	6	17	37	22	85	62	24	11	13
Einb.Traingasse	0	1	1	2	6	12	1	0	1
Traungasse	0	0	3	0	2	2	1	0	1
Einb.Lagergasse	0	0	1	0	0	7	0	0	0
Einb.Ölzeltgasse	0	0	1	1	1	1	1	1	0

The examination of 13 sections, where only accidents with participation of vehicles, moving along our test-route are possible (table 3) shows, that the correlations between accident-variables and traffic-conflicts are lower but still significant.

Table 3: Correlations*) between accident-numbers and traffic-conflicts including only sections with a high probability of participation of vehicles moving along our test-route (n=13)

	KV	KU	ΣK
VN 3	0,49	0,54	0,48
VN 4		0,51	
VN 5			0,54
VN 6		0,61	
VN 7		0,65	
VN 8			0,61

*) $\alpha \leq 0,01$

Thus, after the analysis of this reduced number of sections we some to the same conclusion as above.

Other indicators for possible accident-risks on road-sections

Frequency of erroneous behavior (recorded by the free observer) and the behavioral index (extracted from code-observation) also seem to be good indicators for possible accident risk on certain road-sections (table 4), although, examination of the 13 sections with a restricted number of possible intersectings leeds to somewhat lower correlations (table 5).

Table 4: Correlations*) between accident-numbers and observation-variables, calculated for 37 raod-sections (n=37)

	G-	GØ	V-	VC
VN 3	0,62*	0,74*	0,66*	0,70*
VN 4	0,40*	0,57*	0,62*	0,62*
VN 5	0,28		0,43*	0,45*
VN 6	0,38	0,54*	0,55*	0,57*
VN 7	0,42*	0,55*	0,53*	0,58*
VN 8			0,40*	0,46*

*) $\alpha \leq 0{,}05$, with * $\alpha \leq 0{,}01$

G- = unfriendly communication acts
GØ = neutral communication acts
`G = sum of all communication acts
V- = erroneous behavior
VC = behavioral index (coding observation)

Table 5: Correlations*) between accidents and observation-variables including only sections with a high probability of participation of vehicles moving along our test-route (n=13)

	G+	G-	GØ	∮G	V-	VC
VN 3		0,48				
VN 4	0,53				0,66*	0,79*
VN 5			0,53	0,57	0,50	
VN 6						
VN 7					0,64*	0,55
VN 8					0,54	0,56

*) $\alpha \leq$ 0,05, with * $\alpha \leq$ 0,01

Summarizing, some conclusions can be made:

Traffic-conflicts, communications processes and erroneous behavior are distinct indicators of possible accident risk of street-sections.

Before applying the suggested technique one comment has to be made:

Traffic-volumes should be checked in order to point out if they indicate the same sections as risky as behavioral observations do. In that case one could get the relevant information by only counting traffic, although one has to consider that counting traffic on a route like the one in Vienna includes scrutiny of 51 road sections, countings of all movements of traffic participants (cars, leaving or joining parking lots, pedestrians between cross-roads etc.) thus being quite a complicated behavioral observation in itself.

Accumulations of those behavioral variables should lead to in-depth analysis of the respective road-section.

Thus, if one finds behavioral observation out of driving cars might be a useful method to detect possible risks on sections of the road-network, one could imagine the following procedure on new-built road-sections:

A number of driving-tests could be performed along a new-built road, including parts of the older road-network (where accident accumulations can be found, already).

50 to 100 driving-tests could provide behavioral data in order to decide about possible accident risk of the new road-sections compared to the surrounding streets.

If it is necessary, this procedure could be followed by a detailed analysis of the new-built road-sections with a higher possible accident risk discovered by behavioral observation.

Literature

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IN-CAR DRIVER OBSERVATION AS A TECHNIQUE FOR THE ASSESSMENT AND EVALUATION OF ACCIDENT RISKS OF GEOMETRIC ROAD DESIGN

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Risser presents high correlations (up to 0.80) between driver performance variables recorded at specified locations by in-car observation and the traffic accident data of these locations.
The presented correlations may be spurious because of differences in traffic flow of the various locations. Both accidents and driving errors depend to a high extend on traffic flow and therefore the correlations between accidents and driving errors may by only indirectly correlated via traffic flow.
Before firm conclusions can be stated about the usefullness of in-car observation as a method for risk assessment of road geometry, further research must be carried out to measure the relative explanatory power of traffic flow compared to in-car observation data.

Risser compares only rough driver performance variables rather than more specific driving behaviours. To make full use of the diagnostic potential of in-car driver observation more well-defined situation-specific driving behaviours: head-movements, braking, speed-control etc. must be considered.
In using the method the most suitable subjects would be beginning drivers or more experienced drivers performing as a secondary task some demanding effort.

In the Netherlands the practical driving examination is currently under study. As a result of the study it will be considered to record location bound driving errors of examinees. In which case driving examination records can be used for diagnostic assessment and evaluation of traffic accident risks of the occurring road designs, traffic signs, etc.. In this way an enormous amount of traffic safety information could be gathered by examining the driving test results of license applicants.

TRAFFIC SAFETY IN URBAN AREAS: PRESENT TRENDS IN RESEARCH AND PRACTICE

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INTRODUCTION

Traffic unsafety in urban areas is a major problem : in most European countries, over two-thirds of injury accidents occur in towns or cities, totalling over one third of the fatalities. Unprotected road users are the most frequent victims. While the total numbers of accidents and fatalities have decreased over the last few years in most developped countries, safety in urban areas does not seen to have progressed in the same proportions. It is now clear that more emphasis must be put on local traffic safety activities.

This means that local workers or decision-makers, whose main interests were usually in other fields (town planning, traffic management, road maintenance, teaching, information, etc.) are now getting involved in traffic safety, which raises practical problems such as lack of professional knowledge, lack of appropriate methodologies, difficulties of communication, etc. Also the public, both as road users and inhabitants of the towns or cities, have their part to play in local safety action. And as this is all quite new, most of what can be done in the field is experimental, which also raises problems at three levels: designing the measures, funding them, and evaluating them in the short term.

Given this background, there is clearly a need for research applied to local traffic safety work, in order to provide the necessary training, develop technical tools, and facilitate communication, both between local professionals with different educational backgrounds, and with the public. Conversely, traffic safety experiments carried out in urban areas provide the researcher with a field-laboratory that should be precious to test some of the assumptions made in road safety theory and some of the methodologies developped. In the field of urban safety, research and practice are narrowly linked.

TRAFFIC SAFETY PRACTICE IN URBAN AREAS: SOME HISTORY

Prevention of traffic accidents in urban areas was first attempted by planners when designing new towns (RADBURN in 1928 in the USA, STEVENAGE and CUMBERNAULD after the war in Great Britain, BIJLMERMEER in The Netherlands, etc) or new residential areas (SCAFT guidelines in 1968 in Sweden); the basic principle adopted was to segregate traffic in order to avoid conflictual situations between different road users (mainly pedestrians and vehicles) or different types of use of the road network (through traffic, distribution, or access). When urban growth started to slow down, the same principles were applied to the improvement of existing residential areas or suburbs, by translating some of the methods of traffic separation used in newly built areas into road closures, one-way systems, pedestrian precincts, etc. This new line of action was particularly developped in Great Britain and in Germany. /1/

The concept of integrated traffic appeared for the first time in The Netherlands ("Woonerven") in the middle of the 70's and rapidly spread to Great Britain, Germany and Denmark. It was meant as an alternative to traffic segregation, in view of the growing difficulties encountered in its application (high cost, problems of accessibility, problems to accomodate two-wheeled traffic and public transports, etc.). At this stage, traffic integration was only experimented on access roads or shopping streets with low vehicle flows.

This planning approach provided many examples of possible alternative treatments of urban roads and was thus quite fruitful. Some of the concepts developped were subsequently taken up by traffic planners in charge with traffic improvements in old town centres with narrow streets ill-adapted to heavy car flows. In addition to traffic separation, segregation, and integration, some measures aimed at restricting car usage and promoting public transports were first applied (for instance in NOTTINGHAM in England or GÖTEBORG in Sweden around 1973-74). /2/

In France, the planning approach had very little influence until the early 70's, save for the design of some new towns (CERGY-PONTOISE, LE VAUDREUIL). Traffic safety research and practice only started focussing on urban areas around 1972-73. Black spot treatment was the first type of action undertaken, in direct line with road safety practice in rural areas, and quickly showed its limitations with regards to the overall safety problem. The first traffic plans for city centres were also designed at that time, but although safety was stressed as one of their aims, they dealt essentially with rationalizing car traffic and increasing fluidity: traffic safety was then clearly not a priority for local decision makers or pressure groups. It is only later that pedestrian precincts, and provisions for two-wheeled traffic and public transports were introduced in city centres, and the overall effect of traffic plans on accidents was never really evaluated. /3/

Until the early 80's, there were in France no signs of any real global safety programmes at the local level. The deal changed with both the process of decentralization initiated in 1982, and two incentive packages launched by the central government in order to encourage local authorities to tackle their safety problems, and help them do so both technically and financially ("Minus 10 Percent" and "Safer Cities with Accidentless Neighbourhoods"). Local traffic safety action is now rapidly developing, using the whole range of available safety measures from planning to education, taking up the most difficult problems, as for instance improving areas with both residential activities and heavy traffic, and considering more and more traffic safety objectives as the trigger of urban life improvement (better environmental amenities, economic renewal). This is not an easy process, and research is a necessary part of it.

SOME PROBLEMS WITH LOCAL TRAFFIC SAFETY PRACTICE

Why have local authorities taken such a long time to start designing their own safety policies? Many factors may have contributed to creating the delay:

1 - Both local governments and the public did not seem fully conscious of the importance of the safety problem. Accidents are, statistically speaking, rare events, and therefore not very meaningful in everyday life; besides, accidents were long considered as a manifestation of Fate that one could not really expect to avoid... Hence the low priority given to safety when compared to other objectives of urban management.

2 - Due to the types of safety actions first promoted by the central government (black spot treatment in particular), traffic safety often got a bad image, both with the population and their elected representatives: countermeasures (reduced to traffic lights, pedestrian barriers, etc.) were mostly seen as constraints, making movements more difficult and bringing no help at all to the light road users. Area-wide treatments in city centres or residential areas were usually not associated with possible means of accident prevention.

3 - The lack of appropriate tools and methodologies was also a factor that prevented local administrations or technical services to face the problem squarely. Local accident data files only started developing in the late 70's, and there are still difficulties with data treatment. Safety diagnosis, choice of the types of measures to apply, design of countermeasures, integration of safety and other objectives, follow-up studies, all require a know-how that research has been late in starting providing.

4 - Many local actors may play a part in traffic safety decisions: local governments and technical services, local branches of the national road administration, teachers, road user or resident associations, the general public. In the past, it often proved difficult for the partners involved to reach an agreement. The motivations and views of the local members of central administrations, sometimes backed with strong directives from their respective ministries, were often in contradiction with those of the local elected representatives, engineers or planners. The road users and residents frequently exerted a pressure for action related to subjective feelings of unsafety rather than to observable facts,

which was considered inappropriate by technicians or members of the administration. And so on...

Part of these difficulties were eased by the decentralization process, which gave full decision power to local authorities in many fields of action, and also emphasized local duties. But some problems remain alive and strong, and research is needed in order to solve them.

THE RESEARCH NEEDS

In view of the problems encountered in the past and of the new trend in traffic safety which puts much more emphasis on local action, increased research is essential. The needs can be defined in relation with practical objectives:

1 - Help the new "safety professionals" perform their task.
The duty or will to prevent accidents must be backed by strong methodological tools, adapted to the means and preoccupations of the local safety team. Designing efficient countermeasures is getting more difficult now than it was in the past as all the easy ones have already been applied... Local safety workers are now faced with the task of treating scattered accidents rather than black spots, and mixed areas with both traffic and neighbourhood life rather than purely residential streets or business districts. Diagnosis is difficult due to the low accident figures, the selection of countermeasures cannot draw from past experience, and the final solutions will result from a compromise between several objectives, often contradictory (safety, traffic, access,etc.). Clearly, the effects of the countermeasures applied cannot be forecast with any certainty, and some short-term evaluation is needed to avoid possible mistakes.

A task for researchers is therefore to develop the corresponding methodological tools, which requires close communication between research and practice, as the actual needs must be identified, as well as available means or opportunities. The tools developped must be experimented, to check that they are valid and realistic. Finally, they must be handed over to local safety professionals, together with guidelines for general safety work and coordination between the various fields of action concerned (education, roads and traffic, information, etc.). Training programmes should therefore be produced.

2 - Integrate traffic safety within a set of current urban objectives.
As accidents in urban areas are essentially scattered over the road network, it is hard for a local government to economically justify area-wide countermeasures on the sole basis of traffic safety; it is also unthinkable to start "improving" urban streets without taking into account the needs felt or expressed by the local population, whichever they may be: the residents would no doubt complain to their elected representatives!

This means that the training programmes and the methodological tools developped for local safety workers must be wide open : they should be designed to address a variety of specialists with a background in physical as well as human sciences, and procedures for countermeasure design and evaluation should take into account, not only safety, but a range of factors (accessibility, traffic fluidity, environmental amenities, subjective safety, etc.). This implies a multidisciplinary research team.

3 - <u>Enhance local motivation for traffic safety and especially raise the public awareness of the problem</u>

The residents of a town or a city, or their associations, usually put a lot of pressure on the local government to take action in various fields. Traffic safety should be one of them if it is going to become a local priority. Also, most measures applied to prevent accidents rely on the adaptation of road-user behaviour ; they will be more efficient if the road-users concerned are convinced that they are useful or necessary, and actually choose to make them work. Better information of the public, better explanations of the existing safety problems, and closer association of the population to countermeasure design should be tokens for a successful outcome.

For this communication task, research can bring a plus, first by providing knowledge on the needs and motivations of local road-users: how they perceive their urban environment and how they would wish it to be, what their movements are and the difficulties they encounter in their daily trips, whether they feel safe or unsafe, why, and the importance they give to these feelings among other current preoccupations, etc. Research is only beginning in this field, and criteria to measure for instance subjective safety or the road users' satisfaction with their environment are still very tentative /4, 5/. If suitable indicators for the interest and feelings of road-users can be found, they will also be useful for diagnosis and evaluation purposes, for which the only parts of methodology already developped concern objective safety (accidents or surrogates). /6/.

4 - <u>Help initiate a creative movement at the local level</u>

How can all the local partners actually participate in traffic safety work, from the early stages of the diagnosis to the final programme of action and its implementation ? What is the best possible local form of organisation to enhance communication and facilitate understanding between the different kinds of actors ? Research can help finding an answer to this question, through the observation of existing structures, how they work, what constraints or presures they are submitted to, where they block, and by following-up safety projects from their initial stage to their realization (or "postponement"). Such a research on the local decision-making process appears essential, when one thinks of all the delays and lack of efficiency of road safety practice in urban areas observed in the part...

THE RESEARCH ALREADY CARRIED OUT OR UNDER WAY

Most research on urban safety in France was carried out at ONSER until 1985 and now continuing at INRETS. Some of the outcome is now available for use by local safety workers, but the knowledge available has still got to be added to, formalized and gathered into training programmes.

As far as methodological tools are concerned, procedures for detailed accident analysis based on the comprehensive police reports /7/, and for overall safety diagnoses at city level /8/ have been produced. A traffic conflict technique, aimed at providing surrogates for accident data when the latter is scarce or of poor quality and does not allow direct diagnosis or evaluation, has also been developped and finalized /9/, and a detailed training manual is in preparation.

Methodologies for safety diagnosis are thus relatively well developped ; but there is still no guidance as to the optimum definition of safety programmes or countermeasures, on the basis of such a diagnosis. This is not an easy task however, and it has so far been performed quite empirically, which sometimes results in politically oriented decisions with little logical link to the original findings, partly for lack of proper scientific backing. Providing aids in this field still requires quite a lot of applied research and evaluation results.

Evaluation methodologies themselves are still being developped, on the basis of "objective" safety (accidents and conflicts) as well as of other associated objectives for countermeasures (in particular environmental amenities, and subjective safety). The final tools produced are likely to result from a compromise between scientific requirements (data recording, statistical methods, etc.), and practical constraints (time, money, and manpower available at the local level). While sound and scientific evaluation studies, usually long and costly, can possibly be carried out only at government level or by researchers, the need for local short term evaluation in order to improve local action cannot be denied and meets different criteria.

For most of these topics, the national programme "Safer Cities with Accidentless Neighbourhoods" has been used as a basis for observation and data gathering /10/. Within the framework of this programme, about forty local authorities, assisted by a number of local partners, work at improving their town or an area of it, both to prevent accidents, and to reduce the economical, social and psychological problems resulting from the friction between high traffic flows and local activities. Researchers have been involved in this from the start, as it appeared as a rare opportunity for field experimentation, and also as they were needed to provide practical help.

Evaluation being part of the deal for all local authorities financing a project through the programme, a first set of guidelines was drafted and training seminars were organised. However, these guidelines were, in our present state of knowledge, more intended to make the local safety teams aware of the necessity of short term evaluation and the complexity of the task, than to offer strict procedures. These are under study. In particular, some local safety teams are now, with researchers, developing and experimenting methods for measuring safety feelings, or satisfaction of the public with respects to environmental amenities, through simple questionnaires including graphic elements or photographs. These new pieces of local research are only a starting point, and they can be used as first base for more in-depth studies /10/.

Our knowledge of how measures work, how much, and under which conditions is still scarce and scattered. Again, "Safer Cities with Accidentless Neighbourhoods" has been providing a field of observation, if not yet of evaluation. The main innovating feature in the actions undertaken has been the application of the space-sharing principle to urban arteries with high traffic (some up to ten thousand vehicles per day), so far with no reverse effects. Also new is the way to use and combine different forms and colours of pavement materials, as well as plantations and urban furniture, in order to create an environment likely to influence the drivers into safer behaviour (lowering speed in particular) ; contrast between materials in daytime, at night or under the rain, resistance to tear-and-wear and so on are important factors for the success or failure of such schemes. Some satisfactory examples can already be produced, and half a dozen urban projects are still being followed-up. This is a first step towards a technical catalogue of elements that can be combined to produce the visual and physical effects desired in any new improvement scheme. Checking the underlying assumption as to how these effects will affect the road-users is another line of research, and a longer term one.

The "institutional" aspects of the "Safer Cities" programme are also interesting to observe, as the birth, development and realization of urban projects can be followed-up all along, and the local organization adopted for traffic safety varies from one town to another. A follow-up chart has be drawn to guide the evaluators in charge of each project ; the data collected will be globally analysed after the end of the programme /11/. In parallel to the decision-making analysis carried out on urban areas, an in-depth research is also under way on the distribution of responsibilities for safety action at the level of the "département", intermediate between city and region /12/.

RESEARCH PERSPECTIVES

The follow-up study of "Safer Cities with Accidentless Neighbourhoods" should be going on in 1987, last year of the experimental programme. The findings will be gathered and analysed against a wider background, and should open the way to more in-depth research on particular topics. The work carried out so far is mostly to be considered as a first step of data collection and treatment, intended as a basis to draw strong research hypotheses.

Plans to develop methodologies and training programmes for local safety professionals should also continue, and will require as much work to finish gathering what has already been done in the field as to build up new tools. In order to keep monitoring the needs and activities of local authorities, a survey should be launched on a representative sample of towns and cities, in order to determine more generally what local safety policies are (if any), the main actions undertaken, and the difficulties encountered. The guidelines for such a survey are in themselves a research job, as "safety action" or "safety programme" is not well defined in the minds of many a local actor, so that the right questions have to be asked and the right persons found to answer them, in order to identify the whole range of relevant measures.

The results of such a survey should be useful, not only for methodological research, but also as data for "institutional" analysis. The development of traffic safety is highly dependant on the local administrative and political framework, and institutional and social research is a necessary background for all else that can be studied in this field.

Traffic safety practice in urban areas has taken a definite turn in France in the last three years. The present trend is in line with what past research results were pointing at. If the trend keeps, the dynamics of the situation should go on increasing. Research in this field should meet with more favourable conditions than in the past.

The research team working on local safety programmes at INRETS includes, apart from the author, Jean-Pierre CAUZARD (Sociologist), Anne FAURE (Urban Planner), and Pierre Emmanuel BARJONET (Sociologist). Other researchers that are or have been working on traffic safety in urban areas are F.FERRANDEZ, D.FLEURY, H.FONTAINE, G.MALATERRE, F.SAAD.

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COUNTERMEASURES IN THE INFRASTRUCTURE; SOME DUTCH EXAMPLES

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INTRODUCTION

It is a well known fact that most traffic and transport problems in the last 20 years are mainly caused by the ever increasing ownership and use of motor cars.
The crux of these problems is that car traffic requires more and more space, while creating unsafe conditions for slow-moving traffic, making people aware of traffic unsafety and unfavourably affecting the environment. All these problems have the strongest impact on towns, due to the heavy concentration of both driving and parked cars on the sparsely available space. The traffic function has a suffocating effect on other urban functions, mainly endangering the most vulnerable groups of road users: the pedestrians and cyclists.

Dutch authorities recognised these problems since many years. In the seventies various governmental reports announced experiments for reclassification and reconstruction of urban areas and streets with the goal to improve the quality of life for the people living there.

Such examples of experiments with infrastructural facilities, initiated and partly financed by the government, are:
- reconstruction of residential areas and of streets to form woonerfs;
- reclassification and reconstruction of roads in urban areas in the cities of Eindhoven and Rijswijk;
- experimental bicycle routes in The Hague and Tilburg;
- 30 km/hr regulation in fifteen residential areas;
- facilities for crossing busy traffic arteries by pedestrians in city centre areas at about one hundred locations;
- a cycle path network in the city of Delft;

- facilities on through routes in small centres in ten situations;
- countermeasures in streets with mixed functions for through traffic, shopping and residential functions, in ten streets.

Within these projects always priority is given to the safety of pedestrians and two-wheelers.

THE WOONERF

In 1976 the woonerf obtained legal status. It differs from a normally structured residential street, because the paved area can be (partly) used for traffic as well as for playing, walking and parking. The woonerf has, first and foremost, the functions of a residence, meeting place, playground and walking area (the yard function). Obviously this public area has the additional function of carrying traffic. But it has no function for through traffic.
The woonerf has been the most celebrated Dutch contribution to urban environmental traffic management in the last decade. The idea has been widely applied in Dutch towns and cities and has been the subject of intense interest to professional visitors from other countries. But the woonerf is only part of a whole package of measures - including the design of the urban traffic environment, legislation and law enforcement, tuition, information and training - to influence driver behaviour and thus improve both road safety and the quality of life, which have been under study in the Netherlands in recent years.

The great popularity of the woonerf among the Dutch people is revealed by interviews covering evaluation of a number of features of the residential environment. These interviews gave the following results: 70 per cent considered a woonerf desirable or very desirable, 16 per cent had no opinion, and 14 per cent were against.

Some behavioural evaluation studies have been undertaken. In a project in Gouda for instance, it was shown that the pattern of activities in a woonerf-type neighbourhood was more varied than in traditional neighbourhoods.
It is not yet clear to what extent the woonerf structure encourages resident's activities in the public spaces (which is one of the woonerf's pur-

poses). Interviews with residents indicate that few of them find that living in or near a woonerf encourages them to go out more.

Although elderly people and parents of young children believe speeds are still too high, the speed of motorized traffic in a woonerf is lower than in traditional streets. Most research projects give average speeds of 13 to 25 km per hour. It was found that speed is determined not by the type of reconstruction (changes in alignment, humps etc.), but far more by the closeness of the features.

Besides woonerfs regulated by law, a number of shopping, village and city woonerfs were created at the end of the 1970s. Streets and residential areas were also reconstructed without the intention of turning them into woonerfs.

Research of SWOV into the effects of 69 countermeasures (56 woonerfs, 3 village woonerfs, 4 shopping woonerfs and 6 other infrastructural countermeasures) showed that:
- in the experimental area of woonerfs the decrease in accidents was greater than in the experimental area of the other experimental countermeasures; the decline just failed to be significant at the 5 per cent level;
- in all types of experiments the reduction in accidents was greatest for pedestrians and moped riders;
- accidents between fast-moving vehicles are reduced, no difference being found between woonerfs and other experimental facilities (here again the decrease fell just short of significance at the 5 per cent level).
The overall reduction in injury accidents between the before and after period was about 50 per cent.

Further analyses of the effects of the countermeasures, classified according to road and area characteristics, show inter alia that:
- there is a big reduction in accidents in residential areas between city centres and fringe areas of the cities; these areas mainly resemble a ring around the city centre;
- there is a greater reduction in accidents if the facilities are provided in the form of a woonerf; the reduction is least in shopping woonerfs;

pavements should be retained as much as possible and the details should be intensive, with obstacles, changes in alignment, humps and plateaus. Further:

- the reduction in accidents is greater the more cars are parked in parking bays;
- the number of accidents increases with an increase in the number of connections to suburban roads and in the number of intersections within the experimental area.

Decrease in accidents in the after period was partly due to keeping out through traffic and short-cut drivers and partly to a reduction in motorized vehicle speeds.

EINDHOVEN AND RIJSWIJK

Another recent project relates to reclassification and reconstruction of two urban areas, 100 hectares each, in Eindhoven and Rijswijk.
As an experiment, rigorous countermeasures were taken to keep short-cut drivers out of residential areas so as to increase safety and quality of life. To start with, the road system was divided into traffic arteries, access roads and residential streets. Next, each type of road was reconstructed according to function.

In the case of residential streets, three different options were decided upon.

- Option 1: to ban through-traffic from the streets.
- Option 2: to ban through-traffic from the streets and to limit the speed of the rest of the traffic.
- Option 3: to ban through-traffic, to limit the speed of the rest of the traffic and to create an attractive layout in the streets.

The appropriate sets of countermeasures vary from fairly simple ones (one-way traffic and a single hump), to rather more complicated (one-way traffic combined with a variety of speed-retarding facilities) and to very drastic ones (woonerf or similar structure).
The reclassification of the urban area involving the division of public spaces into traffic or residential areas, presented no great problems. In

the two municipalities some roads and streets were appointed as traffic area. On the arterial roads, various categories of traffic have been segregated from one another as far as possible, thereby ensuring a safe and smooth traffic flow. In addition, due attention has been given to crossing places for pedestrians and cyclists.

Behaviour studies and interviews were held to ascertain whether the measures in the experimental area had met their primary objective. Traffic counts showed that excluding short-cut traffic from residential streets was at least a partial success. Car traffic decreased by 12 per cent in the residential streets in the experimental area, while in fact it rose slightly in those in the control area.

The interviews also revealed that there was less short-cut traffic after the reconstruction. In the woonerf streets the residents said such traffic had almost entirely disappeared. But in the other streets many people thought there was still too much.
Reducing traffic speeds was a major objective of the measures. Some two-thirds of the residents believed cars were indeed driving more slowly. Speed measurements showed that motorists drove most slowly in woonerf streets. But they also showed that moped-rider speeds in residential streets were difficult to curb; in woonerf streets they are often even faster than motorists. Perhaps this is why their safety was not improved after reconstruction.

The initial results of accident research indicate that such a structural approach may have a positive effect on road safety in urban neighbourhoods (Table 1). In residential streets in the experimental area the number of accidents involving injury per vehicle kilometre was halved. On traffic arteries and access roads, the reduction was about 15 per cent. The aggregate reduction for all types of road and street in the experimental area was about 20 per cent.
This research also showed that the measures taken in the experimental area had no adverse effect on road safety in the wider area around. The measures taken in the experimental area did not therefore shift the problem to other parts of the city. Improved safety in the residential streets in the experimental area certainly did not apply to moped-riders: there was a proportionate worsening in their safety.

In conclusion the following can be stated.
In the experimental areas some of the unwanted through-traffic disappeared from residential streets and the speed of other traffic dropped. The number of accidents involving injury fell, both in the residential streets and on main roads. At this stage it is not yet possible to say which package of measures for residential streets has the greatest favourable effect on safety, as the results of the behavioural studies and opinion polls do not provide an adequate basis. Accident surveys will presumably enable a conclusion to be drawn, bu not until accident data are available for a longer 'after' period.

It may be noted that about 80% of accidents involving injury in urban districts occur on main roads. Purely from the point of view of road safety, then, it is here that measures can be expected to have the greatest effect. It would seem, therefore, that relatively simple measures to keep out through-traffic and restrict the speed of other traffic are more appropriate for residential streets than complex and expensive measures such as the construction of woonerf areas. Moreover, Dutch municipal authorities have recently been given the power (under certain conditions) to establish 30 km/hr zones in built-up areas, which is a major addition to the measures available to compel drivers to adapt their style of driving to the needs of residential streets.

30 KM/HR COUNTERMEASURE

Since April 1st 1983, it is possible in the Netherlands to institute a maximum speed of 30 km/hr on certain roads within built-up areas. Since January 1st 1984, it is also permitted to indicate this speed limit by zone boards. This countermeasure is the consequence of the idea that the compulsory 30 km/hr speed limit has a favourable effect on traffic safety.

The 30 km/hr speed limit is one of the basic principles of the policy aimed at creating in the future, within built-up areas, two categories of roads: so-called traffic streets and residential streets. The speed limit will apply to residential areas, with the characteristic traffic feature, that motorized traffic must give priority to the habitat function of the area and its environment.

This investigation concerns fifteen residential areas in order to evaluate the effects of the countermeasure on attitudes, behaviour and safety.
The goals to be achieved by the 30 km/hr speed limit are expected to bring forth two important and direct effects, namely the reduction of the speed of motorised traffic and the elimination of sneaking traffic.
The countermeasures are now implemented in all the experimental areas. The results of this study will become available in 1989.

What can be expected of the 30 km/hr countermeasure as regard to traffic safety?

An indication of the expected results gives us a German study. In Berlin-Charlottenburg reconstruction areas as woonerf and 30 km/hr countermeasures are compared with a residential area without countermeasures but situated adjacent to the experimental area where is tried only to prevent the through-traffic. The provisional results shown in Table 2 indicate that the accidents in the woonerf are more reduced than in the 30 km/hr area. The main difference, however, is that in the woonerf the number of injury accidents is reduced, while in the 30 km/hr area only the number of damage only accidents are reduced.

SOME REMARKS

In case in The Netherlands similar results will be found as in Germany some remarks can be made.

- Relatively expensive countermeasures like the woonerf are, applied in the right way, really effective measures to influence road user behaviour and to reduce injury accidents in residential areas.
It is even probable that these so-called expensive countermeasures are cost-effective.
- The policy in The Netherlands is changing. In the near future less research money will be spent in the field of the quiet residential areas.
Time is coming now that countermeasures will be developed for the main roads within the built-up area because there one can achieve good profits.
It is still better to incorporate the main roads into the traffic management schemes to ascertain overall traffic safety. Some demonstration projects in Germany, United Kingdom and The Netherlands are good examples of this approach.

ACTIONS FOR IMPLEMENTATION

In this contribution some examples of infrastructural countermeasures in residential areas have been treated within the framework of the Dutch experiment-policy.
Experiment-policy means that the national government will play a stimulating role in order to show local governments the favourable effects of means and measures.
The national government is helping local governments by paying them 80 percent of the costs of the countermeasures; a condition is that the experiments will be accompanied by a before and after study dealing with aspects of experience, behaviour and accidents.

In this paper some results of three examples have been described: the woonerf, the demonstration project Eindhoven and Rijswijk and the 30 km/hr countermeasure. One of the most important conclusions is that injury accidents can be reduced by half.

In the coming years, however, the national government will invest less money in their experiment-policy in infrastructural countermeasures in residential areas; furthermore it will shift its attention more to the urban arteries.

When looking back, one can say that in the last decade a lot of information has been gathered about the effects of infrastructural measures in urban areas. We do not yet know everything, but we know a lot.

The question now is, what to do with all this knowledge? Besides less efforts in future research, there are two ways in using this information for implementation.

1. Principles for a traffic safety policy and viewpoints for safety practice should be implemented by decision makers from the beginning in the planning stage in town and country planning, and in urban renewal plans.

The second point is more relevant for researchers.

2. The information from research, gathered through the years by carrying out investigations with community money, must become available for, let's say, the man in the street.
Besides doing research, it is also a task of researchers to bundle this information in manuals, leaflets, etc. in order to be able to tackle the local road safety problems in a practical way.
On the other hand, local governments are assuming increasing responsibility for road safety. Decisions, actions and follow-up become more and more frequently assumed by local authorities. In this context, it then seems important to review the means presently available to highlight promising examples and to emphasize needs in order to guide future research.
In a decentralized policy with programmes as REAGIR in France, Minus 10 percent in France and in Austria, with local traffic circulation plans, with reclassification and reconstruction plans of residential areas, and so on, it can be very helpful for local authorities, for action groups and for the residents themselves to have practical research results at their disposal.

To summarize, researchers ought to make the results of their work applicable for effective use at the local level by different consumers; and give the local researchers, decision makers and the residents the relevant tools in their hands so that for them will also apply that "knowledge is power".

In The Netherlands one is at the beginning of this process, while at least France and Austria are already developing some relevant tools.

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Effects on the safety of residential streets

	accident rate [1)] experimental areas	control areas
before	2.26	0.60
after	1.04	0.57

Effects on the safety of main roads

	accident rate [1)] experimental areas	control areas
before	2.00	1.80
after	1.29	1.39

1) accidents involving injury per million vehicle-kilometres.

Table 1. Accidents involving injury on residential streets and on main roads of the experimental and control areas in Eindhoven and Rijswijk during the before and after period.

	Umbau (Woonerf)		Tempo 30		Preventing through traffic
	Midblocs	Junctions	Midblocs	Junctions	Midblocs
Total accidents		-48%*	-38%*		-45%*
Seriously injured	-67%*				
Slightly injured		-77%**			
Heavy damage only		-42%*	-42%*		-57%*
Slight damage only		-42%*	-42%*		-57%*
Motorcars	-27%*	-48%**	-43%**		-11%*
Two-wheelers		-38%*			
Pedestrians	-78%**				
Children	-81%**				
Accident causes:					
Turning, crossing		-78%**			
Parking	-63%**		-34%**		
Crossing the street	-60%*				

** $\alpha = 0,01$, χ^2 - test

* $\alpha = 0,05$, χ^2 - test

Table 2. Accident reduction in different types of residential areas (Source: Brilon, 1985)

MAJOR ROADS IN THE GERMAN AREA-WIDE TRAFFIC RESTRAINT PROJECT

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In the Federal Republic of Germany three ministers)[1] sponsored an interdisciplinary research project on 'Area-Wide Traffic Restraint' in six model cities: Berlin, Mainz, Ingolstadt, Esslingen, Buxtehude and Borgentreich.

1. The Aims of 'Area-Wide Traffic Restraint'

The aim of the project is to reduce any disadvantages caused by vehicle traffic in large areas within cities. During the 1970's promising results were achieved with traffic restraint measures taken in residential areas. (Pfundt, 1979; Keller, 1981)

How could these measures be transferred to larger areas, including roads with heavy traffic and businesses? For this more widespread application, it was important to develop a clear aim and to apply this in an operationalized manner. First, in the form of specifications for the planning of concrete constructional and traffic control measures to be taken in the city, and second, for an effectiveness study using the various research projects (see Figure 1). The specifications for the planner determine which modifications are to be made to the traffic network - in the area breakdown and for traffic control - and what behaviour is intended to be achieved on the part of the road users. In the specifications for the research team, the investigation hypotheses are formulated and prepared for a quantitative study including the use of measurements, observations and questionnaires. Figure 2 shows a survey of the main and secondary aims in the areas of traffic, environment and urban development. The subordinate aims are sub-divided into study hypotheses. These, however, are not shown separately here.

In the six model cities, traffic restraint measures will be implemented in large areas, either in the centre or on the edge of the city centre. This will take place in the period from 1983 to 1987 according to priority. The following outlines the programme of measures.

2. Major Roads and Residential Streets

The road network for the model area Berlin-Moabit is shown in Figure 3. The area has 30,000 residents, living in high-density four-, five-, and six-storey buildings. In addition to the residential buildings, the area has business premises and other infrastructure facilities such as a post office, schools, kindergardens, a market hall, various shops, the local town hall and other administrative buildings. The traffic includes not only residents, but also suppliers, shoppers, school traffic and, on the major roads, a high volume of through traffic. These factors must all be taken into consideration when planning traffic facilities.

In purely residential areas in Germany a system of roadway alteration measures, one-way streets and loops are set up in order to reduce through-traffic at low cost. A system of this type, such as shown in Figure 3, is not a feasible solution for the multiple utilization of the roads in Berlin-Moabit. Unfortunately, such systems are used in Germany even outside residential areas and are applied to mixed development areas. People not familiar with the area lose their way, large detours are caused and traffic rules are broken more frequently. The result is that such problems often have brought traffic restraint into disrepute among the public.

For this reason, it is advisable to avoid one-way road systems. Our models apply a different philosophy: All destinations in the area should be accessible using direct routes, roads should also remain open for motorized traffic, but the resistance to fast driving should be increased by narrowing roads, by slightly elevating road surfaces or by installing green areas. Figure 4 shows a typical street scene of this type. It is a residential street with shops and small businesses. In this example, the special model design of the street is apparent. We used to use the deviation alignment of centre lines as a successful traffic restraint measure to remove drivers' long-range sight and to induce a slower, more considerate way of driving. The State Conservation Office, however, objected to this: A road should retain its historical straight character. Therefore, only a narrowing of the road was used and no deviation alignments on junctions and on some sections. New trees and plants also help to maintain the symmetrical character of an avenue. At narrower points, pedestrians should be able to cross the road more easily. Trucks can only pass one at a time at these points (width 4. m). The humps are designed so that a level roadway remains for (motor)cyclists, busses and big trucks. The narrower points with the humps are repeated at frequent intervals (every 40 to 50 meters).

Although the streets in Berlin retained their straight centre lines, reconstruction of the residential streets was extremely successful:

- near elimination of dangerous, high-speed driving - very few drivers exceed the 30 km/h speed limit;
- the average speed now driven is approximately 20 km/h;
- parking practices that mostly conform to regulations;
- pedestrian crossings not obstructed by parked cars. Some problems still do exist with motorcycles hindering the unobstructed use of crossings by pedestrians.

In comparison with other traffic restraint projects we come to the 1. thesis: When traffic restraint measures are not strictly enforced, the effectiveness of reducing vehicle speeds cannot be achieved.

The main roads in Berlin are also being redesigned, although using other measures:

Case 1: Reduction of Lanes

The main business street passing through the area (Turmstraße) is to be reduced in width from three lanes in each direction to two lanes plus bicycle paths and more pedestrian crossings. This extensive redevelopment is to take place outside the scope of the model project after 1986.

Another major road (Stromstraße) was reduced from three to two lanes in each direction, and additional bicycle paths were included during the time prior to the model project. The street, however, retained its character as a high-speed roadway. There were few crossings for pedestrians and a dividing strip with high curbs.

Case 2: Reconstruction Without Changing the Street's Function

Another business street on the edge of the area (Beusselstraße) is to be redeveloped in 1986. At present, however, controversies about the redesign of the road continue between the local authorities. One side agrees with our recommendations and intends to reduce the width of the road from 11.0 m to 8.50 m (two traffic lanes) along with the possibility of a broad sidewalk and a bicycle path on the left side of the stand of trees (Figure 5a). The other, more conservative side refuses to reduce the width of the road (Figure 5b). It can be expected in the latter case, that if no change in the width of the road is made, drivers will continue to drive at high speeds (mean speeds of cars = 49 km/h; 80 to 90 per cent of single unimpeded cars go faster than 50 km/h) and that the previous high level of accidents will be retained.

It is difficult to understand why a solution so disadvantageous as the one presented in Fiqure 5b is not rejected immediately. Traffic flow and capacity problems do not exist in either of the two alternatives. Traffic volume will mainly be controlled by regulating the traffic lights at intersections not by the planned changes in road widths. The volume of traffic amounts to 20,000 cars between the hours of 7 a.m. and 7 p.m. including 10 per cent truck traffic. Illegal second-lane parking and stopping often takes place outside of rush hour. In the future, special loading/unloading areas are to be designated for suppliers. The presented case 2 is not just intended for use in Berlin, but also for major roads in the other model cities: Mainz, the medium-sized cities of Esslingen, Ingolstadt and Buxtehude and the small city of Borgentreich.

Case 3: Reconstruction Changing the Street's Function

Through traffic and public busses on another street in the model area of Berlin-Moabit (Waldstraße) were redirected to other parts of the road network by reconstruction of the road. Motor vehicle traffic remained only on one side of the tree-lined avenue. The other side and the middle section were made into areas for play, rest and relaxation. (Figure 6) The result was a calm residential street, although to the disadvantage of the neighboring Beusselstraße. The reconstruction of the Waldstraße, which took place before the model project began, was very expensive (185.00 DM/m^3) because the entire area had to be remodeled.

3. Special Problems Involving Public Busses

Public transportation companies in many German cities have reservations concerning traffic restraint measures. They are concerned about time schedule delays and reduced comfort due to uneven road surfaces, especially from humps, narrow areas and sharp curves. Indeed, the intention of area-wide traffic restraint is to promote rather than to hinder public transportation. Therefore, if the humps are designed as shown in Figure 4, an even driving surface for busses will be provided and only car traffic will be hindered. (Figure 7) Busses continue to have the advantage of unobstructed travel if humps or curves are constructed to have an effect only on motor vehicles. Figure 8 gives an example of this design as implemented in the city of Siegen.

Figure 9 illustrates a plan to reduce motor vehicle speeds by narrowing the road, placing a traffic island in the middle and then narrowing the road again, in succession. Busses also have to follow this slalom-like course but only near the bus stops where they have to drive slowly in any case.
Here, the initial driving tests using double-length busses and farm vehicles, whose results were used to set the dimensions of the new construction, resulted in positive response and support from the public transportation officials and farmers. Recently, however, opposition by the transportation officials has been renewed and they have gathered signatures from bus drivers whose comfort in driving is said to have been reduced through

the implementation of these measures. The experiences made during the next few months will determine whether this design can be retained or whether it will have to be removed. Large-scale restrictions with raised road surfaces and road narrowings that also effect busses, as done in several other cities and as shown in Figure 10, are only possible if they are installed at single points and not repeated at short intervals.

A special research project (Baier, et. al. 1984 a) summarized information gathered from experiences using public busses in traffic restraint areas in the Federal Republic of Germany. The report also discusses, in addition to the problems at bus stops that are shown here, the effects on time schedules for bus routes etc.

4. Problems With Ring-Road Systems

Ring-road systems are proven and widely-implemented instruments of city traffic planning. City traffic is concentrated on the ring roads. The result of the ring-road construction is urban relations being disturbed, a sort of barrier being contstructed and hence, dangers mainly to pedestrians but also disruptions to the residential environment. Therefore, existing and planned ring-roads should be closely examined, especially if they are intended to pass through areas near the city centre, that are heavily built up or house sensitive facilities. A close look at Buxtehude (33,000 inhabitants), one of the model cities in our research project 'area-wide traffic restraint', showed that a ring-road system around the medieval part of the city was no longer necessary (Erbstößer, Hachenberg, 1983). Figure 11 shows the northern part of the city where a test using speed limits of 30 km/h throughout nearly the entire street network has been running successfully since November 1983.

The results attained on reduction of accidents, noise and exhaust pollution were presented in 1985 (Kahrmann, 1985 and Holzmann, 1985).

The streets in Figure 11 that appear in bold-face type retained a speed limit of 50 km/h, and in one case 70 km/h. The western section of the ring road proved to be dispensable. Schools, a swimming pool, apartments and other sensitive facilities are located there. The traffic volume on this part of the ring road came to about 1,500 vehicles between 6:00 and 9:00 p.m. During the same time period there were about 300 bicycle riders and 300 sidewalk pedestrians.

The reconstruction of the western section of the ring road assumed that the other major roads had sufficient capacity levels and that corresponding restrictions on neighboring streets were made so that the traffic would not be directed onto them. Figures 12a and 12b show the reconstruction of a residential street in the neighborhood.

The interim results of the accident survey in Buxtehude shows nearly the same increase in the number of accidents on major roads in the model area (North of Buxtehude: + 24 %) as in the comparison area (South of Buxtehude: + 29 %). During the time of the traffic restraint project, the accident figure in the residential streets hardly showed any change (model area: - 3 %; comparison area: + 4 %).

There is a decrease in the number of major injuries, as shown in Fig. 13. Pedestrians have experienced advantages, cyclists drawbacks, as demonstrated by the development of accidents up to the present stage of the project. A final interpretation of the developments will be possible only when exposure data of road users and extensive behavioural studies are available.

Thus the second thesis

> For traffic safety research and especially into the effects of traffic restraint measures behavioural studies are required in addition to accident statistics.

The model city Ingolstadt (91,000 inhabitants) also has a problem with its ring-road system. It problems, however, is of another kind. Two parallel ring roads circle around the medieval part of the city. (Figure 14) Large parking lots are located there, allowing for parking near to the city centre. Consequently, pedestrians often cross the inner ring road. Bicycle traffic is also heavy at this location because Ingolstadt has a higher percentage of bicycle riders in general (approximately 20 per cent of all trips are made by bicycle). The inner ring road serves as a distributor for traffic to various entrances into the medieval part of city. An analysis of the functions that the two ring roads have, showed that it was not necessary to have two ring roads for use by fast-moving traffic. Instead, the inner ring road should have reduced speed limits in order to project pedestrians and bicycle riders. Improvements regarding noise and exhaust emission levels in nearby housing developments and recreation parks are also connected to this change. (Eichenauer, et. al., 1983).

Based on the above, reconstruction of the inner ring road has already taken place at three points along the ring with the purpose of reducing motor vehicle speeds. The reconstruction included narrowing the road, placing centre traffic islands, planting trees as optical restriction devices and installing cobblestone stripes.

Further research will have to produce information about two questions: first, the detailed problem of cobblestone stripes: upon completion of the ring-road construction whether or not the noises produced by cars passing over the cobblestone stripes at low speeds will still be disturbing, and second, the general question to be dealt with: how densely the measures must be taken in order to make it an adequately safe area for all modes of traffic.

5. Major Roads in Small Villages

Although traffic restraint has been devoted to heavily-populated areas in large and medium-sized cities in the Federal Republic of Germany during the last ten years, the trend now is to concentrate on such areas in small villages, which usually suffer from heavy and sometimes high-speed through traffic. Such problems cannot always be solved by constructing by-passes - a plan of action supported during the past few years by the Minister of Transportation. There are a number of reasons: Be it the destruction of the countryside that has resulted in increasing opposition by the public, or that the construction of by-passes does not always effectively re-route traffic out of villages.
In many cases in the past, the concerns of the high-speed, long-distance traffic were given precedence and old roads directly through villages were renovated without taking the needs of the inhabitants into consideration and to the disadvantage of the village setting as a whole. The result was wide roadways with smooth surfaces and narrow sidewalks.
Recently, however, a new line of thinking has developed that no longer accomodates high-speed traffic going through the villages themselves: the interests of the residents are being emphasized and through traffic is to move using caution and at moderate speeds.

The traffic restraint measures used in cities are, of course, not appropriate for these settings: streets have to remain accessible to and practical for wide farm machinery, the village setting has a different structure that must be retained, and last but not least, the country population has completely different needs than those of the city. The last point offers a surprise to planners: whereas parks and trees are strongly desired in cities, the addition of new trees is not something appeals to many farmers. (Figure 15) In autumn, leaves have to be swept from the streets and the passing wagons with hay and manure would more easily lose their loads.

Figure 16 displays an early example of through-streets that was particularly successful.
The street remains at full width almost the entire length and curbs are not elevated. Wide farm machinery and wagons that drive at low speeds anyway are able to make use of the sensitive zones directly in front of the houses. The lanes are made to appear narrower optically, by using cobblestones of varying colours. The level of the road surface corresponds in height to the various driveway and courtyard entrances and is no longer like an even plank stretched along between the rows of houses. The result is a slight uphill and downhill sensation without disturbing humps, yet effective in inducing moderate speeds. This wave-like structure of the road surface increases directly in front of the houses, as is to be expected, and is effective, for the most part, in keeping traffic away from them. Pillars or other obstructions need only be installed in a few individual situations. Consequently, the result is an area that is harmonious and operational, with a street no longer heavily burdened by traffic other than that of local residents and one that fits well into the village setting. Houses no longer stand along the edge of roads like strange objects, but instead have a direct connection to the street.

The design reminds one of the way streets used to be. Such recollections cannot be realized to an great extent, however, if the traffic volume is heavy. In such cases, compromises will have to be made for the different modes of traffic - with or without engines. One of the many projects that have been currently started in Germany is shown in Figures 17 and 18. The roadway must be reconstructed from the access to the village into the centre in order to attain a moderate speed by vehicles, enough room for pedestrians and bicycle riders; and thus, a higher level of safety and a more liveable village (Heinz, Moritz 1985).

6. Further Plans

Slowly but surely new ways of thinking are developing in Germany on the construction of major roads in built up areas - ones that increasingly take the interests of residents, businesses and shops on such streets, pedestrians and bicycle riders into consideration (Baier, Heinz, et. a., 1984; Schnüll, Haller, 1984).

The opinions of the citizens who are effected could not be reported upon in this article. The planning of such major roads must certainly be agreed to by those who are directly effected. This is an area where a lot of work is being done in Germany to provide exact information to and inspire participation by the public (Bechmann, Hoffmann, 1984).

For residential and distributor streets, the newest version of our technical standards is available. It takes the knowledge acquired on traffic restraint into consideration.)[2]

A corresponding guide for planners of major roads does not exist yet. The examples given here, in addition to several other projects)[3] should contribute to the development of such standards for major roads.

These are, however, only the start of traffic restraint measures on major roads. All of the cases mentioned here have been and continue to be met with opposition. Some have been solved, to others no compromises have yet been found. But the opinion grows among experts and also among politicians that: A substantial part of projects with area-wide traffic restraint is to include also the major roads (3. thesis)

NOTES

1 The Federal Minister of Regional, Housing and Town Planning, the Federal Minister of the Interior and the Federal Minister of Transport. Their assigned institutes for town development (BfLR, Bonn), for the environment (UBA, Berlin) and transport (BASt, Bergisch Gladbach) are carrying out the project.

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3 Kreis Neuss: Gestaltung von Ortseingängen und Ortsdurchfahrten im ländlichen Bereich, 1985. (Neuss district: Design of village entrances and through-streets in rural areas)

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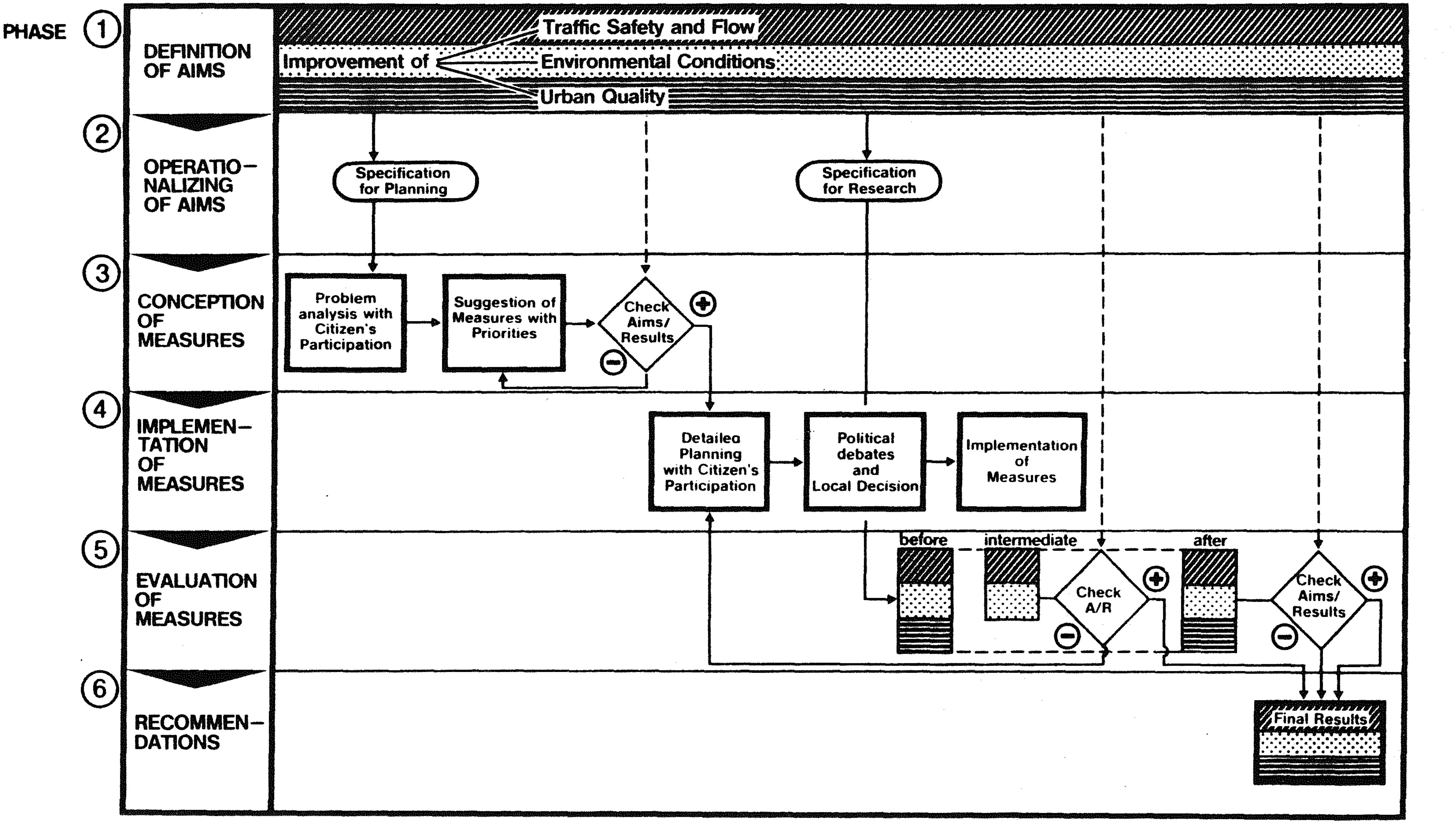


Figure 1: Research Project Area-wide Traffic Restraint, Aims and Evaluation

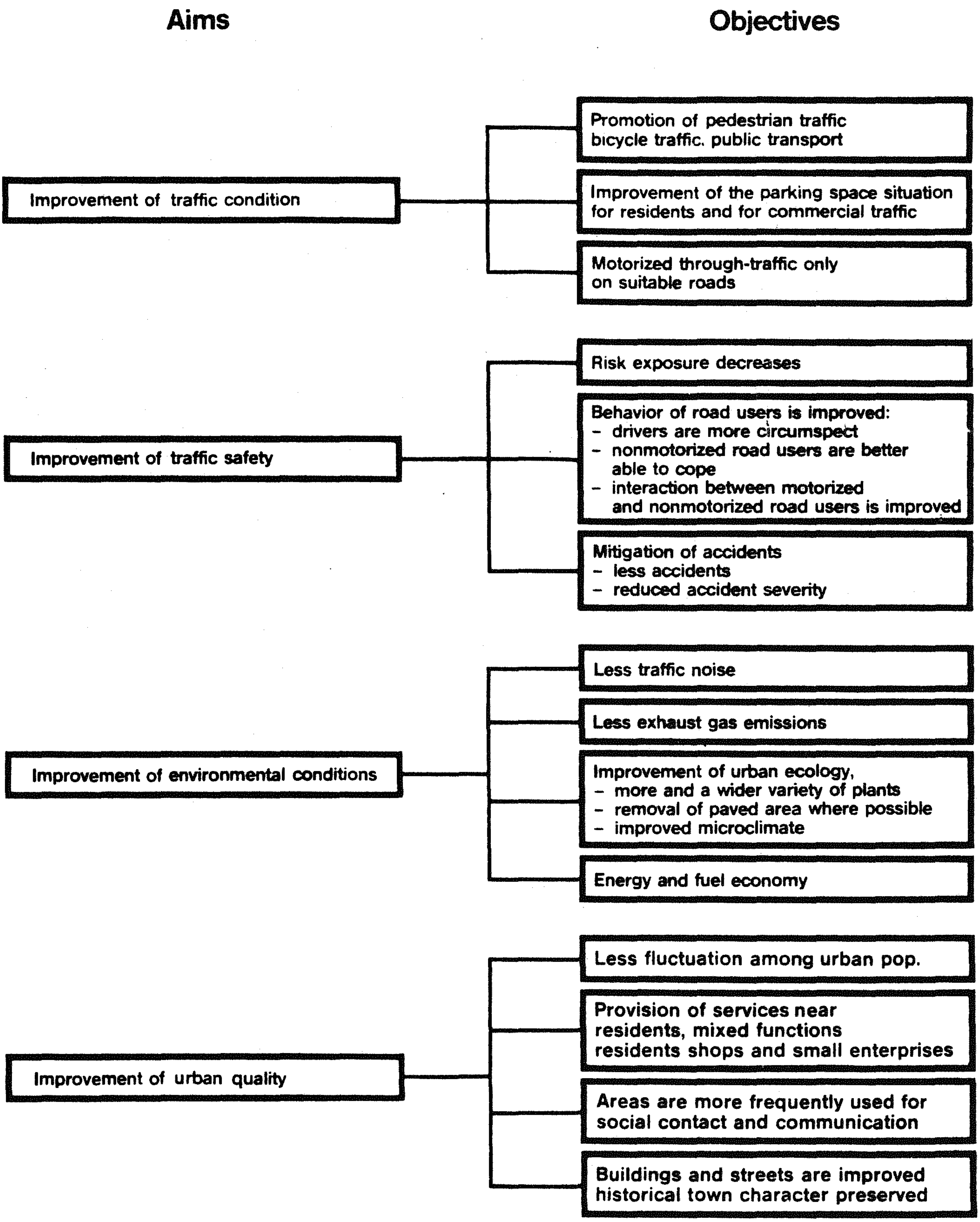


Figure 2: Aims of area wide traffic restraint

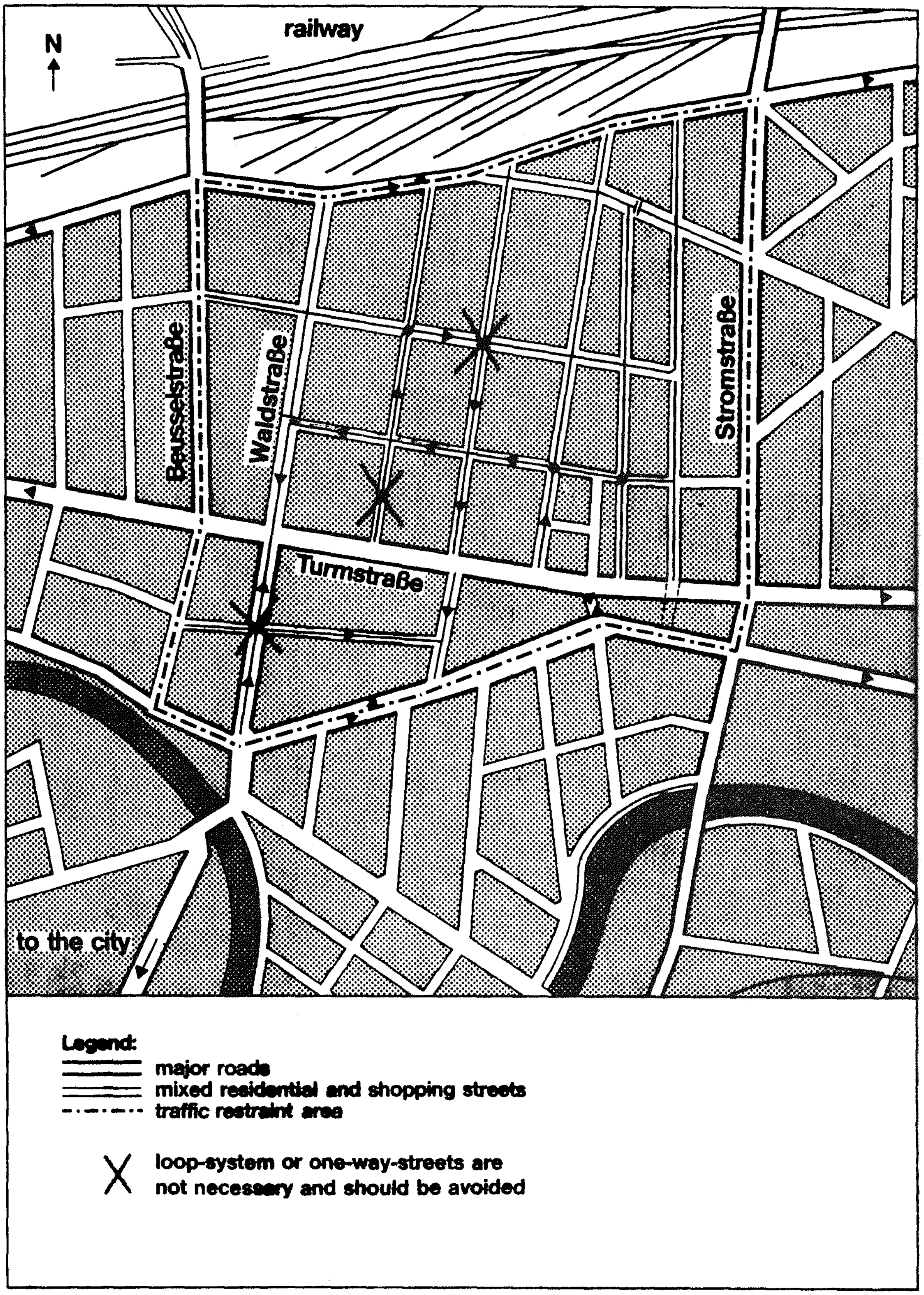
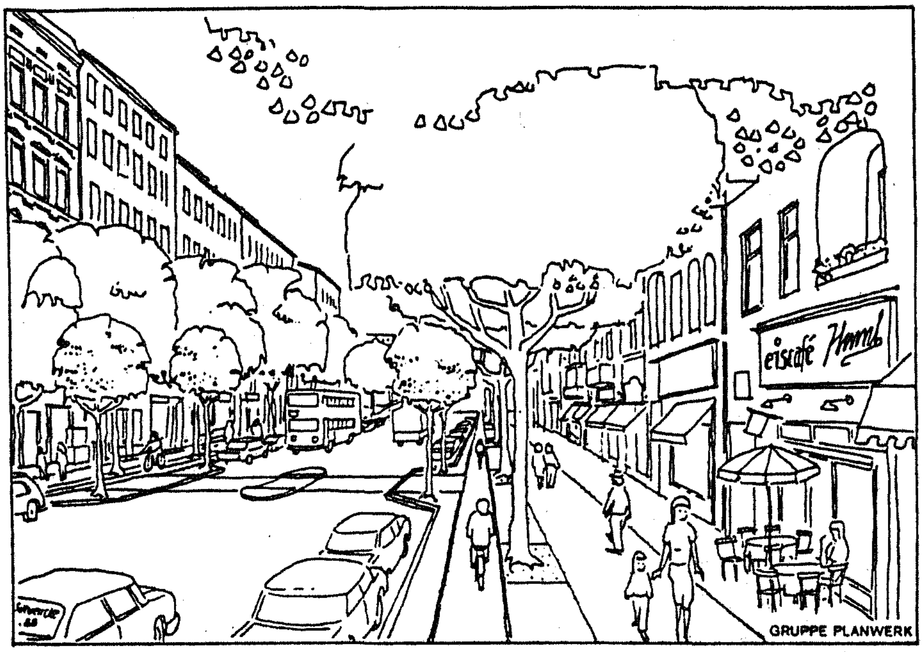


Figure 3: Traffic restraint area in Berlin-Moabit

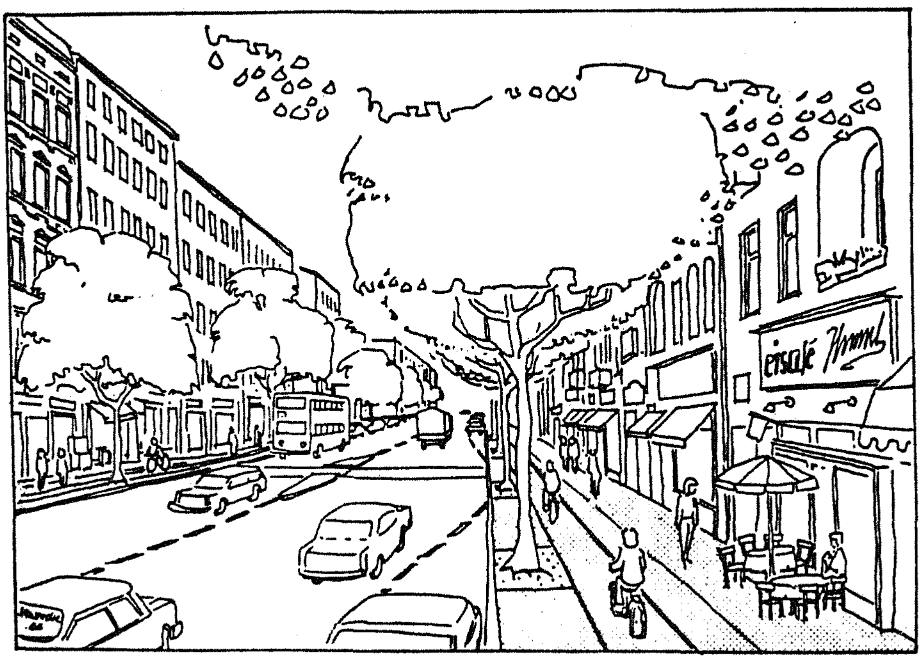
a) before street alteration in winter 1983

b) after street alteration, May 1985

Figure 4: Area wide traffic restraint, Berlin-Moabit, residential street (Bremerstr.), (Foto Höppner 1985)



a) first proposal reconstruction: reduction of the width for vehicles from 11m to 8,50m (lanes for driving) and additional bike-path, pedistrian crossings and trees



b) second proposal with the old width of driving lanes (11m) and a bike-path on the sidewalk, additional pedestrian crossings and trees

Fig. 5: Reconstruction of a major street with a lot of shops (Beusselstr., Berlin) and with through traffic (see Tibbe, H. 1985)

Figure 6: Reconstruction of a major road, (Waldstraße Berlin Moabit)
In the past car traffic used both sides of the street on the left and right hand from the trees. Now, after reconstruction, car traffic has only one side for two way traffic with narrow lanes, the other side provides room for playing, talking, cycling and also for fire engines.

Figure 8: Traffic restraint and public transport
Bus stop (Siegen): speed humps and one lane for motorised traffic, the lane to the right is kept for busses.

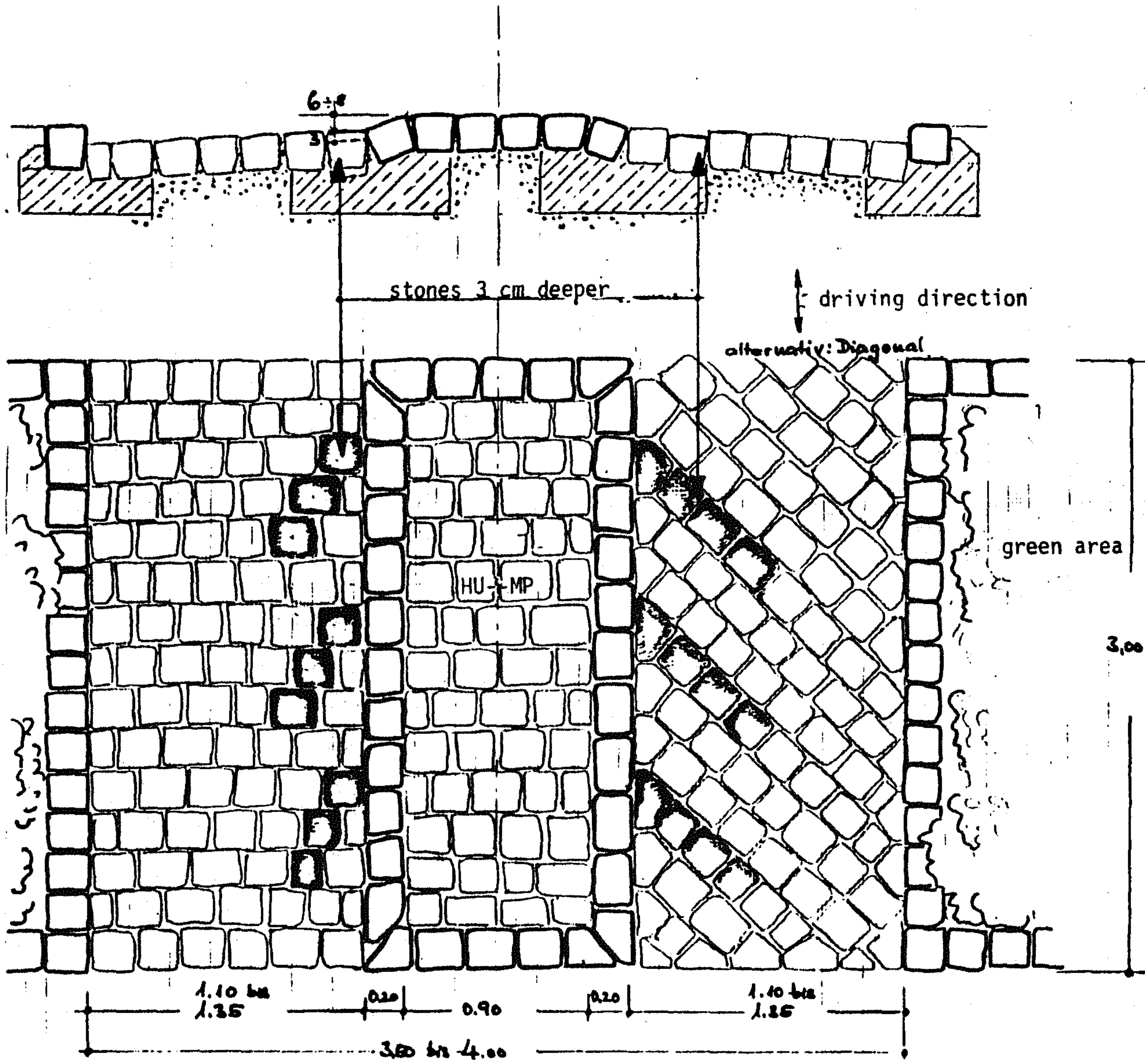


Fig. 7. BERLINER PLATEAU

without disadvantage for busses, heavy goods vehicles, two-wheel riders

Figure 9: Traffic restraint and public transport
Bus stop underconstruction (Mainz): two road narrowings and an island for pedestrians to reduce the speed of cars and trucks. The bus has to drive slowly at the stop anyhow and does not lose time.

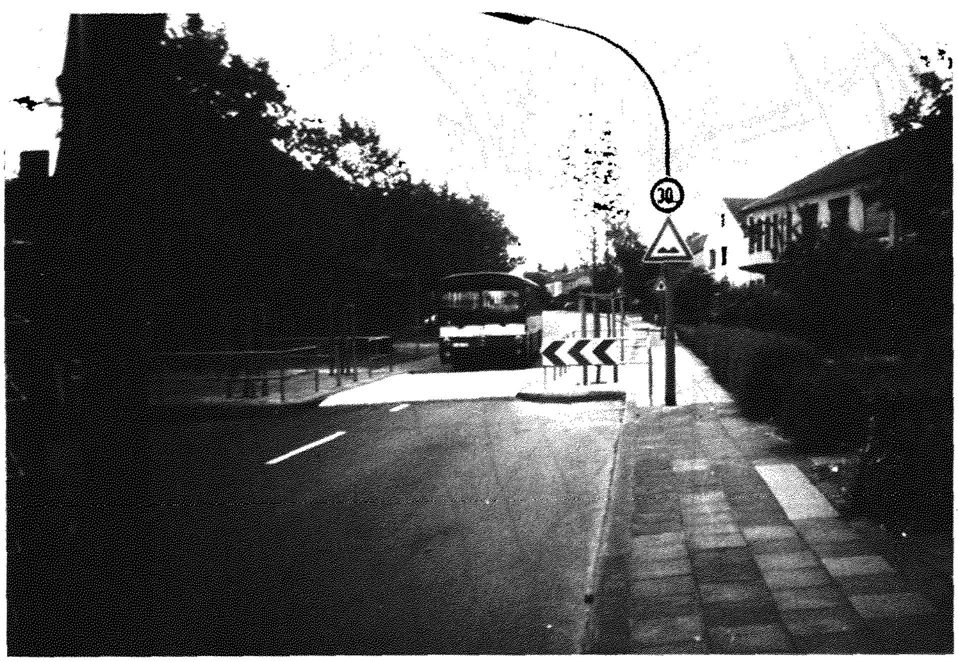


Figure 10: Traffic restraint and public transport
Speedhumps and road narrowing (Köln): This solution is tolerated by the public transportation company in isolated points - but not transport network on the total public.

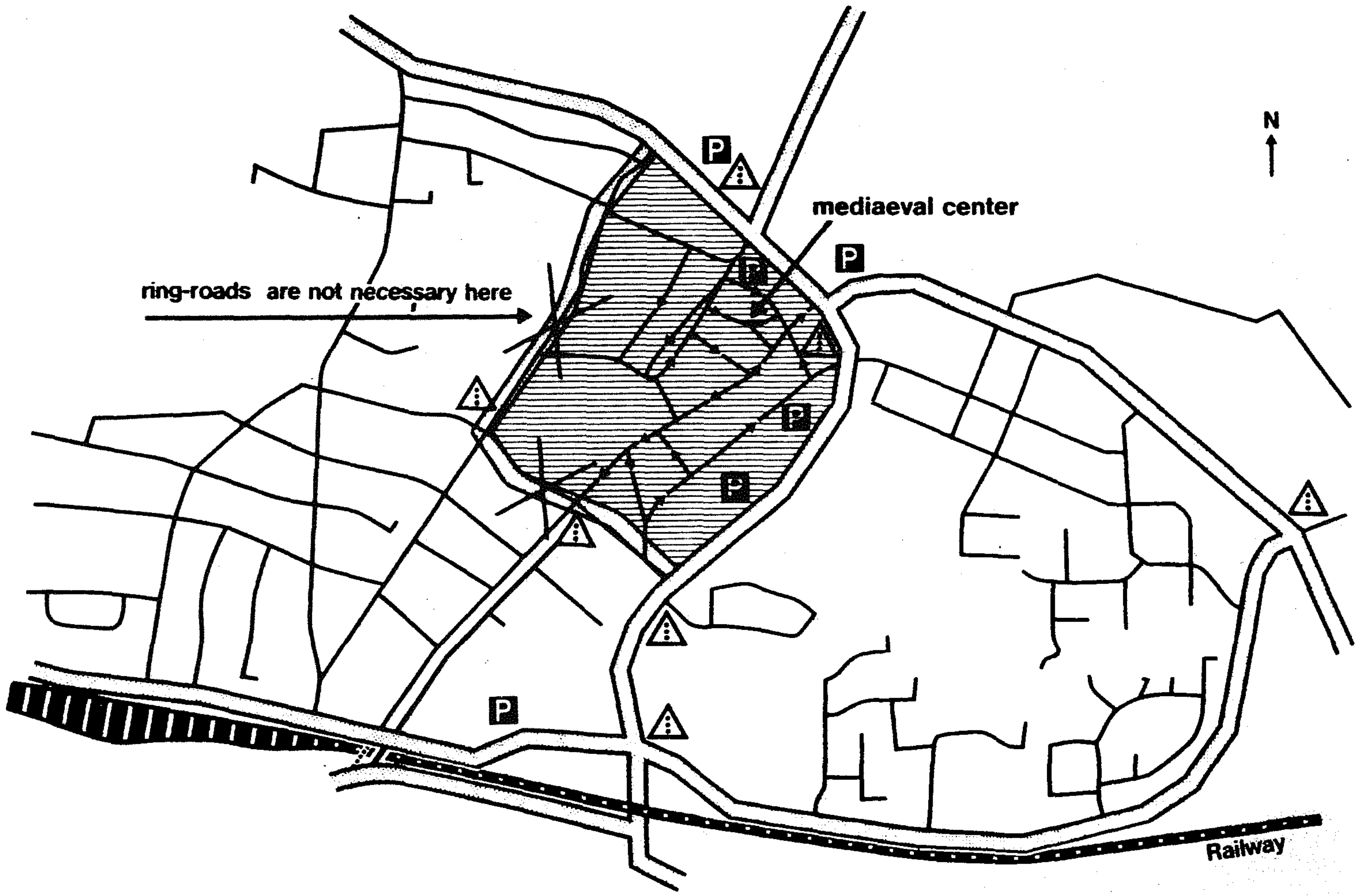


Figure 11: Model area of Buxtehude, street network

Figure 12a: A residential street including through traffic before reconstruction (Buxtehude).

Figure 12b: A residential street after reconstruction (Buxtehude)

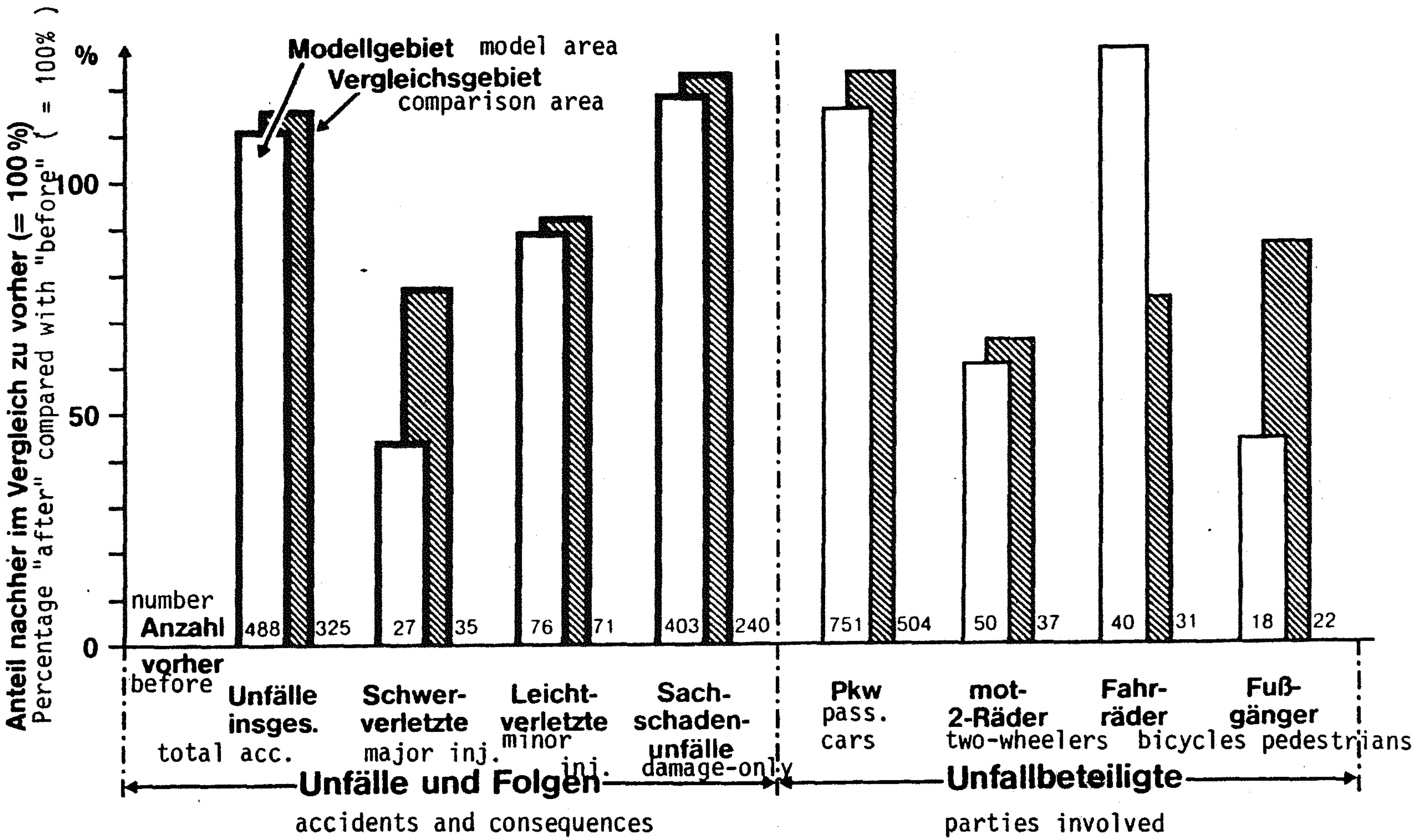


Fig. 13: Area-wide traffic restraint in Buxtehude: accident analysis
Before and after study (Nov. 14, 1981 - Aug. 31, 1983)/ (Nov. 14, 1984 - Aug. 31, 1986)

Source: B. Kahrmann, 1986

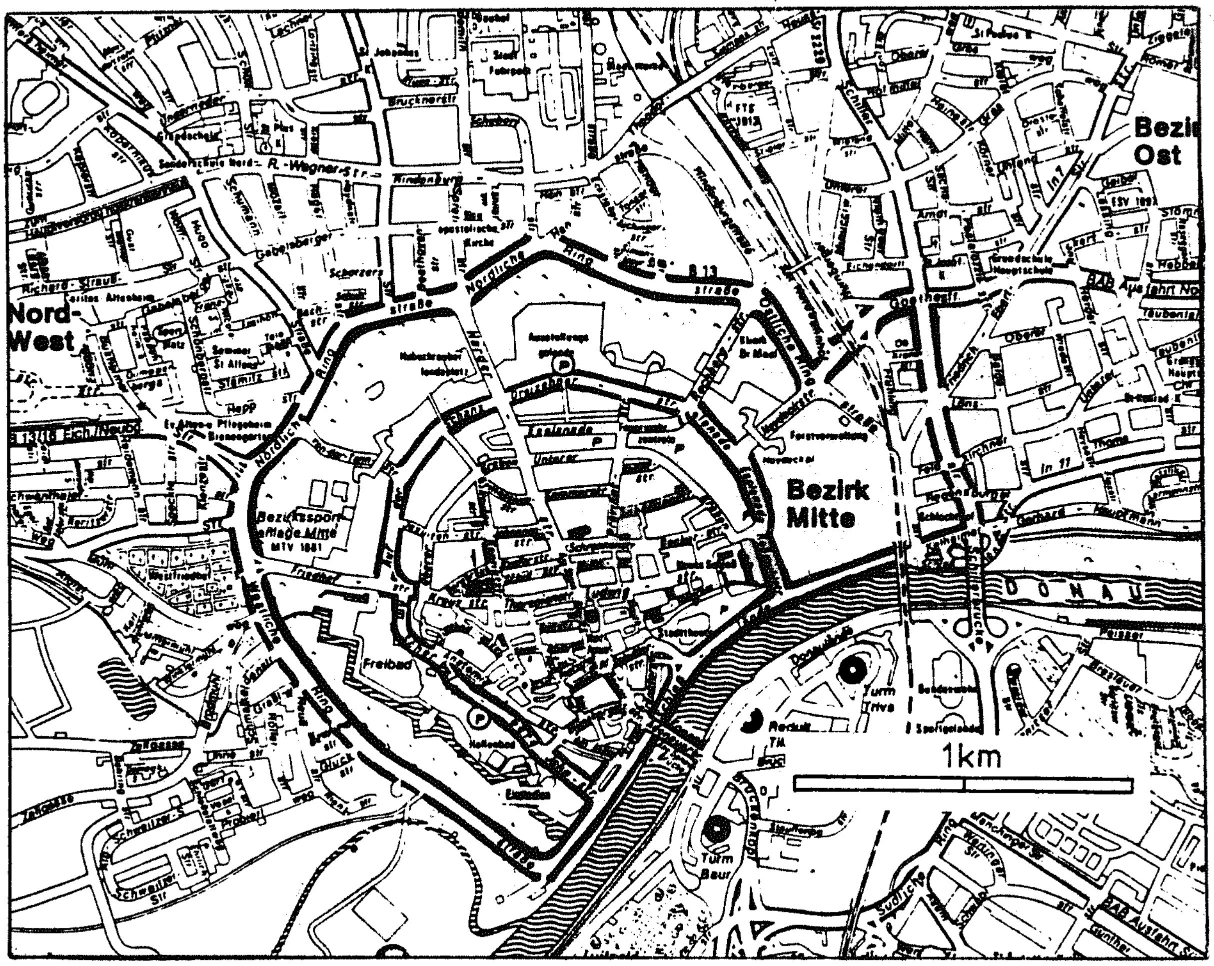
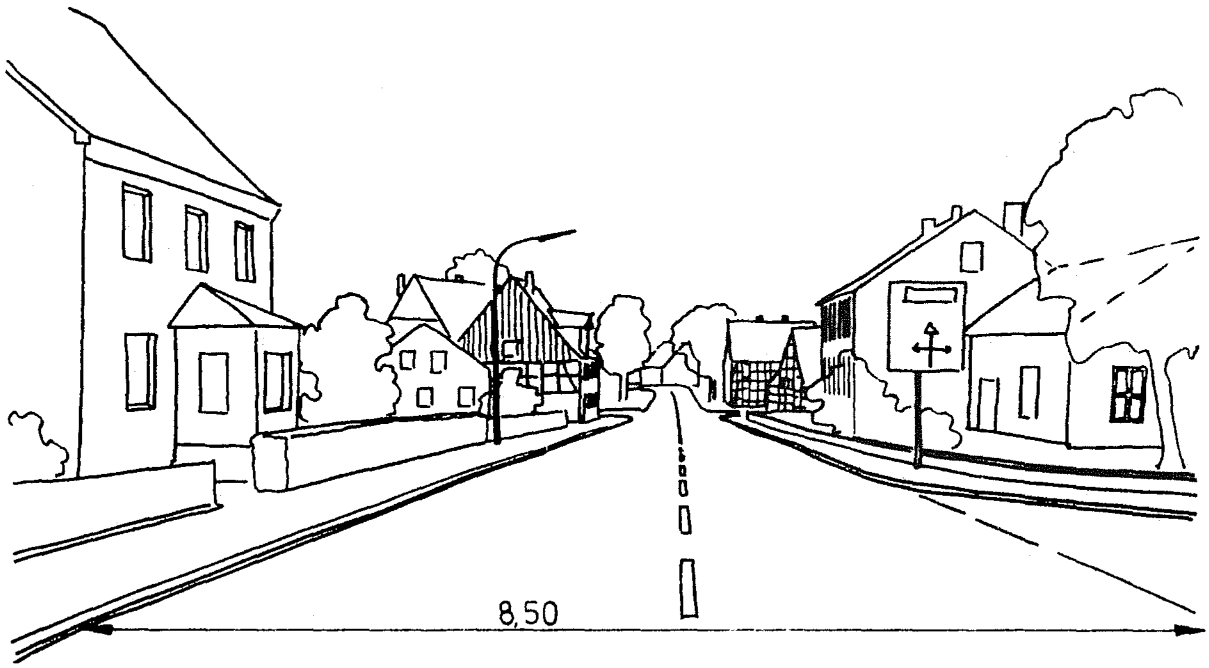
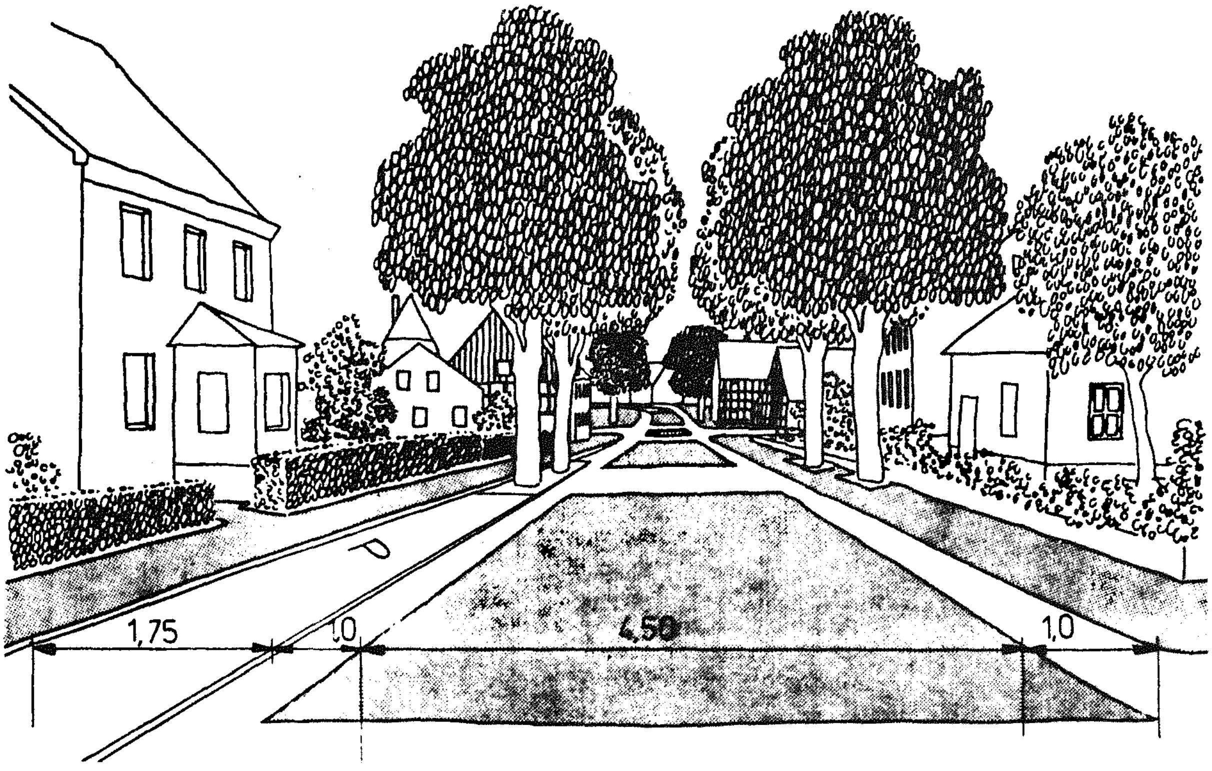


Figure 14: Two parallel ring-road-systems (Ingolstadt). The inner ring road has started to be reconstructed for slower moving traffic



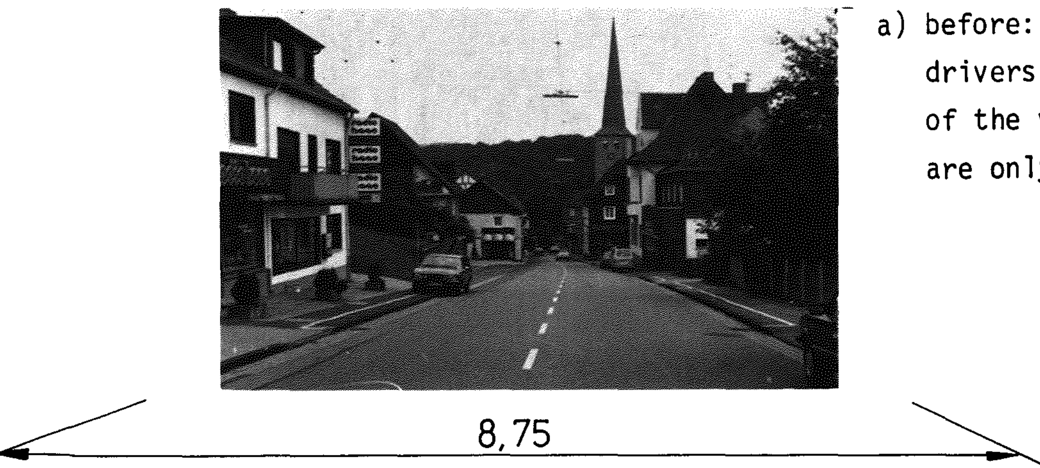
a) before reconstruction



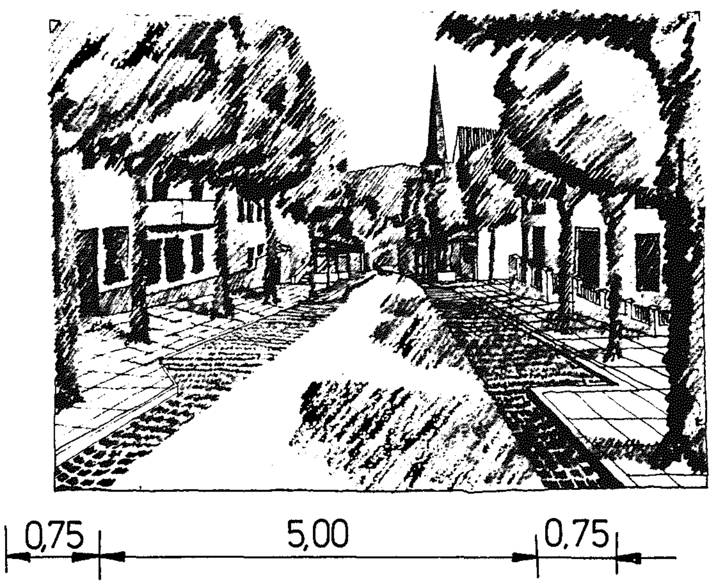
b) after reconstruction

Figure 15: Major road in a small village (Borgentreich) with through traffic
(50% from 4000 veh/day) (Baier R., Schröder D., 1983)

Figure 16: Village street (Borgentreich /Borgholz) reconstructed in an exemplary manner, formerly used locally as bypass route



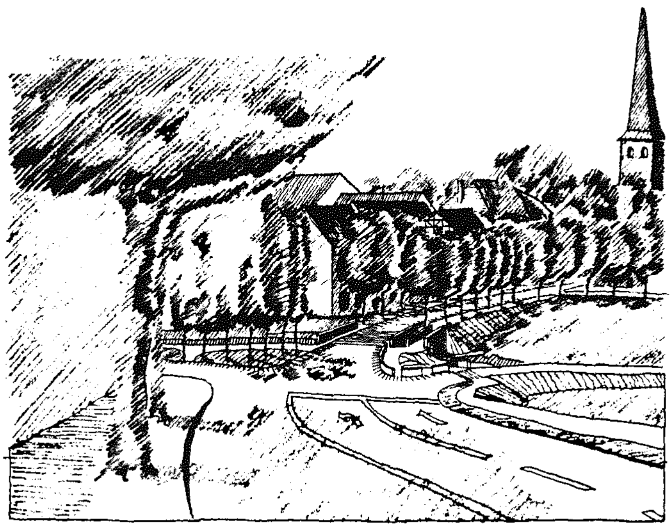
a) before: a wide carriageway invites drivers to approach the centre of the village too fast. Pavements are only 80 cm wide.



b) after: a narrower carriageway with paved strips and trees on both sides discourages drivers from driving too fast on the approach to the village centre.

Figure 17: Major road in a small village (Much) for through traffic (Heinz H., Moritz A., 1985)

a) before: overdimensioned intersection especially for the minor road.



b) after: suggested narrower design of intersection and village access road; village access road is narrowed by tree planting on both sides

Figure 18: Village access (Much), reconstruction of interstate- and state road (Heinz H., Moritz A., 1985)

BESONDERE VERKEHRSGEFAHREN IN KLEINEN ORTEN; MÖGLICHKEITEN ZUR VERBESSERUNG AUF ORTSDURCHFAHRTEN

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1. Unfallstatistik und Ortsgröße

In den Verkehrsunfallstatistiken werden die Unfälle und die Ausprägungen des Unfallgeschehens unterschieden nach der Ortslage (Autobahnen, übrige Außerortsstraßen, innerorts). Dies erweckt den Eindruck, als sei das Innerortsgeschehen unabhängig von der Ortsgröße, so daß die aus solchen Unfallstatistiken abgeleiteten Empfehlungen zur Erhöhung der Verkehrssicherheit sowohl für kleine Gemeinden als auch für große Gemeinden zutreffende Hinweise beinhalten. Am Beispiel Nordrhein-Westfalen kann deutlich gemacht werden, daß die Unfallstatistik der Innerortsunfälle eine Unfallstatistik der Großstädte ist (vgl. Abbildung 1).

60% der Innerortsunfälle in Nordrhein-Westfalen geschehen in 7% der Gemeinden (Städte mit mehr als 100000 Einwohnern); 83% der Gemeinden haben weniger als 50000 Einwohner, sind aber nur mit 27% der Unfälle in der Innerorts-Unfallstatistik vertreten:

Besonderheiten im Unfallgeschehen kleinerer Gemeinden werden durch die Vielzahl der Unfälle in den Großstädten überdeckt.

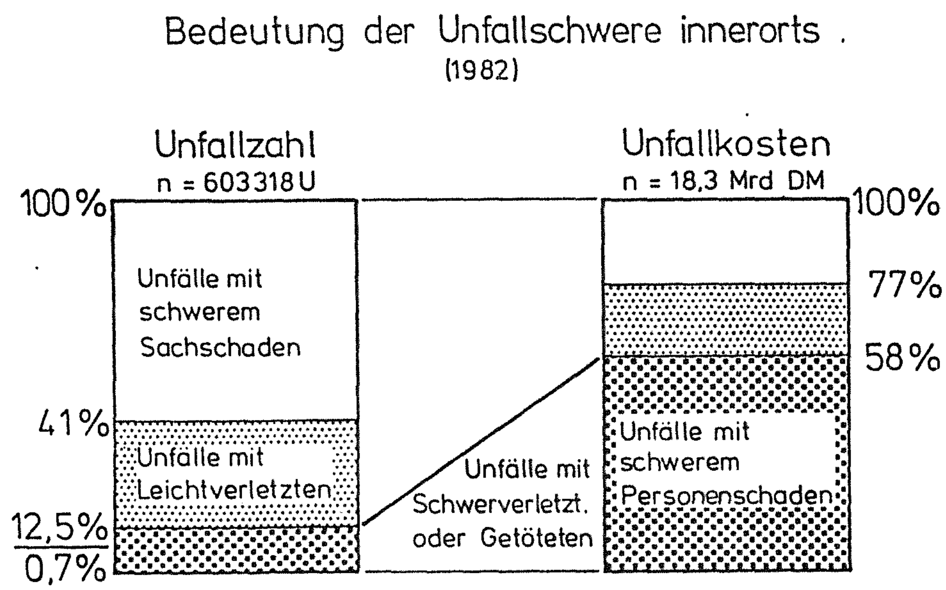

Abb. 1: Unfallstatistiken und Ortsgröße (NW 1982)

2. Unfallzahl und Unfallschwere

Betrachtet man die Unfallstruktur der Innerortsunfälle im Hinblick auf die schwersten Unfallfolgen und die Unfallkostenstruktur der Innerortsunfälle (volkswirtschaftliche Verluste durch Straßenverkehrsunfälle in Abhängigkeit der schwersten Unfallfolge) /1, 2/ so zeigt sich (vgl. Abbildung 2), daß

- fast 60% der Unfälle Sachschaden zur Folge haben und fast 30% der Unfälle zu leichten Verletzungen führen. Lediglich 1/8 der Unfälle (12,5%) führen zu schweren Verletzungen, d.h. zu stationärem Krankenhausaufenthalt oder zum Tod. Ziel der Unfallverhütungsarbeit sollte es aber sein, gerade diese schweren Unfälle, durch die es auch zu bleibenden Behinderungen kommt, zu vermeiden;

- die Unfälle mit schwerem Personenschaden ein völlig anderes Gewicht erhalten, wenn man die volkswirtschaftlichen Verluste durch Straßenverkehrsunfälle berücksichtigt: 12,5% der Unfälle erlangen mit 58% der volkswirtschaftlichen Verluste herausragende Bedeutung.

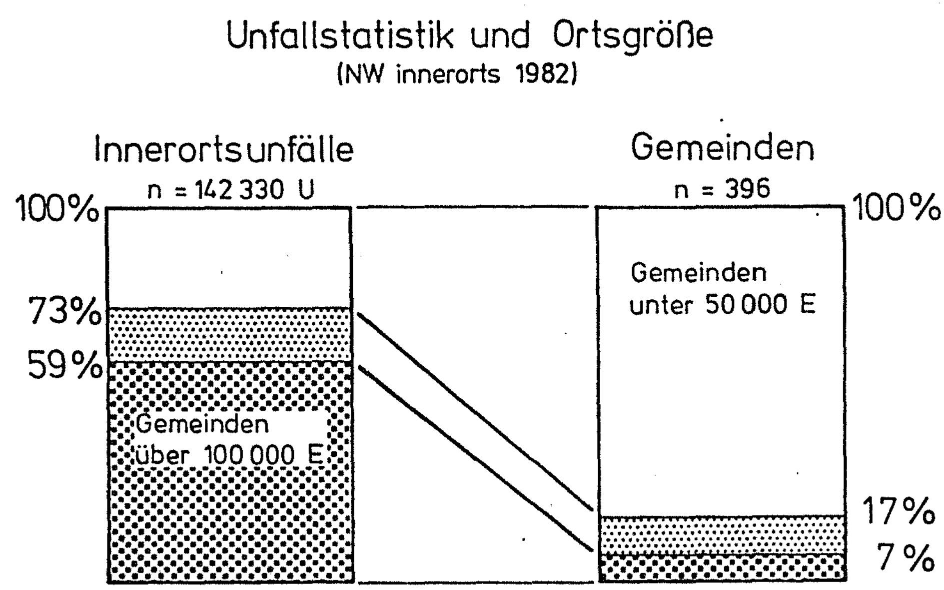

Abb. 2: Bedeutung der Unfallschwere der Innerorts-Unfälle: Verteilung der Unfälle und der Unfallkosten auf die Unfallkategorien (schwerste Unfallfolgen)

Den Unfällen mit schwerem Personenschaden muß also besondere Aufmerksamkeit gewidmet werden.

3. Durch Unfälle betroffene Fußgänger, Radfahrer und Kraftfahrer in Gemeinden unterschiedlicher Größe

In Abbildung 3 ist die Unfallkostenbelastung (auf die Einwohnerzahl bezogene Unfallgefahren innerorts) aller 396 Gemeinden in Nordrhein-Westfalen über die Einwohnerzahl der einzelnen Gemeinden dargestellt. Da die Mehrzahl der Gemeinden eine Größe bis zu 100000 Einwohner hat, wurde zur Verdeutlichung für die Einwohnerzahl ein logarithmischer Maßstab gewählt.

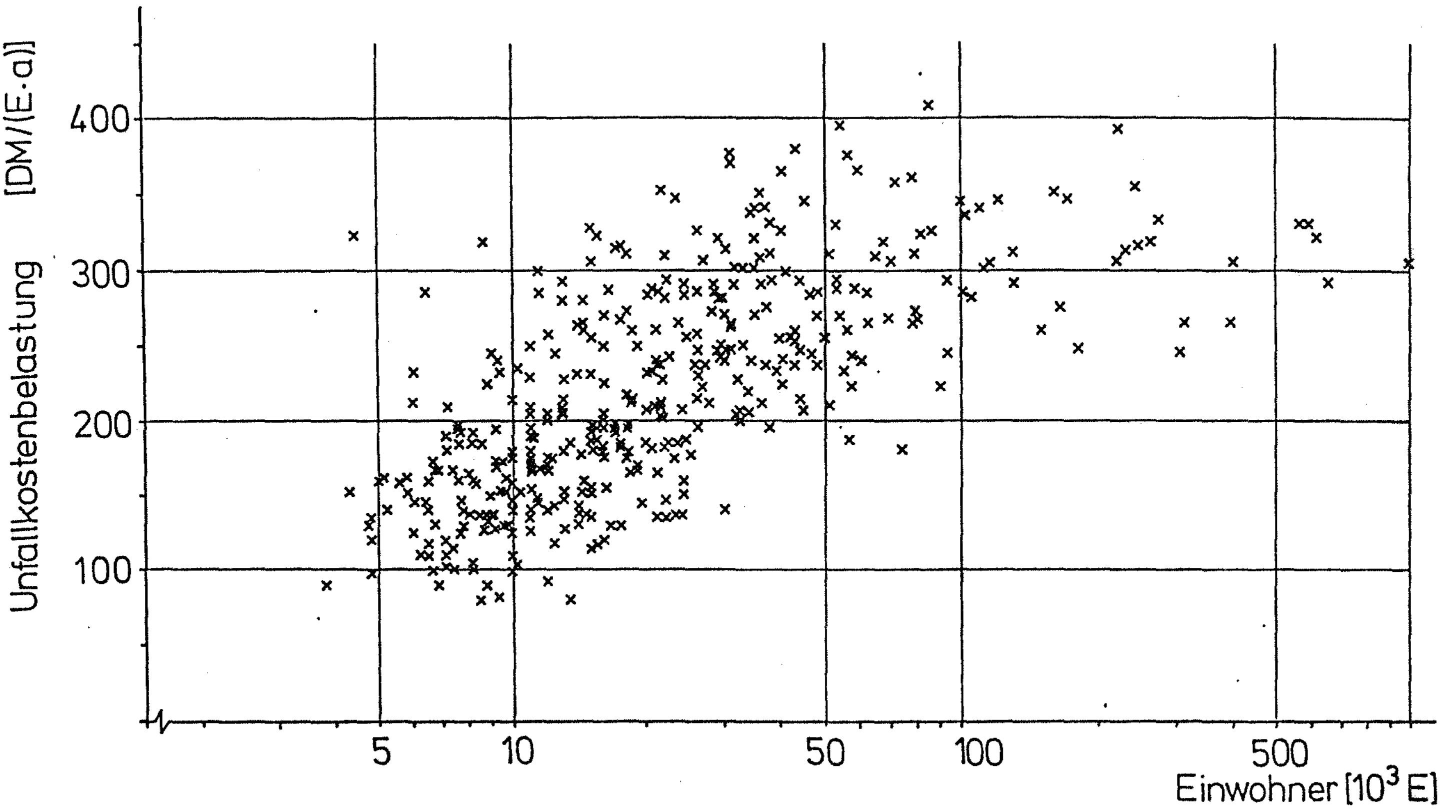

Abb. 3: Unfallkostenbelastung und Einwohnerzahl der 396 Gemeinden in NW (Unfälle 1980-1982)

Der Abbildung ist folgendes zu entnehmen:

- In der Unfallkostenbelastung der einzelnen Gemeinden gibt es sehr große Unterschiede, so streuen die Werte zwischen 100 DM je Einwohner und Jahr und über 400 DM je Einwohner und Jahr, d.h. um den Faktor 4.

- Kleine Werte der Unfallkostenbelastung (unter 150 DM je Einwohner und Jahr) treten nur in Gemeinden mit kleiner Einwohnerzahl (unter 80000) auf; hohe Werte der Unfallkostenbelastung (über 300 DM/[E.a]) kommen bei allen Ortsgrößen vor.

- Auch bei den Großstädten (mehr als 100000 Einwohner) sind die Unterschiede in den Unfallkostenbelastungen noch beträchtlich (UKB = 250 bis UKB = 400).

Es kann also keine Rede davon sein, daß die Unfallgefährdungen in den einzelnen Gemeinden etwa gleiche Größenordnungen haben. Ziel der Verkehrssicherheitsarbeit in den Gemeinden mit hohen Unfallkostenbelastungen sollte es sein, die Gründe für diese ungünstigen Werte zu finden und nach Möglichkeiten zu suchen, Unfallzahl und Unfallschwere systematisch zu senken.

Betrachtet man die Struktur der Verkehrsunsicherheit in Abhängigkeit der Gemeindegröße (die Gemeinden wurden in Gruppen nach der Einwohnerzahl zusammengefaßt, Abbildung 4), so zeigt sich unter Berücksichtigung von Unfallzahl und Unfallschwere, d.h. in den Unfallkosten, folgendes:

- Weitgehend unabhängig von der Ortsgröße entfallen zwischen 43% und 44% der Unfallkosten auf Unfälle mit Fußgängern oder Radfahrern (Lediglich in kleinen Gemeinden mit weniger als 20000 Einwohnern ist dieser Anteil mit 36% geringfügig niedriger).

- Wegen des hohen Anteils von Fußgängern und Radfahrern an den Unfallkosten ist ein verstärktes Bemühen um Verkehrssicherheit für die schwachen Verkehrsteilnehmer dringend geboten.

- Je größer die Gemeinden sind, desto stärker sind Fußgänger die Betroffenen. So steigt der Anteil der Unfallkosten, die am Fußgänger entfallen, von 17% bei Gemeinden unter 20000 Einwohnern kontinuierlich mit der Ortsgröße auf 30% bei Großstädten mit mehr als 500000 Einwohnern.

- Für Radfahrer sind die Gefährdungen völlig anders: Hier ist der Anteil der Unfallkosten bei Großstädten relativ gering mit 13% und steigt mit abnehmender Ortsgröße an bis auf etwa 20%.

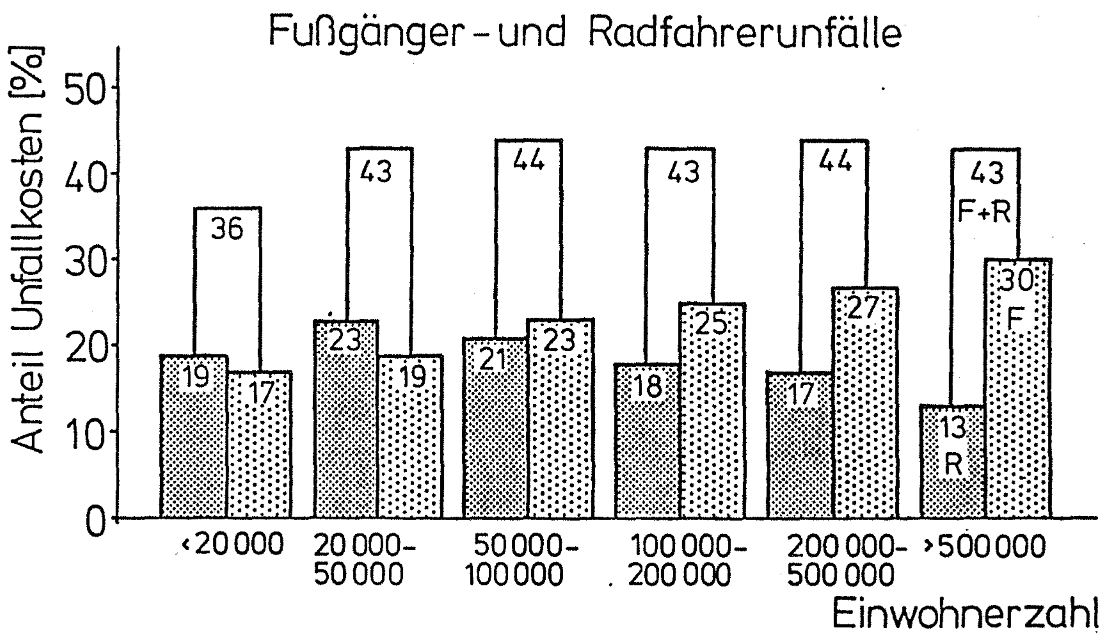

Abb. 4: Ortsgröße und Struktur der Unfallkosten

Diese Betrachtung schließt nicht aus, daß für einzelne Gemeinden die Unfallstruktur von der zugehörigen Ortsgruppe deutlich abweicht.

4. Wesentliche Einflußgrößen auf das Unfallgeschehen bei Gemeinden bis 80000 Einwohnern

Wie bereits Abbildung 3 gezeigt hat, kommen bei Gemeinden bis etwa 80000 Einwohnern sowohl sehr große Unfallkostenbelastungen zwischen 300 und 400 DM je Einwohner und Jahr vor als auch besonders niedrige Unfallkostenbelastungen in der Größenordnung von 100 DM pro Einwohner und Jahr. Von der Tendenz her ist aus Abbildung 3 abzulesen, daß die Unfallkostenbelastung mit zunehmender Ortsgröße ansteigt.

Zwischen Unfallkostenbelastung und Einwohnerzahl der Gemeinden ergibt sich ein Korrelationskoeffizient von r = 0,55, d.h. ein Zusammenhang zwischen Unfallkostenbelastung und Einwohnerzahl ist nicht abzulehnen. Der Korrelationskoeffizient besagt außerdem durch das Vorzeichen, daß mit zunehmender Einwohnerzahl einer Gemeinde die Unfallkostenbelastung ansteigt. Ein derartiger Einfluß ist erklärbar: Während in Großstädten ein hoher Anteil der Fahrten im Innerortsbereich stattfindet, nimmt der Innerortsanteil von Fahrten bei kleinen Gemeinden stark ab. Daraus ergibt sich ein Hinweis auf eine mögliche weitere Einflußgröße: Die Fahrleistung. Da es kaum möglich ist, für eine große Zahl von Gemeinden die Innerortsfahrleistung einigermaßen zutreffend zu beschreiben, wurde zunächst die Fahrleistung auf den klassifizierten Straßen innerorts ermittelt über die Angaben der Verkehrszählung 1980 auf den klassifizierten Straßen (ohne Gemeindestraßen) und der Innerortslänge dieser Straßen. In Gemeinden bis zu 80000 Einwohnern ist damit die Fahrleistung auf den Verkehrsstraßen relativ gut beschrieben, weil das Hauptstraßennetz dieser Gemeinden im wesentlichen aus den klassifizierten Straßen gebildet wird. Mit der Fahrleistung auf den klassifizierten Straßen wird zudem ein recht großer Anteil der Gesamt-Innerortsfahrleistung einer Gemeinde abgebildet, weil auf den Straßen außerhalb der Verkehrsstraßen, die zwar auch in kleineren Gemeinden oft die größere Straßenlänge bilden, die erbrachte Gesamtfahrleistung relativ gering ist. Für die weiteren Betrachtungen wurde - um den Einfluß der Ortsgröße aus den Betrachtungen zunächst herauszuhalten, der triviale Einfluß zwischen Fahrleistung und Ortsgröße (je größer eine Gemeinde ist, desto größer ist auch die Fahrleistung) dadurch eliminiert, daß die Fahrleistung auf den klassifizierten Straßen - entsprechend dem Unfallgeschehen - auf die Zahl der Einwohner bezogen wurde, d.h. in die weiteren Betrachtungen geht eine einwohnerbezogene Fahrleistung auf klassifizierten Straßen FLE ein mit der Dimension Kraftfahrzeugkilometer je Einwohner und Tag.

Die unterschiedliche Siedlungsstruktur von Gemeinden (Aufteilung auf Teilorte, die durch Außerortsstraßen verbunden sind) läßt sich durch die Einwohnerzahl EOT des einwohnergrößten Ortsteils berücksichtigen.

Eine Zweifachregression zwischen der Unfallkostenbelastung der untersuchten Orte bis 80000 Einwohner, der einwohnerbezogenen Fahrleistung auf den klassifizierten Straßen FLE und dem einwohnerstärksten Ortsteil EOT ergibt sich zu

$$UKB = 30,70 \cdot FLE^{0,412} \cdot EOT^{0,173}$$

mit

UKB [DM/(E.a)] = Unfallkostenbelastung Mittel aus den Jahren 1980-1982)

FLE [Kfz.km/(E.24.h)] = einwohnerbezogene Fahrleistung auf den klassifizierten (B, L, K) Straßen einer Gemeinde.

Der Regressionskoeffizient beträgt r = 0,78. Eine Analyse der Teilkorrelationskoeffizienten ergibt, daß die reduzierte Einwohnerzahl EOT und die einwohnerbezogene Fahrleistung auf den klassifizierten Straßen FLE weitgehend voneinander unabhängige Einflußgrößen sind.

In Abbildung 5 sind die Ergebnisse der Regressionsrechnung grafisch dargestellt.

Die Form des mathematisch statistischen Zusammenhangs, die in Abbildung 5a und 5b grafisch dargestellt ist, macht deutlich, daß der Einfluß unterschiedlicher Fahrleistung erheblich stärker auf die Unfallkostenbelastung ist als die Einwohnerzahl: Lediglich im Bereich sehr kleiner Ortsgrößen (bis etwa 20000 Einwohner) steigt die Unfallkostenbelastung mit zunehmender Ortsgröße stark an, während der weitere Anstieg eher flach ist (etwa um 50 DM pro Einwohner und Jahr).

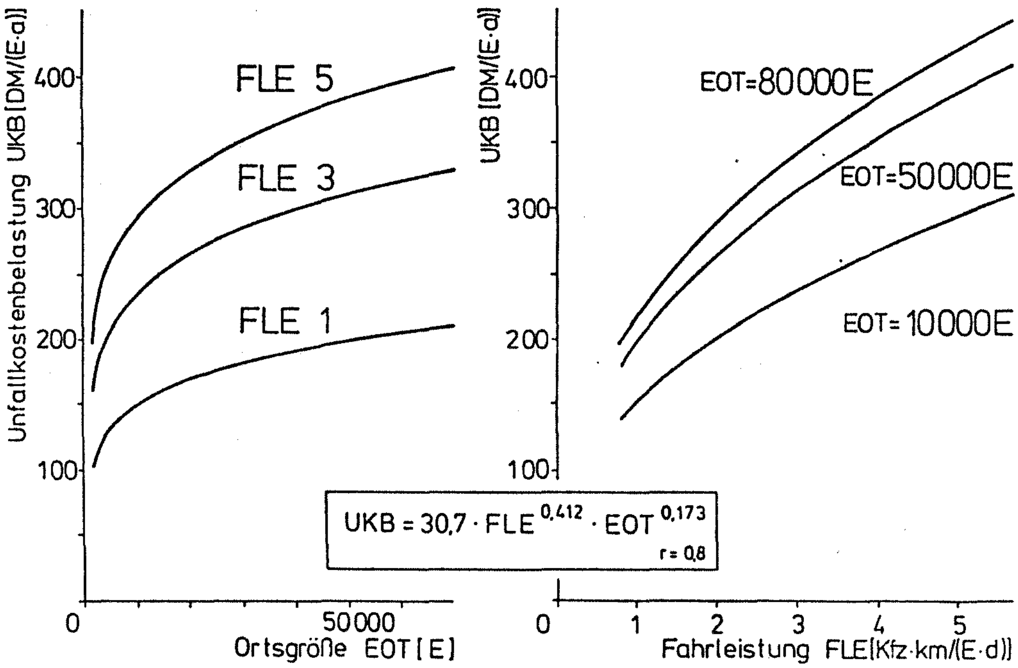

Abb. 5: Ergebnisse der Regression zwischen einwohnerbezogener Fahrleistung auf den klassifizierten Straßen, Einwohnerzahl (des einwohnerstärksten Ortsteils) und Unfallkostenbelastung von Gemeinden in Nordrhein-Westfalen

Wenn auch der Regressionskoeffizient darauf hindeutet, daß durch die genannten Einflußgrößen die unterschiedlichen Werte der Unfallkostenbelastung in einzelnen Gemeinden recht weitgehend erklärt werden kann, bleibt doch eine große Streuung der Werte der Unfallkostenbelastung, die durch dieses Modell nicht abgedeckt ist. In einem weiteren Analyseschritt wurde daher die Streuung der Einzelwerte näher analysiert.

Da die Fahrleistung einen größeren Einfluß auf die Unfallkostenbelastung hat als die Einwohnerzahl, ist in Abbildung 6 die

Abweichung der tatsächlichen Werte der Unfallkostenbelastung von den nach der obigen Regression errechneten näher analysiert.

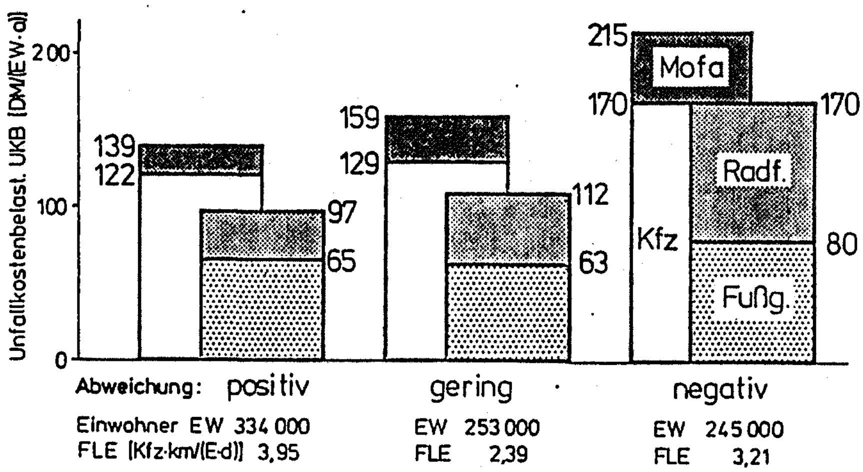

Abb. 6: Struktur der Unfallkostenbelastung (betroffene Verkehrsteilnehmer) in Gemeinden, die im Verhältnis zu Fahrleistung und Ortsgröße positive, geringe oder negative Abweichungen der Unfallkostenbelastungen gegenüber den Ergebnissen der Regressionsrechnung zeigen

Die Abbildung 6 zeigt, daß bei Gemeinden mit stark negativen Abweichungen von den Ergebnissen der Zweifachregression zwar alle Verkehrsteilnehmergruppen grundsätzlich stärker gefährdet sind; die Zunahme der Gefährdung ist aber bei den schwachen Verkehrsteilnehmern wesentlich größer als bei Unfällen, in die nur Kraftfahrzeuge verwickelt sind. Gegenüber Gemeinden mit einer günstigen Unfallkostenbelastung (Abweichung stark positiv) haben Gemeinden mit ungünstiger Unfallkostenbelastung (Abweichung stark negativ) folgende Unterschiede:

- Die Unfallkostenbelastung infolge von Unfällen, bei denen nur Kraftfahrzeuge aber keine Mofafahrer beteiligt waren, steigt um 39%.

- Der Unterschied der Gefährdung der nicht motorisierten Verkehrsteilnehmer beträgt +75%. Besonders stark ist dabei die Zunahme der Gefährdung der Radfahrer auf nahezu das Dreifache.

- Die Zunahme der Verkehrsgefährdung bei den schwächsten Kraftfahrzeugverkehrsteilnehmern (Mofafahrer) ist ebenfalls groß (nahezu das Dreifache), ähnlich wie bei den Fahrradfahrern.

Zusammenfassend kann aus der Betrachtung von Ortsgröße, Fahrleistung und durch Unfälle betroffene Verkehrsteilnehmergruppen folgendes für kleinere Gemeinden (bis 80000 Einwohner) festgestellt werden:

- Generell steigen die Verkehrsgefahren mit zunehmender Ortsgröße weniger stark an als mit zunehmender Fahrleistung auf den klassifizierten Straßen.

- Wo möglich sollte die Fahrleistung, die nicht zu einer Gemeinde gehört (Durchgangsverkehr), auf für diesen Verkehr geeignete Außerortsstraßen verwiesen werden (z.B. durch den Bau von Ortsumgehungsstraßen /3/).

- Ungünstige Werte der Unfallkostenbelastung (die nicht durch Fahrleistung und/oder Ortsgröße erklärbar sind) treffen vor allem die schwachen Verkehrsteilnehmer Radfahrer und Mofafahrer. Die Unterschiede in der Unfallkostenbelastung aufgrund von Unfällen, bei denen lediglich übrige Kraftfahrzeuge beteiligt waren, sind deutlich geringer.

- Zwar sind die Unterschiede der Fußgängerunfallkostenbelastung nicht so groß wie bei den nicht oder schwach motorisierten Zweiradfahrern, jedoch sind Fußgänger immer relativ stark gefährdet. Im übrigen handelt es sich bei dieser Betrachtung um Orte bis 80000 Einwohner, bei denen bereits dargestellt wurde, daß hier die Gefährdung der Radfahrer i.d.R. höher ist als die der Fußgänger.

5. Maßnahmen zur Erhöhung der Verkehrssicherheit auf Ortsdurchfahrten

5.1 Ziel der Versuches in Nordrhein-Westfalen

Systematische Versuche auf Ortsdurchfahrten sind notwendig, weil durch die bisherigen Ausbaustandards nicht gewährleistet wird, daß die zulässige Höchstgeschwindigkeit von 50 km/h auch nur einigermaßen eingehalten wird. Zwar werden in der Literatur Maßnahmen zur Verbesserung von Verkehrsstraßen - auch Ortsdurchfahrten - vorgeschlagen, deren Wirkungsweise ist jedoch bisher nicht überprüft.

Der Minister für Stadtentwicklung, Wohnen und Verkehr NW hat daher eine Projektgruppe mit der Vorbereitung, Durchführung und Auswertung des Versuches "Verbesserung der Verkehrssicherheit auf Ortsdurchfahrten" beauftragt*. Als Ergebnis des Versuches wird erwartet, daß in Abhängigkeit städtebaulicher und verkehrlicher Randbedingungen Lösungsvorschläge zur Geschwindigkeitsreduzierung in Ortsdurchfahrten entwickelt werden können.

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*) Der Projektgruppe gehören an: Der Minister für Stadtentwicklung, Wohnen und Verkehr des Landes Nordrhein-Westfalen; die Beratungsstelle für Schadenverhütung des Verbandes der Haftpflichtversicherer, Unfallversicherer, Autoversicherer und Rechtsschutzversicherer e.V. (HUK-Verband); die Bundesanstalt für Straßenwesen; der Landschaftsverband Rheinland, Abteilung Straßenbau; der Landschaftsverband Westfalen-Lippe - Straßenbauverwaltung; der nordrhein-westfälische Städte- und Gemeindebund sowie der Technische Überwachungs-Verein Rheinland e.V.

5.2 Auswahl der Ortsdurchfahrten

Der Versuch soll in solchen Ortsdurchfahrten gemacht werden, bei denen aufgrund stark überhöhter Geschwindigkeiten die Verkehrsunsicherheit groß ist. Daher wurden die Landschaftsverbände Rheinland und Westfalen-Lippe gebeten, solche Ortsdurchfahrten zu benennen, bei denen im Jahr 1982 mindestens 2 Straßenverkehrsunfälle von der Polizei registriert wurden. Darüber hinaus waren bei der Auswahl der Ortsdurchfahrten folgende Randbedingungen zu erfüllen:

- Die Länge der Ortsdurchfahrten soll zwischen 300 m und 1000 m liegen.

- Die Ortsdurchfahrten sollen durchgängig Vorfahrtstraßen in beiden Fahrtrichtungen sein.

- Die Straßenführung soll zügig sein.

- Die Verkehrsbelastung der Ortsdurchfahrten soll zwischen 2000 Kfz/24 h und 8000 Kfz/24 h liegen.

In 27 Ortsdurchfahrten werden Veränderungen durchgeführt.

5.3 Maßnahmen

Parallel zur Auswahl für den Versuch geeigneter Ortsdurchfahrten wurden von der Projektgruppe Maßnahmen zusammengestellt, die im Rahmen des Versuchs einzeln oder in Kombination auf ihre Wirkungsweise hin überprüft werden sollten /4/.

Dieser "Ideenkatalog" wurde allen am Versuch beteiligten Gemeinden zur Verfügung gestellt.

Zu unterscheiden sind Maßnahmen

- vor dem Beginn der Ortsdurchfahrt;

- am Anfang der Ortsdurchfahrt und

- innerhalb der Ortsdurchfahrt.

Im einzelnen sollen folgende Maßnahmen erprobt werden:

(1) Änderung von Verkehrszeichen und Verkehrseinrichtungen (VZ): Dazu gehören Veränderungen der zulässigen Höchstgeschwindigkeit, Veränderung der Ortstafeln, Blinkzeichenanlagen, Änderung bestehender Fußgängersignalanlagen dergestalt, daß auf die Geschwindigkeiten des Kraftfahrzeugverkehrs eingewirkt wird, Überholverbote, Leitlinien.

(2) Veränderung der Eingangsbereiche (EB), z.B. durch optische oder akustische Bremsen, durch Betonung der Ortseinfahrt mittels Torsituationen oder Fahrbahnteiler.

(3) Veränderung der Fahrbahnrandführung (MR) durch Fahrbahnverschmälerung in voller Länge, teilweise oder punktuell sowie durch die Anlage bzw. Verbreiterung von Radwegen oder Gehwegen auf ganzer Länge, teilweise oder punktuell.

(4) Veränderung der Fahrbahnfläche (MF) mit Hilfe von Materialänderungen, Farbänderungen sowie Änderungen der Fahrbahnhöhe.

(5) Maßnahmen an Knotenpunkten oder Fußgängerquerungsstellen (MK): Fahrbahnteiler oder Kreisverkehrsplätze.

(6) Einbauten in Fahrbahnmitte (MM): Fahrbahnteiler zwischen Knotenpunkten.

(7) Neuordnung des Parkens (MV).

Diese Maßnahmen werden einzeln oder in sinnvollen Kombinationen eingesetzt und auf ihre Wirkungsweise hin analysiert. Bei der Zuordnung von Maßnahmen und Maßnahmekombinationen zu den jeweiligen Ortsdurchfahrten wurden die verkehrlichen und städtebaulichen Besonderheiten berücksichtigt.

5.4 Wirkungskontrolle

Im Rahmen umfangreicher VORHER/NACHHER-Messungen werden die Auswirkungen der Umgestaltung dokumentiert. Im Kern der VORHER/NACHHER-Analysen steht die Verkehrssicherheit. Da aber bis zum Vorliegen aussagekräftiger NACHHER-Unfallzahlen große Zeiträume erforderlich sind, müssen die Sicherheitsauswirkungen durch "sicherheitsrelevante" Indikatoren möglichst kurzfristig beschrieben werden. Dazu gehören vor allem die Ergebnisse von Geschwindigkeitsmessungen sowie von weiteren Beobachtungen des Verhaltens der Verkehrsteilnehmer. In Abhängigkeit der einzelnen Maßnahmen sind weitere VORHER/NACHHER-Untersuchungen vorgesehen, wie Lärmmessungen, Befragungen, Verkehrserhebungen.

In allen Ortsdurchfahrten werden die Veränderungen der Örtlichkeit durch eine VORHER/NACHHER-Fotodokumentation festgehalten.

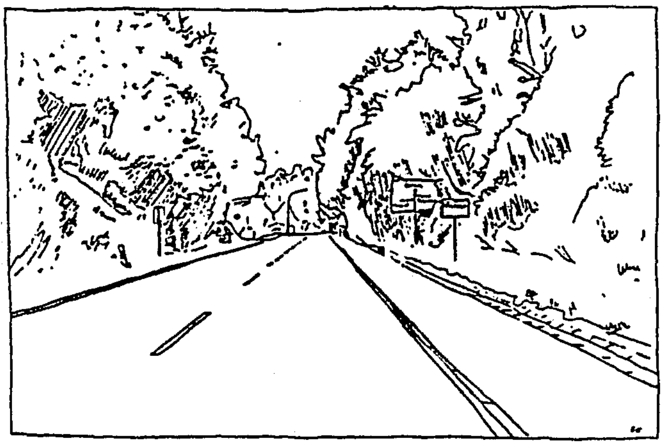
5.5 Beispiele

Im folgenden werden einige Beispiele für die Veränderung von Ortsdurchfahrten gezeigt:

(1) Änderung der Eingangsbereiche

(a) Optische/akustische Bremse vor der Ortstafel durch Materialwechsel der Fahrbahnoberfläche*.

vorher



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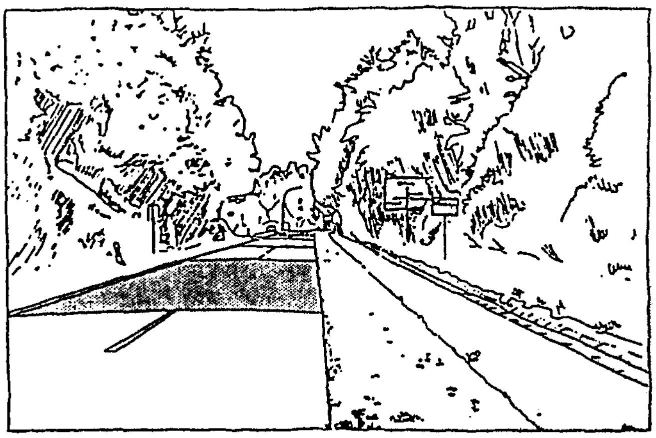

(b) Betonung der Ortseinfahrt durch bepflanzte Mittelinseln

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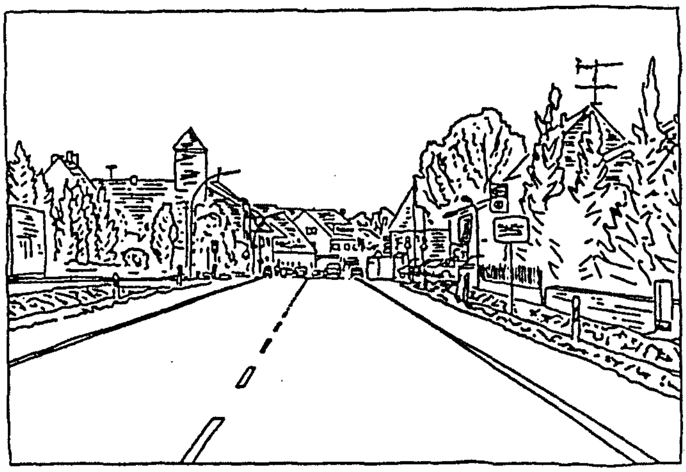

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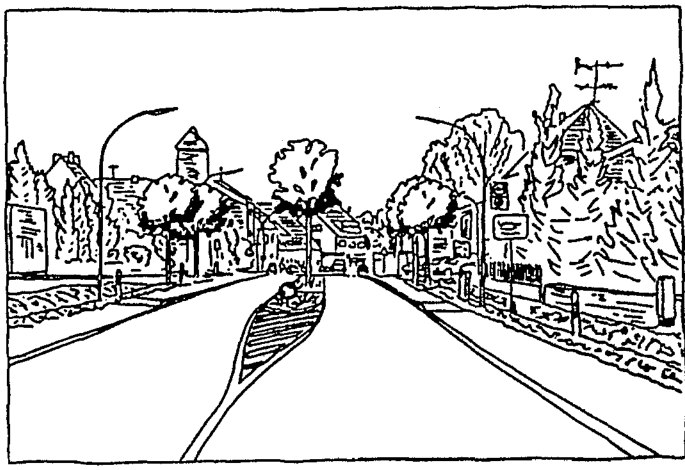
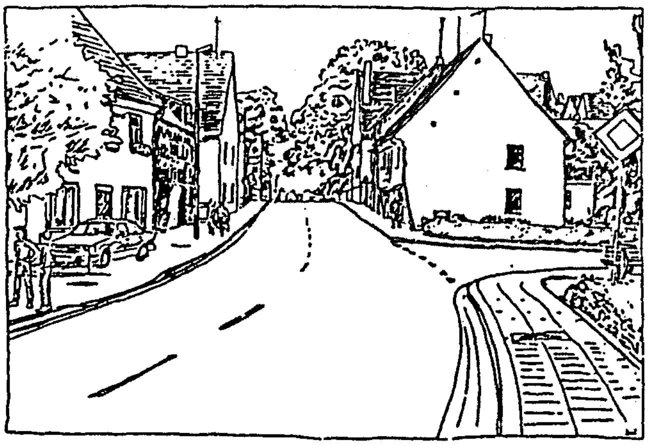


*) Der Minister für Stadtentwicklung, Wohnen und Verkehr des Landes Nordrhein-Westfalen, Kurzinformation I, 1986: Untersuchung "Geschwindigkeitsreduzierung auf Ortsdurchfahrten", 1. Teilbericht der Projektgruppe - Dezember 1985.

(2) Änderung der Fahrbahn vom Rand

(a) Verringerung der optischen Breite der Fahrbahn durch Anlage andersfarbiger Beläge*.

vorher



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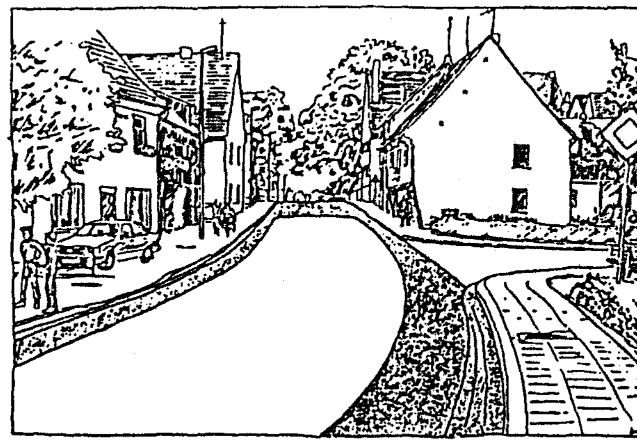

(b) Veränderung der Fahrbahnoberfläche

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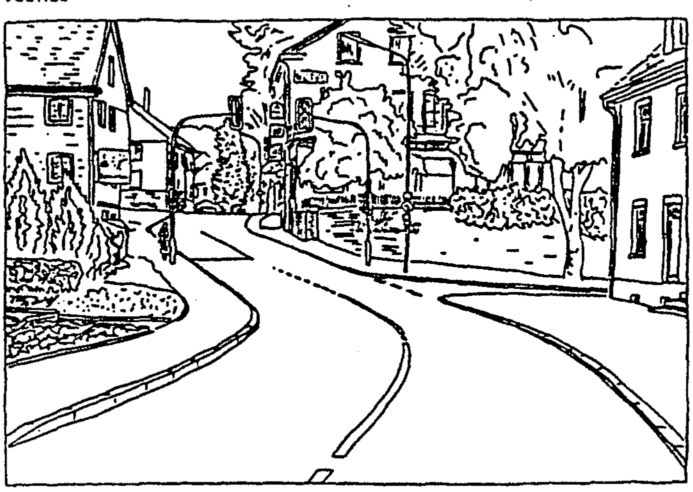

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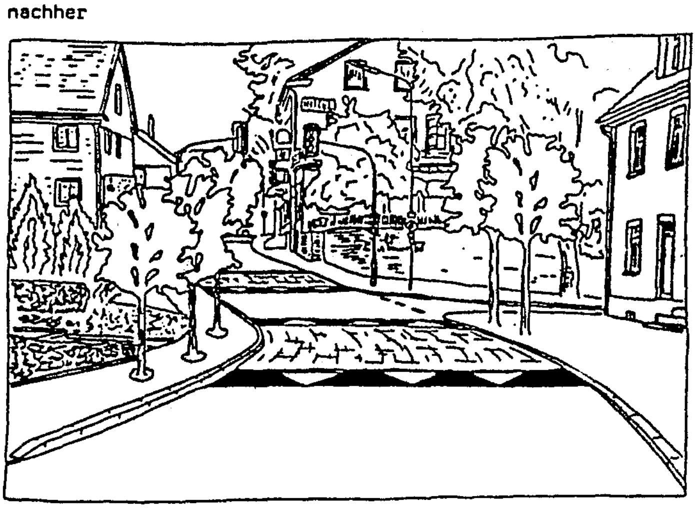

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*) Der Minister für Stadtentwicklung, Wohnen und Verkehr des Landes Nordrhein-Westfalen, Kurzinformation I, 1986: Untersuchung "Geschwindigkeitsreduzierung auf Ortsdurchfahrten", 1. Teilbericht der Projektgruppe - Dezember 1985.

(3) Maßnahmen an Knotenpunkten

Beispiel Kreisverkehrsplatz

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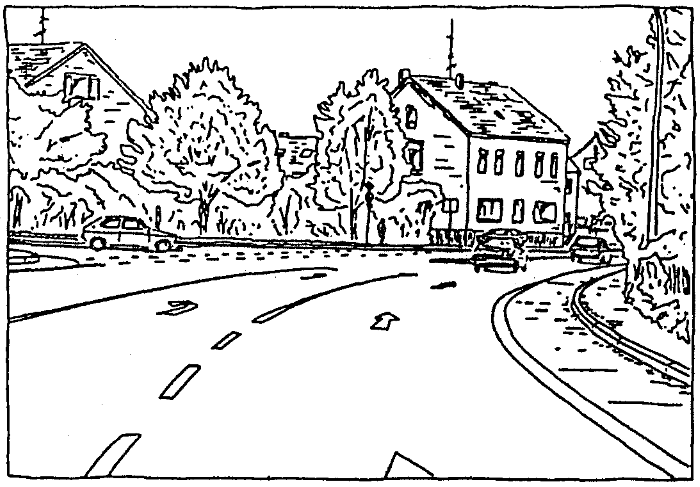

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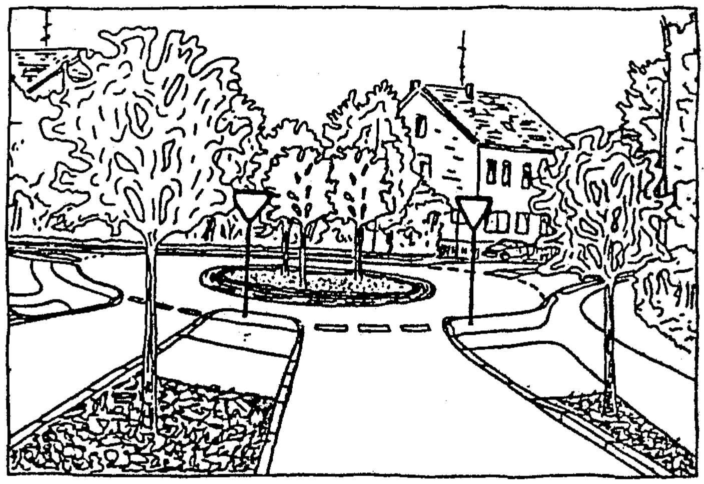

(4) Maßnahmen in der Fahrbahnmitte und am Fahrbahnrand

Mittelinseln und Einengungen (Inselversätze) in nicht zu großen Abständen

vorher

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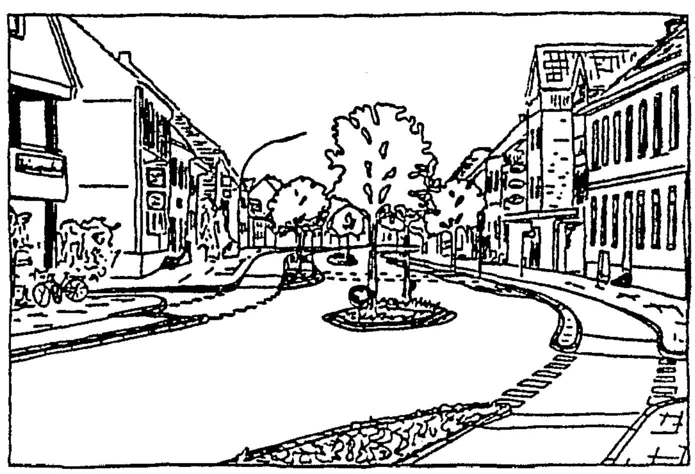

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SAFETY EFFECTS OF TRAFFIC RESTRAINT

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Introduction

In recent years the effectiveness and acceptability of traffic restraint measures in residential areas has been investigated. Results of accident investigations indicate that a new layout of residential areas has a positive effect on traffic safety. Accident reductions are mainly dependent upon the degree to which through-traffic in the residential area decrease. Also, the number of accidents involving injury per vehicle-kilometre in residential streets drop considerably. But if measures are taken only in residential zones the improvement is not likely to be radical: 10 % of all accidents involving injury are recordedd as taking place in residential streets. The remaining 90 % are recorded on main traffic arteries, the roads on which through-traffic is permitted, or desired.
Research into road safety should therefore not be restricted to residential streets; attention should also be paid to the problems of traffic zones and particularly the transitions from residential to traffic zones. Therefore traffic restraint measures should be implemented in larger areas; see the contributions of Hartmut Keller and Volker Meewes.
My paper presents some thoughts about evaluating speed-limiting measures.

Control of traffic speeds and density of risks

In traffic safety research the factor speed is very complicated. The theory assumes that the road user tries to adapt his behaviour to the environment. A car driver, for example, has to adjust his speed to the geometrical layout of the road and to other motor vehicles, pedestrians, and bicycles. This is because of his risk-acceptance.
Also, the car driver has a 'desired speed'; he has to be in time at his destination. Unexpected or undesirable delays have to be compensated for, per-

haps at the cost of his comfort and/or his safety. Limiting driving speed by altered road design will have a positive effect if the reason for the traffic restraint measures is clearly indicated to the driver. In order to evaluate the road safety effects, changes in perception and acceptance of risks have to be measured. It must be clear for the road user that there is a relationship between speed and risk, particularly in circumstances of mixed traffic (i.e., motorised and non-motorised).

What happens with the perception of risks if speed has been restrained to a lower level? Driving a car at half speed means doubling the time that the driver is exposed to the traffic process. In addition, the time that cyclists and pedestrians are exposed to the car is also doubled. However, the number of risky manoeuvres and the seriousness of the risks in that period of time have to be more than halved.

Suppose its a matter of density of risks: the number of potential risks in a given period of time. Risks can be divided into three classes of seriousness: exposure to fatalities, to injuries, and to proper damage. In general, road safety measures are intended to lower the risks per kilometer road length and per vehicle kilometer. More consequent are risks per straight line travel distance, per unit of traffic performance, and per unit of travel time; see Figure 1.

The density of risks may not be the same for different road sections.

In the case of a trunk-road through a residential area, the risk density will be high because of interactions with vulnerable road users.

The objective of traffic restraint measures for that part of the road network is the reduction of motor traffic speed without changing the traffic performance or the road length. Which changes in the traffic process enable the measures to have a positive effect on road safety?

Let's look at it on a high level of aggregation. Figure 2 presents risk density over a given route. Road section II has a relative high density of risks because of the presence of cyclists and pedestrians and because of the access function of the road. The risk density for the individual car driver is dependent on his speed. His exposure by travelling over the route is given by the travel time; see Figure 3. Speed limiting measures taken on section II were aimed to decrease the risks. If those measures really reduce speed then the exposure time over section II increases; see dotted line in Figure 3. The car driver will then reach his destination a little later or will travel a little faster over section III.

Nowadays, speed limiting measures are being structurally implemented on a large scale. Therefore, we have to realise that there will be a need for higher speeds on the other sections I and III of the road network if the excess in loss of time cannot be neglected. Because time is scare and limited for all the road users.

Effect of traffic restraint

The effect of traffic restraint in the long term will be a shortening of the travel distance (in road length) for some types of trips such as commutting traffic. In general, however, the road traffic performance (in vehicle-kilometers) has the tendency to grow. In addition, the efficiency of transport increases, especially the loss/cost ratio: travel time / travel distance will continue to decrease.
Driving with higher speeds means a higher risk density, unless the road structure has been adapted to that higher speed; for example, consider motorways. Of course this kind of adaptation is not economical for the whole network, and it ignores the other functions of the road network; for instance, the accessibility of destinations.
Experimental schemes involving the reclassification and reconstruction of road sections are the tools for evaluating the effects of traffic restraint measures when they are practised on the total road network.
Reclassification of traffic zones where traffic arteries become residential streets reduces the original traffic function. There will be a substantial positive effect on road safety if through-traffic is diverted to the main traffic arteries. If this does not work, reconstruction measures to influence behaviour and speed could have an adverse overall effect.

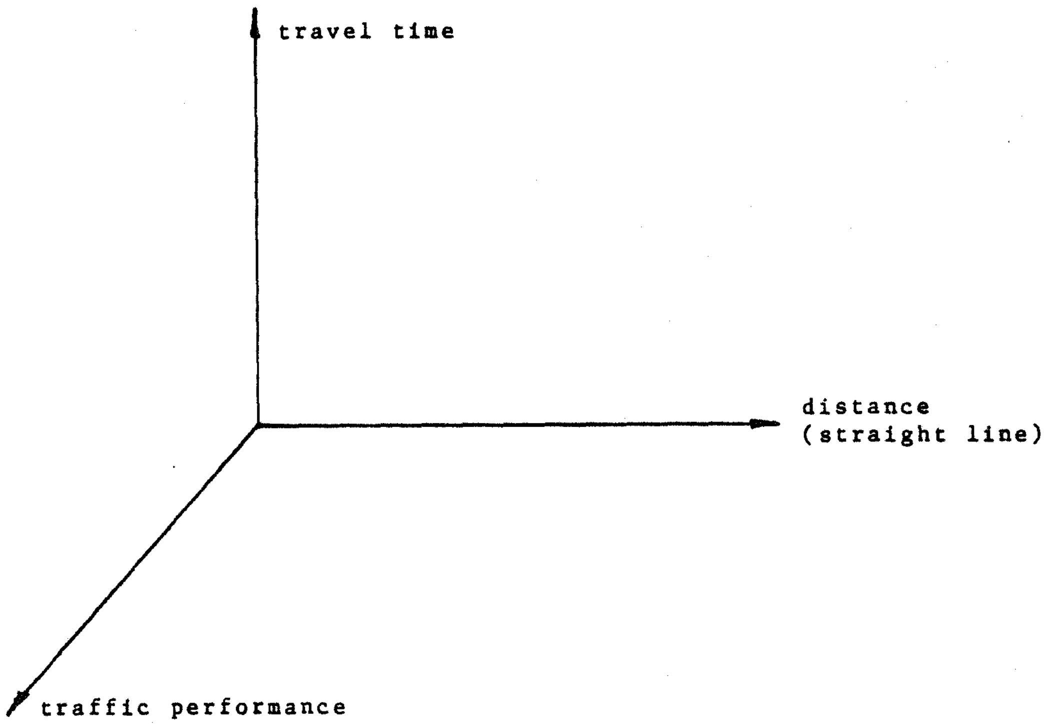
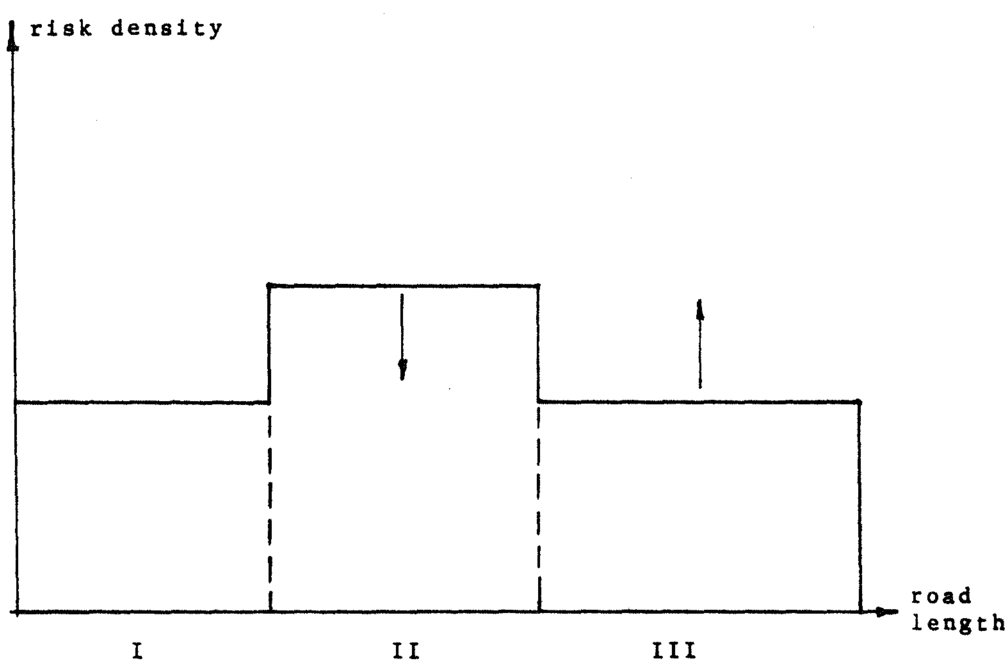


figure 1



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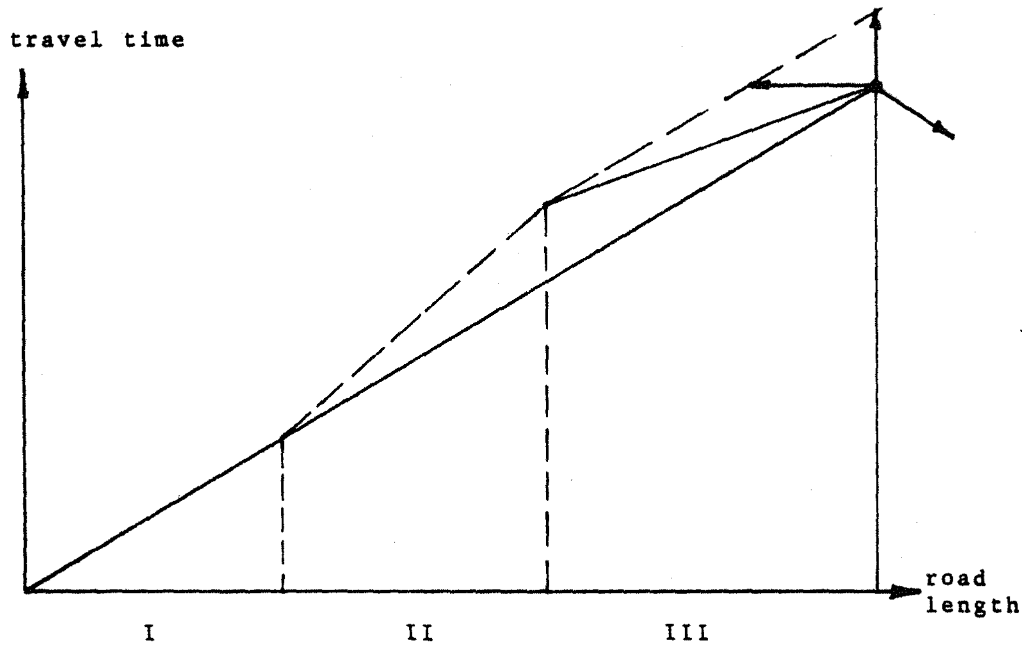

figure 3

ROAD USER VISIBILITY AND CONSPICUITY

K. Rumar
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Abstract

An effort is made to define and treat the two road safety problems of driver visibility and road user conspicuity. Initially the visual tasks and visual performance characteristics are analyzed. Based on this analysis the effects of various measures aiming at improving visibility conditions and road user conspicuity are discussed. Finally it is concluded that there are some effective measures that should be more widely used, many visibility and conspicuity problems are still not answered.

1. Background

By visibility in this context is meant the possibilities of a road user to detect and identify the relevant objects and events in front of him. By conspicuity is meant the ability of a road user to make himself visible and conspicuous to other road users. Consequently visibility and conspicuity is the same problem from two sides. This problem is an important one judging both from subjective statements of accident involved drivers and other road users. "I did not see him...", "I saw too late that..." and from traffic accident statistics which show that the accident rate in bad visibility conditions (night and rain) is considerably higher than in clear visibility (daylight).

Conspicuity and to some extent visibility contain a cognitive aspect. But in this paper only the main visual function is treated. The reason is that there are several general visual problems to pass the absolute threshold. These have to be solved first.

2. Visual task

Since visibility and conspicuity are pure visual functions it would be natural to find a correlation between visual performance and accident records. Studies carried out however contradict this hypothesis, see table 1 (Rumar 1979).

Visual Function	Age Group	Correlation Coefficient
Static Acuity	<25	.00
	>54	.06
Dynamic Acuity	<25	.01
	>54	.05
Visual Field	<25	.01
	>54	.04
Glare Recovery	<25	.01
	>54	.06
Recognition	<25	.03
Low Illumination	>54	.01

Table 1 Correlations obtained between some visual functions and accident rate

There are of course different ways to classify the various visual tasks in traffic. This is one (Rumar 1980).

A 1. To hold the right course on the road (e.g. in curves)

A 2. To maintain the right speed and speed changes considering road geometry and other road characteristics (e.g. crossings, friction)

B 1. To detect obstacles and other road users in the road scene at such a distance that collision can be avoided (e.g. pedestrian, cyclist)

B 2 To estimate and predict the relative distances, speeds, courses, changes and manoeuvres of other road users in order to interact with them in an effective manner (e.g. in queues, overtaking (e.g. road signs, traffic and road user signals)

C To detect and decode signs, signals and other artificial messages in the traffic environment (e.g. road signs, traffic and road user signals)

As indicated in this scheme the tasks can be grouped into three groups - natural information from road environment (A) and other road users (B) and artificial information (C). By natural information is meant basic information not requiring any education or training (e.g. a curve, something coming straight against you). Artificial information is something that we have built into the traffic environment when the natural information is too weak or even lacking (e.g. road signs, traffic signals). Of course we often collect for traffic irrelevant information (e.g. beautiful girls).

It is important to remember that man has developed to be a daylight, good weather creature and has no real basic problems to see in broad clear daylight. In clear daylight traffic there is normally a vast redundance of information available. The ambient illumination and the clear air make visible at long distances the general outline of the scene, the various motions, their differences and directions and various details of the traffic scene depending on their size and contrast against the background. Here the problem is not to see but to select from this overflow of information the parts that are necessary to make correct decisions and predictions.

Of course the corresponding information has the same importance in night and bad visibility traffic as in clear day traffic. But the human visual system does not offer the same information level.

3. Visual performance

The visual tasks outlined above require some visual characteristics. It is therefore natural that specific visual demands are put on individuals that apply for a driver's licence. But are the requirements really the right ones? (Davison 1978).

Visual acuity is no doubt important for most of the visual tasks - mainly, however, for B and C. The visual field is also of relevance for most of the tasks - maybe mainly for A and B 1. Defect colour vision is a drawback in some situations - mainly C.

But important functions that are never tested concern the immediate analysis of the optical flow in the visual field. According to modern research results most imformation necessary to carry out steering and braking (A-tasks) is available in the optical flow and the motion parallax that covers the retina as soon as we are moving. The handling of information concerning relative motion, that is so important in traffic (B 2-tasks), is probably made by immediate analysis of the motion vectors represented in the dynamic visual field. Finally no tests at levels of night traffic or low contrast are carried out.

4. Reduced visibility

There are several types of reduced visibility conditions. The three most essential ones seem bo be (OECD 1986):

- Darkness. Since the human eye is built for daylight conditions the visual performance in lower levels of illumination is seriously impaired - by reduced contrast sensitivity (see figure 1) and glare (see figure 2). Darkness is the most common and regular situation of reduced visibility.

- Rain. The meteorological visibility is reduced roughly according to the Middleton-Koschmieder relation

  $$\text{Visibility} = K \cdot \frac{\text{drop radius}^3(\text{cm})}{\text{water volume }(\text{cm}^3/\text{sec})}$$

  From this equation can be seen that the direct meteorological sight reduction is more severe in drizzle with small drops than in heavy rain with large drops. In drizzle visibility may go down to a few hundred meters. In daylight rain the visibility is rarely below a few thousand meters.

- Fog. From meteorological viewpoint fog is at hand when visibility is less than 1000 m. The droplets are considerable smaller than those in rain. The main effect is the scattering of light.

  Typical traffic visibility distances at 30 m (very thick fog) and 100 m (thick fog) standard visibility conditions are 10-50 m for taillights to high beam and 20-200 m respectively. In daylight the contour of a car is normally seen

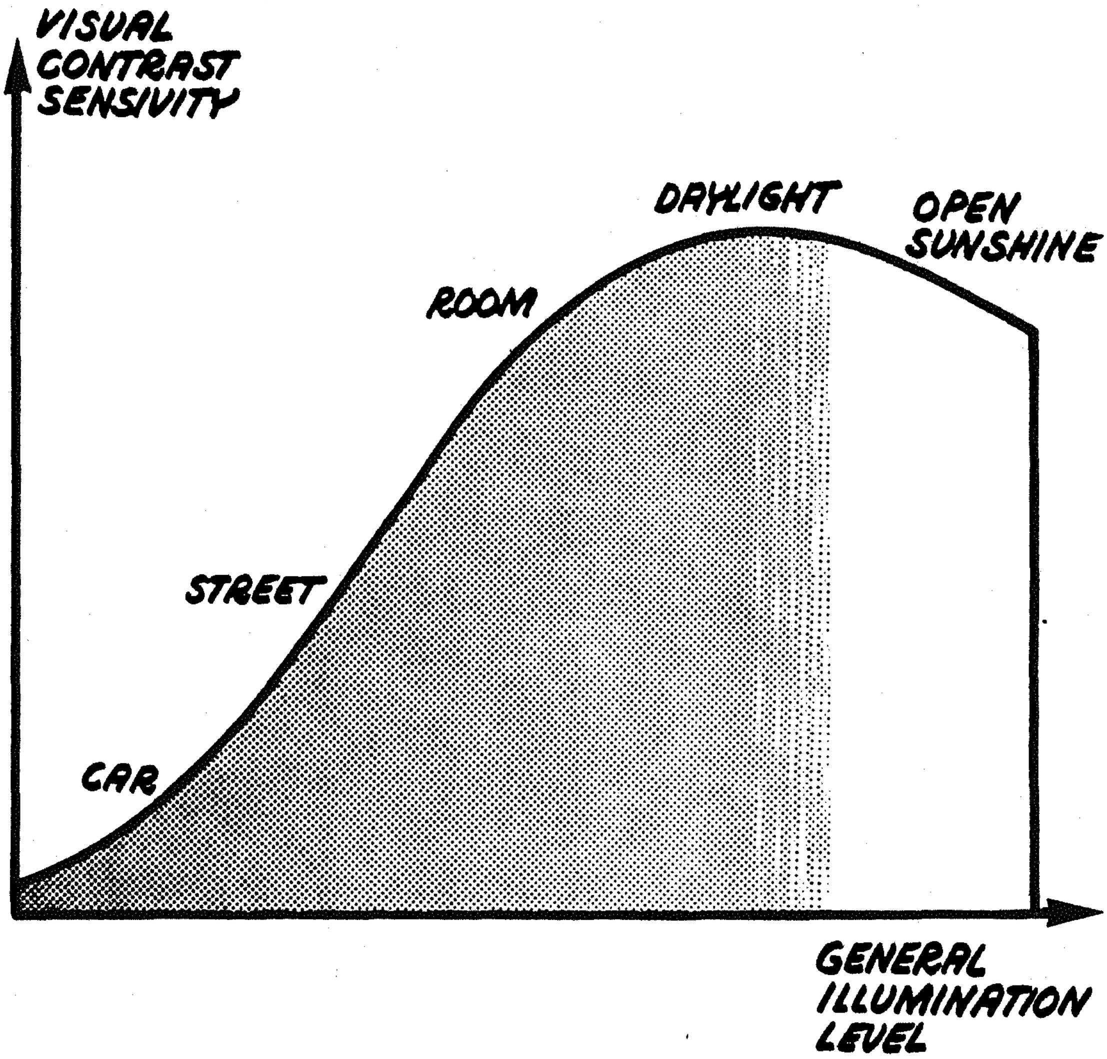
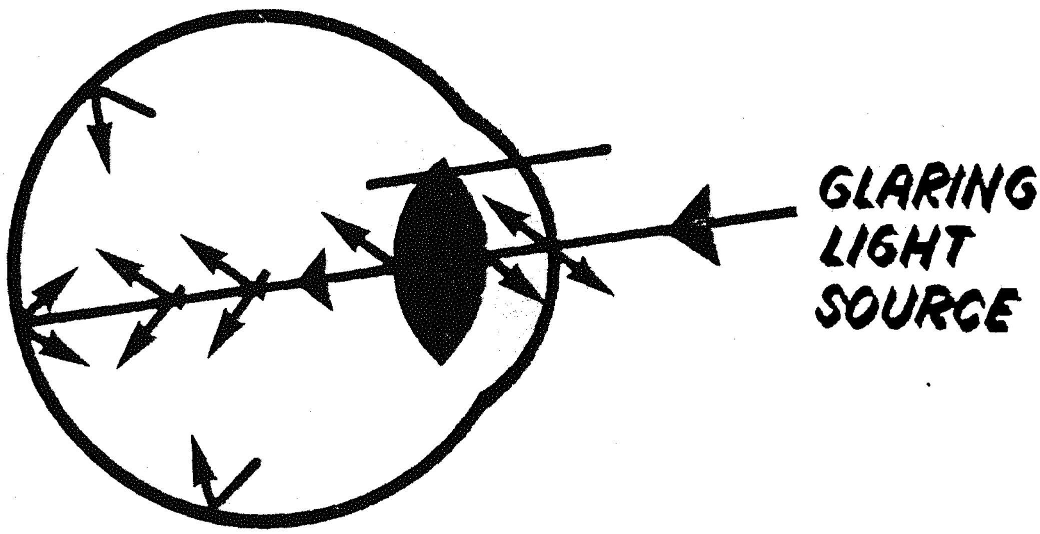


Figure 1. The contrast sensitivity of the human eye is reduced at lower levels of illumination



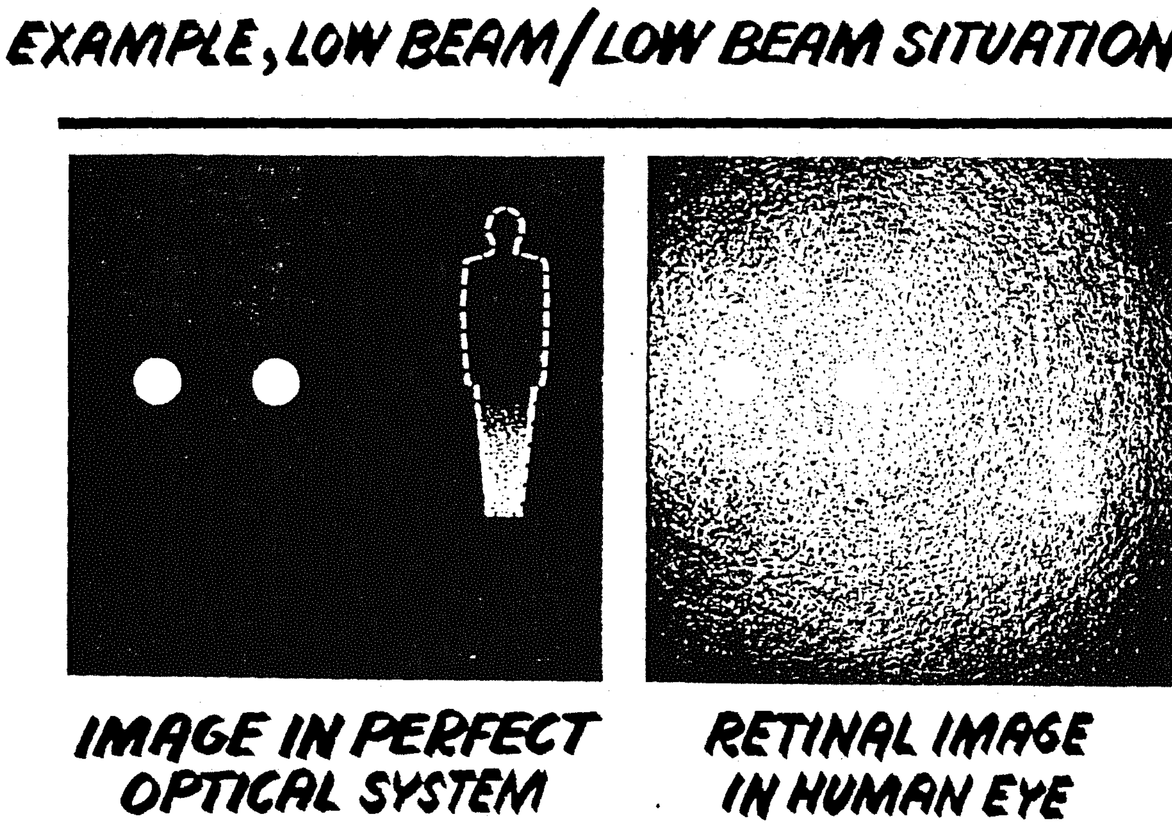


Figure 2. The main component in headlight glare is straylight in the ocular media

before the standard tailights. At night the opposite is normal and the visibility longer.

5. Visual performance in reduced visibility

The three types of reduced visibility have a common visual denominator - reduced contrast. In night traffic the visual contrast sensitivity is reduced due to level of illumination and glare (see figures 1 and 2). In fog, smoke, dust, snow and to some extent rain, the physical contrasts in the visual field are reduced. By wet road surfaces the glare is normally stronger from oncoming vehicles and the effect of street lighting is considerably decreased.

Let us consider the five visual tasks mentioned initially.

It is very hard to hold the adequate course (A1) and speed (A2) when the visual flow over the retina is substantially reduced. In many cases (e.g. night traffic) we only see some point sources. Detection of obstacles (B1) on the road on safe distances will be dependent on the marking of the obstacle (increased contrast). Estimations of distance and speeds (B2) require target background which is often totally missing or very poor. Finally visibility and legibility of signs and signals are impaired by the reduced contrast.

6. Countermeasures for night traffic

In figure 3 an effort is made to summarize the important factors in night traffic (Rumar 1975A).

I Man (dimensioning component)

A. Visual performance and characteristics at levels of night driving illumination (contrast sensitivity, visual acuity, glare sensitivity, visual field etc.).

II The light sources (the purpose of which are to replace the sun)

A. Road lighting (illuminating horizontal surfaces)

B. Vehicle lighting (illuminating vertical surfaces)

III The visual stimulus (meaning what we need to see in order to drive safely)

A. Horizontal surfaces (the road surface, road markings, fields beside the road etc).

B. Vertical surfaces (other road users, obstacles, signs, etc.).

C. Signal lights (brake lights, direction indicators, traffic signals, emergency beacons etc.).

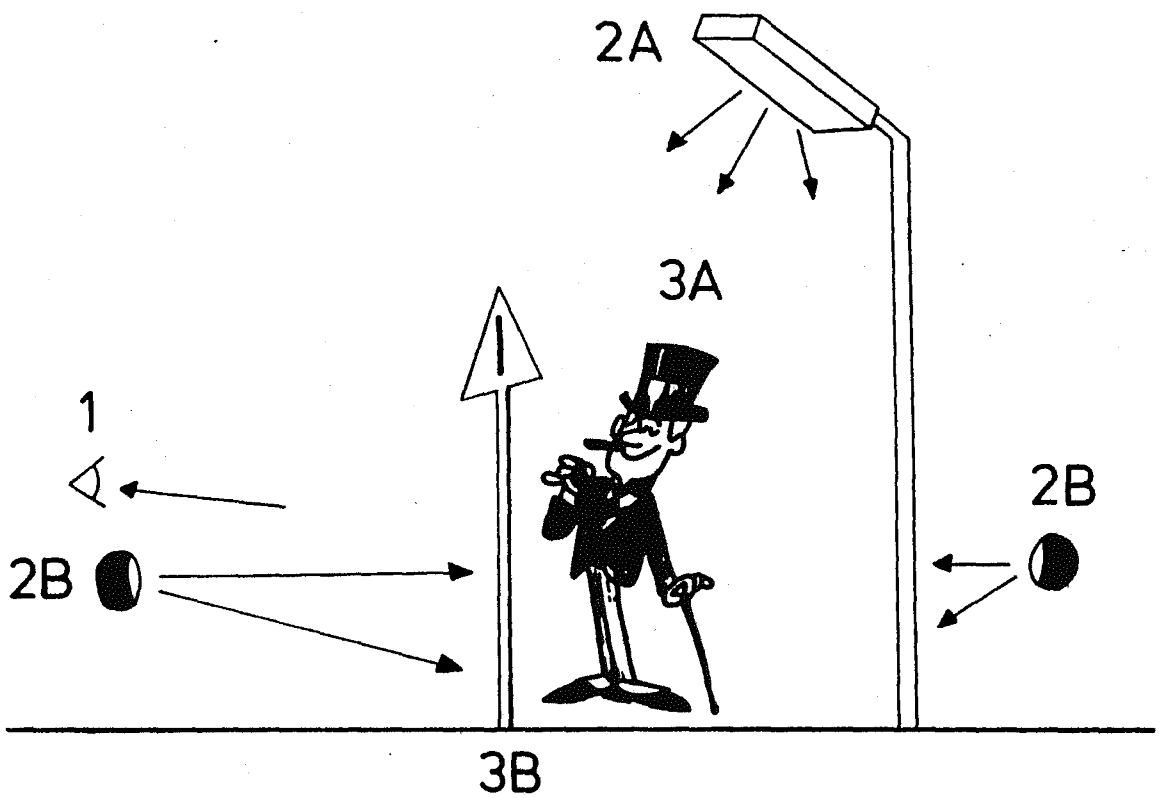


Figure 3. Night traffic split up into its main components

Any effort to increase safety has to try to influence one or more of the components in figure 3.

From functional point of view none of us is capable of adequate visual performance under some of the night driving conditions. The possibilities to improve visual performance by training are very limited. The contrast thresholds are of a physiological optical nature rather than psychological. On the other hand it is quite possible to train drivers what to look for, where to look for it and when to look for it.

The road lighting problems are solved in principle. Many investigations demonstrate the positive effect of the introduction of road lihgting on the accident reduction in night driving. The favourable effect obtained varies around 30% accident reduction. The serious injuries and fatal accidents are often reduced even more. The remaining question is how a given sum of money should be used in an optimum way.

One very important problem is to maintain road lighting effectivity in wet conditions. Rough road surfaces improve the situation and some experimental draining road surfaces seem to be able to solve the problem.

Other problems are to design effective tunnel lighting and to prevent other lighting installations (e.g. petrol stations) from destroying the positive effects of the road lighting (NNTRC 1977).

The vehicle lighting is really problematic only in one aspect (OECD 1971, 1980, NNTRC 1980). The last meeting phase - the low beam/low beam situation is the most difficult from visibility point of view. It has been shown in several studies that the present European low beam system in real traffic situations offers visibility distances about 50 meters while at least 100 meters would be required considering the normal night driving speeds on our roads (100 km/h). The introduction of the halogen bulb improved the situation but far from solved the visibility problem (Rumar et al. 1974). Evolution of plastic headlights and polyelliptical headlights have not really changed the visibility conditions. The dipping system of the present low beam (1% down-wards) makes it very hard to develop. Less dipping means more glare, more dipping means less visibility. This principle cannot cope with road geometry (see figure 4).

Present low beam headlight aiming is independent of headlight mounting height. There are potential advantages to gain by making headlight aiming dependent of mounting height (Rumar 1985).

Research on vehicle headlamps must leave the laboratory and test track environment. The real world with all its variation must be considered in the analyses of optimum light distributions (Helmers et al. 1984). Some of the more important sources of variation are:

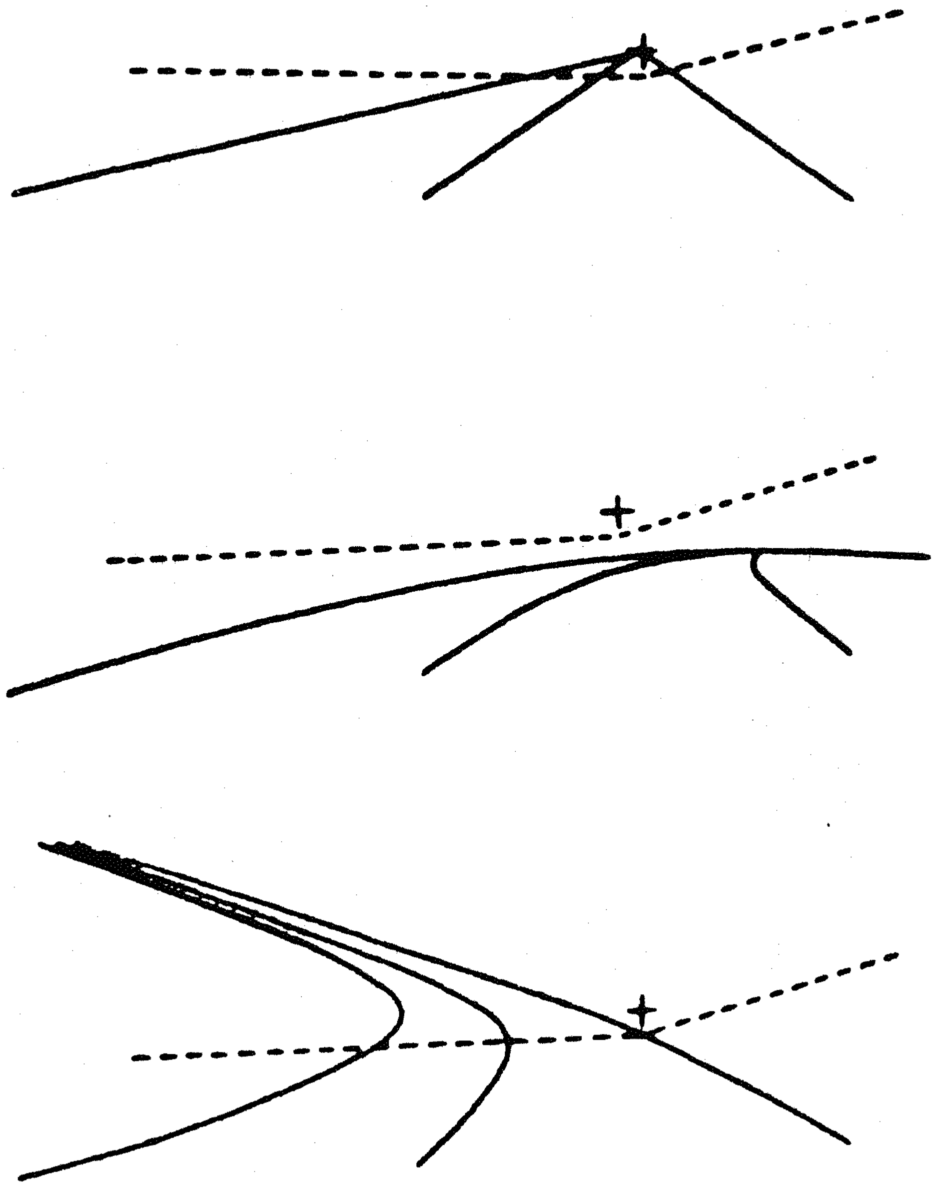


Figure 4. The location of the light-dark border of a correctly aimed European low beam projected on a straight plane road (the dotted line on the first drawing), in relation to a hill crest (second drawing) and to a depression (third drawing).

- horizontal and vertical curves on the road
- aiming of the headlights (including load and lamp adjustment)
- driver visual status and concentration
- headlight condition (including voltage)
- road and traget reflectance factors
- target position and size

When variations like these are introduced it will not be possible to measure visibility. The conditions must be simulated and the visibility calculated (but validated).

In the future polarized (glarefree) headlights may be a solution (Johansson & Rumar 1970). Another possibility is to introduce "electronic vision" as a complement to optical vision.

The main visual stimulus in night driving as in daylight driving is the road itself. (The horizontal surface). The specular glare caused by reflection in wet, smooth road surfaces may be several times more intensive than the direct glare from oncoming headlights. New road surfaces with drainage properties are presently developed. They should be very attractive both from road lighting and from vehicle lighting point of view. Road delineation (marking and markers) is also hampered by rain (NNTRC 1983).

The visibility of vertical surfaces (obstacles) in vehicle lighting is very much influenced by the luminance factor of the obstacle. Results from a Swedish study show that a person completely dressed in black with a small thumbsized retroreflective tab is in vehicle lighting detected at longer distance than a person completely dressed in white. This is a good illustration of the effect of retroreflective materials. By using this kind of material much higher contrasts in the visual field are obtained and thereby the lowered contrast sensitivity of the human eye at levels of night driving illumination is compensated for (Rumar 1976).
The Nordic research group proposes ≥300-400 CIL pedestrian retroreflexes in use (NNTRC 1982).

Signal lights constitute a minor problem in night driving. They are much better visible than in daylight. One risk is that they shall be perceived as so intensive that they are glaring. But it is only in connection with rear fog lighting, high mounted brake lights, and beacons for emergency vehicles that this has been reported as a problem (Rumar 1975B). There should in fact be at least two intensity levels for signal lights - one high for daylight, one lower for night conditions. A promising improvement seem to be the high mounted brake lights that in US-studies gave rear end accident reductions around 50%.

The interaction between road lighting and vehicle lighting constitutes a specific problem. The vehicle headlights (low beam) partly destroy the favourable visibility conditions created by road lighting by introducing glare into the visual scene. This is the background for the suggested intermediate beam (citybeam) between position lights and low beam (OECD 1971, 1980, Hörberg & Rumar 1975). A reduced low beam is now introduced by law in U.K.

7. Daylight conspicuity of vehicles

A very common explanation from drivers involved in road traffic collisions with other vehicles is of the type "did not see..., detected too late...". Therefore increased vehicle conspicuity should be one of the primary problems in road safety work.

Daylight detection of other vehicles in central vision where the resolution capacity and the contrast sensitivity is high is normally no problem. But in strong shadows and with dark backgrounds detection may be a problem even when we look straight at the vehicle - in central vision. However, when another approaching vehicle appears where we do not expect it we are not looking for it, and if we do not detect it in peripheral vision the situation might develop into a critical one. Consequently peripheral detection is the crucial visual function concerning detection of other unexpected approaching vehicles.

Experiments to study the effect on conspicuity of the colour of the car against various backgrounds have been carried out (Dahlstedt & Rumar, 1973). The results show a marked effect of contrast. A colour which is good in one situation (e.g. black in winter) may be bad in another situation (e.g. forest road in summer). This is of course quite in line with all the laboratory studies that have been carried out (e.g. Blackwell, 1946). But the most interesting result was that with low beams all cars (irrespective of colour) reached the same conspicuity as the best colour for each background. Consequently some kind of daytime running lights (DRL) seem to be a possible way to improve vehicle detection.

The idea and the first systematic studies of DRL came from USA in the late fifties and the beginning of the sixties. The Greyhound bus initiative and results are the most well known among the first ones.

Then, the idea was taken up in the Nordic countries. It was e.g. suggested as one of the measures to prevent accidents at the Swedish change over from left to right hand traffic 1967. DRL and its effects were systematically studied at University of Uppsala (Hörberg & Rumar 1975, Hörberg 1977) and the Swedish Road and Traffic Research Institute. Finland was the first country to have a DRL-law (1972). It was limited (during winter in rural areas) but it permitted a first evaluation of effect on accidents (Andersson et al. 1976). Based on that evaluation both Finland and Sweden made DRL compulsory on a general basis with very good safety effects on reduction of daylight collisions (Rumar, Andersson & Nilsson 1981, Transport Canada 1986).

Present legislation concerning DRL mainly concern motorcycles (Australia, France, Canada, several states in USA, Denmark and some others) and only state conventional low beam (300-625 cd in HV (straight ahead) in Europe) except for USA where modulated low beam is accepted.

Finland and Sweden have laws on compulsory DRL for motor vehicles with special standards although low beam is permitted in both countries. Sweden specifies 300-800 cd in HV while the Finnish standard specifies 600-1200 cd in HV.

Norway and Canada have introduced DRL-laws for new vehicles. (In Canada valid from September 1, 1988).

The very positive effect of DRL on detection and road safety is established. Daylight collision accident reductions of 5-20% are obtained. A suitable intensity range in HV during daylight seems to be 600-1500 cd. If DRL is allowed also in dawn and dusk 400-1000 cd seems more suitable. The colour could be white or yellow. The optimal light distribution remains to be studied.

8. Conclusions

Driver visibility conditions and road user conspicuity are still two serious problems in the present road safety situation. Most of the basic visual problems are to a large extent not answered.

For some of the practical problem aspects there are effective but expensive countermeasures - e.g. road lighting, polarized headlights. But for a few other aspects there are effective and inexpensive countermeasures that are not generally applied - e.g. retroreflective markings, daylight running light. For still other problems there are no acceptable countermeasures - e.g. visibility for motorcyclists in night driving, conspicuity of bicyclists and pedestrians in daylight. For no problem the final solution is found. Research must go on ...

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ROAD USER VISIBILITY AND CONSPICUITY, SOME COMMENTS

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Introduction

The general overview, as given by Rumar in his draft, gives me the opportunity to sketch some additional view points.
I will do this by commenting firstly on the 'status' of visibility problems in the driving task, secondly on the definition of the loosely operationalized term 'conspicuity', and thirdly by sketching visual selection as influenced by cognitive processes.

The status of visibility problems

Visibility problems can be divided in three categories: properties of the drivers (visual functions), properties of the information carriers, and the influence of external conditions.

- Visual functions

  As mentioned by Rumar, substantive correlations between measured visual capabilities of drivers and their number of registrated accidents do not exist.

There are obvious many (hypothetical) reasons for this state of affairs:

1 the range in capabilities is, due to existing selection systems and general eye-care such, that all drivers do have sufficient capabilities;
2 drivers with visual deficiencies compensate for this deficiency by adapting their driving behaviour;
3 accidents are low probability events, only predictable with low validity, even by accident frequencies in an earlier period. Furthermore, accidents specifically related to visual deficiencies may be only a small subgroup. This further reduces the expected correlation in such an extent, that it becomes highly improbable to find ever substantive correlations on the basis of individual data. See appendix.

It thus seems hardly possible to state that visual functions play an important role in the accident statistics. It seems to me, that testing of visual functions should have as a main goal the correction of shortcomings and/or making individual drivers aware of their deficiencies and not so much for selection.

- Information carriers

In the past, many studies have been performed into the visibility of traffic signs, roadmarkings, signal lights, and so on. Many of the results are embedded in national and international regulations. This is especially true for traffic signals and lights. Since this field is rapidly absorbing micro-electronics, newly developed informationcarriers as temporary signs, lane restriction signs, traffic lights for special categories like buses and so on, may pose further visibility problems in this field.
Research in the field of information carriers gradually shifts to questions about the necessary information, and where, how and how long to present it.
The visibility of road markings is a substantial problem at night during bad weather conditions. It takes special materials to maintain sufficient contrast at the required preview distances, or a second additional system of raised pavement markers. The question about an optimal configuration was studied by Blaauw et al.(1984).

- External conditions

  Rain, fog and darkness are global visibility reducing conditions. The usual countermeasures are vehicle lighting (headlamps, taillights, foglights) and public lighting.
  Glare remains a substantial problem.
  Also the mutual effect of different countermeasures is not completely known. For instance, retroreflective traffic signs do have reduced visibility distances in areas with public lighting.

Conspicuity

Visual conspicuity is a rather intuitive term for depicting the 'phenomenological' appearance of objects as 'hitting the eye', attracting attention, easily recognizable etc.
As a researcher, one has a certain uneasiness with such a term, since it defies a simple operational definition. The main reason I think is that both stimulus aspects and subject characteristics contribute to the 'phenomenological' conspicuity, i.e. not only stimulus characteristics as colour contrast, luminance contrast, fore-background relation, motion contrast but also cognitive determinants like expectation, visual search patterns, valuation of relevance contribute to the experienced conspicuity.

For the traffic environment there are two main issues:
- firstly one has to guarantee a balanced distribution of conspicuity over the traffic elements. By making all cars highly conspicuous, other traffic participants like motorcycles, bicycles and pedestrians are more often 'not seen', so there should be done more research on what constitutes an optimal balance.
- Secondly, conspicuity can not only be enhanced by larger luminance contrast for instance, but also by a more appropriate placing in the visual field. For instance, a traffic sign should be placed at locations, where they 'normally' are expected.

On certain road categories one is not prepared to see a pedestrian or cyclist, because they are normally not allowed at these categories.
How large a difference it can make, whether one expects certain elements or not, is demonstrated by Hughes & Cole (1986). They found

percentages of reporting disc targets of about 10% versus 70% depending on whether subjects were instructed to report 'anything' that attracted their attention (attentional conspicuity) versus an instruction, mentioning the existance of these disc targets and asking to report them as well as all traffic control devices (search conspicuity).

Furthermore, one sees in practice that special care is needed to signal to drivers that for instance the situation on a crossing is changed (changed priority rules, installation of traffic lights and so on). This additional signalization is needed until the new situation is learned to be the normal expected visual scene. Thus, only elements, which are not expected should have higher signal strength to make their timely detection probability higher. Even then it is difficult to 'compensate' unexpectedness by signal strength judged by the very bad accident records of policecars and firedepartment cars.

It is for certain, that whether one is, or is not willing to include attentional aspects in the term 'Conspicuity', much more research is needed to clarify the meaning of this variable and its impact on driver behaviour.

Visual selection

Given the time constraints under which drivers have to make decisions, it is to be expected that perceptual as well as cognitive filtering processes are at play during driving.
These processes will be governed by cognitive schemata, which result from experience and education.
Cognitive factors will furthermore not only govern the filtering of information but also the visual search processes and the preparation for actions possibly called upon.
It seems to me that these factors also determine the 'conspicuity' of for instance a crossing pedestrian, as does 'tagging' him with retroreflective materials.

The relative degradation of visual search processes at night, as can be concluded from eye movement studies (reduced fixation distances,

longer fixation durations, a more concentrated fixation pattern) may contribute in a substantial way to the visibility problems at night. Despite the importance of this kind of 'top-down' effects, not much research has been devoted to this topic.
The recognition of road categories and the 'naive' categorizations of traffic participants are being studied by our institute. Preliminary results suggest, that 'naive' categorizations are based on other objective properties, than are emphasized in the 'official' categorization.
It seems relevant, to study this kind of naive categorization and the expectations derived from them also for night time scenes, since a number of informational elements then are no longer visible, while others like the presence (and color) of public lighting become available in a rather dominant way.

I have tried to sketch a context, in which visibility and conspicuity characteristics play their role in the driving task.
The ultimate goal to be aimed at, seems to be to furnish the road and the road side in such a way that during daytime as well as during nighttime, correct expectations are formed by the driver. Much more research in the cognitive processes also governing the perceptual processes seems to be needed before attaining this.

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Appendix

Assuming that the accident count of a person, a road stretch etc., follows a Poissondistribution with parameter λ_i and denoting the number of accidents (realisations) by y_i, then there are certain restrictions for the expected maximum correlation coefficient.
It is easily derived that:

$$\varepsilon\ (\text{var}\ y_i) = \text{var}\ \lambda_i + \bar{\lambda}$$

thus dependent on the mean λ_i and the variance of λ_i . Since only the variance of λ_i is 'systematic', the expected correlation between two 'replications' i.e. the reliability of the accident count is:

$$\varepsilon\ (r(y,y')) = \text{var}\ \lambda_i\ /\ (\text{var}\ \lambda_i + \bar{\lambda})$$

From this formula it is clear that the expected correlation is very much dependent upon the ratio of the systematic and the total variance. When var λ_i is low compared to $\bar{\lambda}$, then only a low reliability of accident counts exists.
This has also consequences for the possible correlations with predictors of accident counts.
Even assuming a perfect predictor of λ_i, say x_i, which is measurable with a reliability of 1.00 and correlates 1.00 with λ_i, then the expected correlation between y_i and x_i is:

$$\varepsilon\ (r(x,y)) = \sqrt{r(y,y')}$$

When a predictor is in the same way related not to λ_i but only to a part of it say to λ_{1i} defined by $\lambda i = \lambda_{1i} + \lambda_{2i}$ and also assuming that λ_{1i} and λ_{2i} are uncorrelated, then the expected correlation coefficient of x_i and y_i reduces to:

$$\varepsilon\ (r(x_i,y_i)) = \sqrt{\frac{\text{var}\ \lambda_{1i}}{\text{var}\ \lambda_i}} \cdot \sqrt{r(y,y^1)}$$

Let me illustrate this by an example. I take for this the table of Shaw & Sichel, 1971 page 243 on 148.006 Californian drivers.

For this table $\bar{\lambda}$ can be estimated as the mean number of accidents and var λ_i as the difference between var y_i and $\bar{\lambda}$

$$\text{var } y_i = \text{var } \lambda_i + \bar{\lambda} \quad \text{thus is}$$
$$0.2412 = 0.0367 + 0.2044$$

When the same drivers should complete a second period of three years and nothing should have changed, then the expected correlation between accident counts of first and second period is:

$$\varepsilon\ (r(y_{i1}, y_{i2})) = 0.1525$$

The maximally possible expected correlation with a perfect predictor x_i then is

$$\varepsilon\ (r(y_i, x_i)) = 0.3905.$$

When a single predictor is only related to a small part of all accidents, say to one tenth, as is reasonable for e.g. visual functions, this results in

$$\varepsilon\ (r(y_i, x_i)) = 0.03905.$$

Such a figure nicely fits in the range of correlations, Burg et al reported!

Ref. Shaw, L., Sichel, H.S., 1971, Accident Proneness, Pergamon Press.

SPEED AND TRAFFIC SAFETY

G. Nilsson

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The three components forming the road transport system, the road, the vehicle and the driver, together have a speed potential which is higher than the highest speed limits and also of course considerably higher than the lowest limits i urban areas.

While car drivers in general accept speed restrictions, the actual level accepted varies among them.

Speed restrictions are often based on traffic safety ground, even if their introduction in certain countries is related to today's energy considerations or tomorrow's environmental situation.

The debate around speed limits has in many cases resulted in a bargaining with killed and injured in traffic as stakes.

If, for example, one of the above components is improved for traffic safety reasons, there will often be a demand for increased speed limits or a reduction in penalties for speed limit infringements.

Experience from changes in speed behaviour, generally in connection with speed limit changes, has shown that small differences in journey speeds exert a large effect on traffic accidents and traffic casualties.

The effect in the number of killed is significant in that a certain change in speed has a greater effect on the number of serious accidents than it does on minor accidents. One explanation is that accident situations on the average result in less serious accidents when speeds are reduced, the opposite being true when speeds increase.

Very few drivers who express their opinions on speeds and speed limits think that the limit is too high. Their opinion is that the speed limit is too low for the conditions in which they drive. In the debate, however, the concepts of speed and speed limit become confused, and consequently it is thought that if the speed limit is raised by 10 km/h, speeds also increae by 10 km/h. This is not the case, since the choice of speed depend on several other factors. The majority of drivers are much more sensible than the speed limit system.

ACCIDENT STATISTICS AND RISKS

In Sweden, about 500 motorists were killed i 1985.

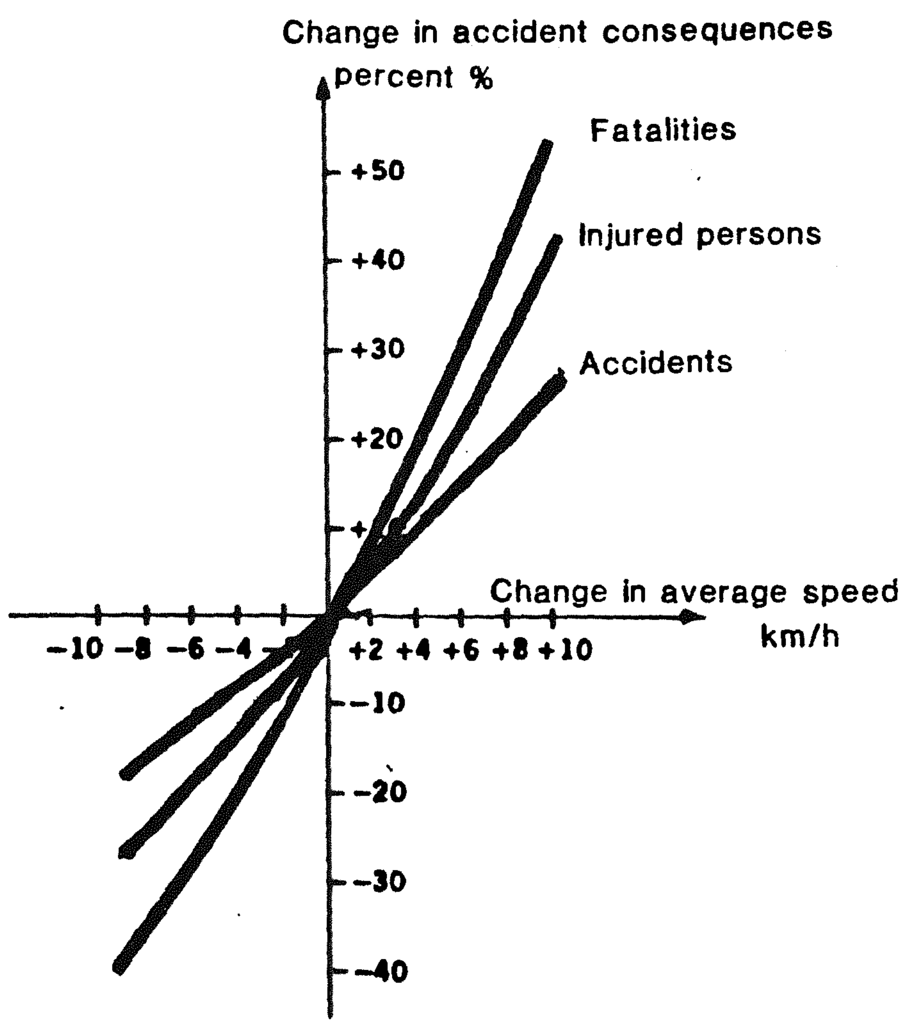
1/3 were killed in single vehicle accidents
1/3 were killed in head-on collisions
1/3 were killed at or near junctions or in other regulated traffic situations.

4 motorists out of every 10 killed motorists were passengers.
An average car driver in Sweden is involved in a personal injury asccident once in 167 years, i.e. every year, 1 out of 167 motorists is involved in a traffic accident with personal injuries.

Every year, one out of 6 700 car drivers is involved in a fatal accident where a motorist is killed.

Accident statistics are one of the few means available of publishing changes in risks.

CHANGES IN ACCIDENT CONSEQUENCES OF CHANGE IN AVERAGE SPEED



SPEEDS AND TRAFFIC SAFETY CALCULATIONS

Assume that a group of 1 000 000 car drivers increases speed by an average of 10 km/h, from 80 to 90 km/h, and that other drivers maintain their speeds. We can then expect the number of injured motorists to increase

from 3 900 to 4 940 = 3 900 $\cdot \left(\frac{90}{80}\right)^2$

i.e an increase of about 1 000 injured motorists or 27%.

Since this group of drivers appears in traffic together with others, the increase will affect other car drivers.

The number of motorists killed also in this group increases

from 120 to 190 = 120 $\cdot \left(\frac{90}{80}\right)^4$

an increase of 70 fatalities or 58%.

If we in the example consider all drivers in Sweden, the average speed will increase by 3 km/h. Repeating the calculation for all car drivers, the following increase is obtained:

13 000 to 13 993 = 13 000 $\left(\frac{83}{80}\right)^2$

i.e. an increase of about 1 000 injured motorists or 7%.

The number of motorists killed will increase

from 420 to 487 = 420 $\left(\frac{83}{80}\right)^4$

i.e. an increase of about 70 fatalities or 16%. The absolute result is approximately the same.

In Sweden, the official statistics record shows the following for 1983-1985.

	Mean 1983, 1984	Mean 1984, 1985
Number of injured motorists	13 075	14 020
Number of killed motorists	418	469

During the corresponding period, the averages speed of car traffic increased by 2-3 km/h.

Even if the above is a corrected example, the agreement with reality is not a coincidence. Similar calculations have given equivalent results.

SPEED LIMIT SYSTEM AND THE UPPER SPEED LIMIT

The most significant factor is perhaps not the speed limit system itself, but the gradual increase in speeds of road traffic. To a certain extent, this increase is the result of habitual fast driving.

The larger the number of motorways and dual carriageways with high speed limits, the more widespread is the habit of driving fast. High speeds on such roads influence speeds and behaviour on normal two-lane roads and streets with lower speed limits.

On the basis of the above, a restrictive upper speed limit appears essential.

The USA level of 88 km/h (55 mph) is one example. Speed measurements from the USA show that the median speed is almost the same as the speed limit, which means that half the drivers travel faster than the speed limit. At the same time, the speed dispersion is very small compared with European conditions.

National Safety Council

June 1, 1986

COMPLIANCE WITH THE NATIONAL 55 MPH SPEED LIMIT

Compliance with the national 55 mph speed limit has slackened somewhat since the law was adopted in 1974, but according to the Highway Users Federation the annual percent of drivers exceeding 55 mph remains far below pre-1974 levels, as indicated here:

YEAR	AVERAGE SPEED	PERCENT EXCEEDING 55 MPH
1970	59.2	66%
1972	60.3	68%
1974	55.3	50%
1976	55.6	54%
1978	56.3	56%
1980	55.2	50%
1981	54.9	49%
1982	55.3	53%
1983	55.7	54%
1984	55.9	56%

SPEED SURVEILLANCE

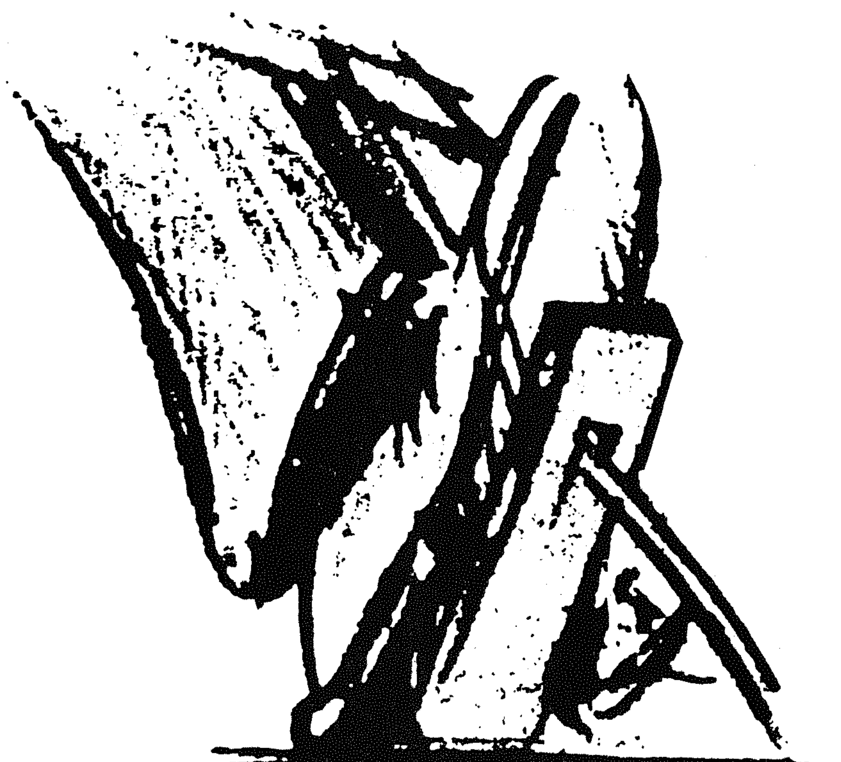
Another problem is the extent of speed surveillance. Wtih increasng traffic, the posibilities for police surveillance of traffic behaviour are reduced with present surveillance methods. This means a reduced probability of speed infringements being detected, which in turn leads to increased speeds.

The surveillance problem must be solved with automatic methods, progressive penalties and suspension of driving licences for serious infrignements.

The reponsibility for vehicle speeds must rest with the vehicle owner, regardless of who is driving the vehicle.

THE ACCELERATOR

In terms of speed potential alone, cars have developed considerably in recent years, although the speed regulator, the accelerator, remains the same. Today, it is far more difficult to regulate speed in relation to the speed limit. This is an opportunity for innovation. As cars become all the more comfortable, so the sensation of speed is reduced, according to many motorists. The background to this is partly an attempt by drivers to shed responsibility. The increasingly common cruise control units are one solution to this problem.



WHEN IS SPEED A PROBLEM?

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The general argument of Nilsson's paper arouses little criticism on my part. I should like to look in detail at three points to which it does not give sufficient consideration. Whether there is a big gap between his ideas on them and mine is not something I am able to judge from the paper: it may be that we are completely in agreement.

The three points are:

1. How are we to decide what is an optimum driving speed from the social point of view?
2. What speeds (of what vehicles, where and when) should be given priority in future research?
3. Is it always unsatisfactory if safety measures result in higher speeds?

1. The impression gained from reading Nilsson's paper is that, in his opinion, from the social point of view driving speeds ought to be lowered, always and everywhere. He is right solely from the road safety point of view. Taken to its logical conclusion, this argument would mean bringing all traffic to a standstill, since the only absolutely safe speed is 0 kmph. I presume that this is not what Nilsson is proposing. This conclusion raises the point that speed of travel is relevant not only to safety but also to the value of the journey: in many cases fast travel is regarded more highly than slow travel, and the cost is accordingly often higher.

It is relatively pointless, therefore, to make pronouncements on what, in certain circumstances, is a safe driving speed for road users; it is interesting, however, to indicate what is an optimum speed from the social point of view, after weighing up the various pros and cons, including safety. Ultimately this is a question of personal preference, and it is the politicians' preferences that determine policy and measures. Knowledge of the factual relationships is useful to the political weighing-up process; Figure 1 (from Salusjarvi, 1981) shows what information can be used here. As in Nillson, the accident costs are here regarded as a function of average speed; so as not to overcomplicate the discussion of Nilsson I shall assume that this is correct, although there are not insubstantial indications that the accident costs are also heavily influenced by <u>differences</u> in driving speeds.

Other external cost curves could be added to the figure, e.g. for noise and air pollution.

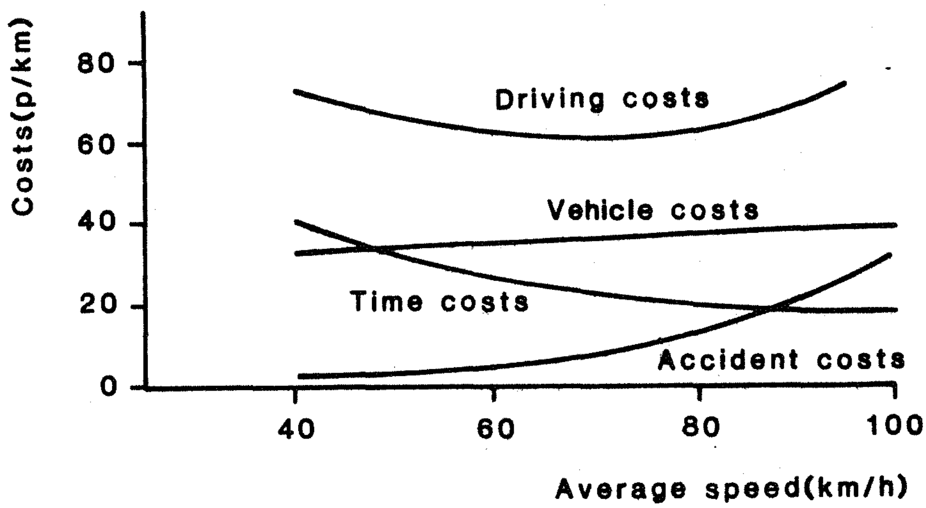

Figure 1. The dependency of time, vehicle and accident costs on the average speed on the trunk roads in Southern Finland.

It can be seen from the figure that on this type of road the optimum speed v_{opt} for cars is approximately 70 kmph (this is the speed at which the driving costs curve - the sum of the accident, time and vehicle costs curves - is at its lowest). If the actual speed v_{act} differs from v_{opt}, measures can be taken to bring the two closer together.

If the decision-maker, on the basis of political preference, weights the accident costs more heavily than the author of the graph has done, the driving costs curve changes, giving a lower value for v_{opt}. See Figure 2.

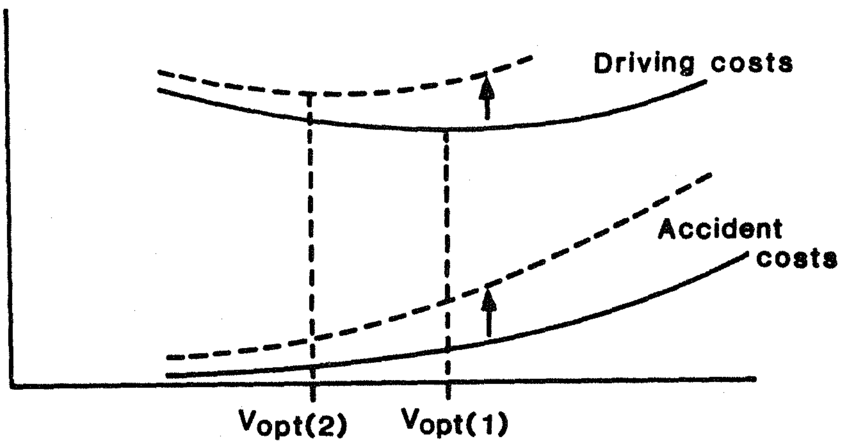

Figure 2. Heavier weighting of the accident costs changes $v_{opt(1)}$ into $v_{opt(2)}$.

It is my presupposition that the accident costs curve is different for different human/vehicle/road/environment combinations (and this presumably also applies to the time and vehicle costs curves). The accident costs curve is likely to be very different in the case of experienced drivers on a motorway in daylight during the off-peak period, for instance, than in that of inexperienced moped-riders on an urban main road in darkness during the evening rush hour.

A different v_{opt} could thus be determined for each different human/vehicle/road/environment combination, and we should not restrict ourselves to combinations which occur in practice: when designing new roads, for instance, it is important to know the v_{opt} for possible routes and longitudinal sections and cross-sections.

To determine v_{opt} we should need a graph, on the same lines as the one above for Finnish trunk roads, for each combination. Our knowledge of the relationship between speed and accident costs is scanty, however, it is up to road safety researchers to collect this information. Some types of information are more important than others. The obvious course would be to give priority to research into situations where the accident costs are expected to be highest as a result of discrepancies between actual speed and v_{opt}. This brings me to my second point: which situations are these?

2. Until now research has concentrated on cars on non-urban roads, as does Nilsson's paper. The question is whether this is the correct priority.

To establish the priorities for research I would suggest the following approach:

(i) Select human/vehicle/road/environment combinations characterized by large numbers of accidents involving injury and a high risk of injury due to accidents.

(ii) From these, select the combinations where the high accident risk could be explained by the relatively high speed of one of the crash partners.

This has not yet been done in the Netherlands. I have made some attempt to apply these steps using readily available data, and my provisional conclusion from this exercise is that three areas should be given priority in future research in the Netherlands:

(a) speeds of cars on non-urban roads other than motorways (i.e. the same area that Nilsson discusses in his paper);

(b) speeds of cars on urban roads, particularly traffic arteries and access roads (not residential streets);

(c) speeds of mopeds on urban roads, again other than residential streets: one of the considerations here is that speeds of mopeds in urban traffic approach those of cars, according to recent research.

3. Information on v_{opt} could be used in various ways when taking measures. When building new roads it is important to provide road users with information such that their actual driving speeds coincide with v_{opt} (on which the design of the road is based). In the first instance this is a matter of lines and other road markings, vertical elements along the road etc.; recommended speeds, limits and enforcement should be used only in the second instance.
Other measures are indicated where actual speeds are found to differ from v_{opt} on existing roads. Essentially, two approaches are conceivable.

First, attempts could be made to influence actual speeds without changing the accident costs curve, e.g. by changing the road design (e.g. with "sleeping policemen", narrow sections), driving instruction, limits, speed limiters in cars etc. See Figure 3.

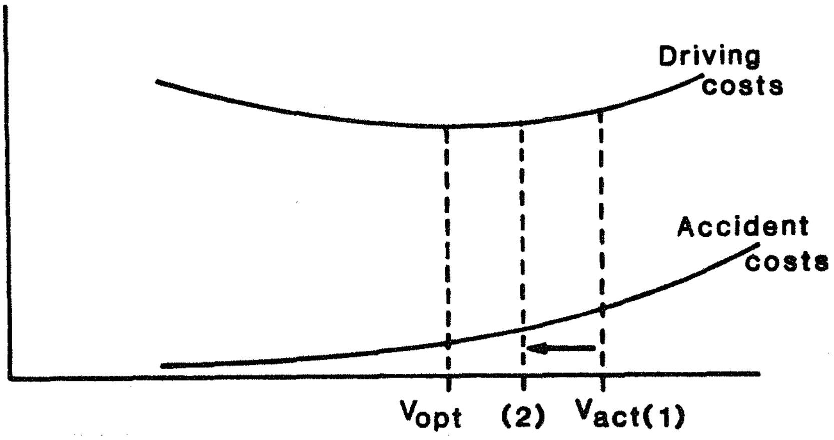

Figure 3. By changing $v_{act(1)}$ into $v_{act(2)}$ driving costs are reduced.

Second, attempts could be made to influence the accident costs curve, i.e. to reduce the risk of an accident given a certain speed, by intervening in the human/road/vehicle/environment factors: e.g. by reducing reaction times, installing grade-separated intersections (as on motorways), shortening braking distances. It is presumed that vehicle and time costs don't change. If these countermeasures are effective driving costs are reduced. In certain instances this can lead to a higher v_{opt} (see Figure 4). It is even conceivable that, as a result, actual speeds would have to be somewhat higher after the rise in v_{opt} to coincide with it. In this case it could not be said that the increase in driving speeds is undesirable from a social point of view. See Figure 4.

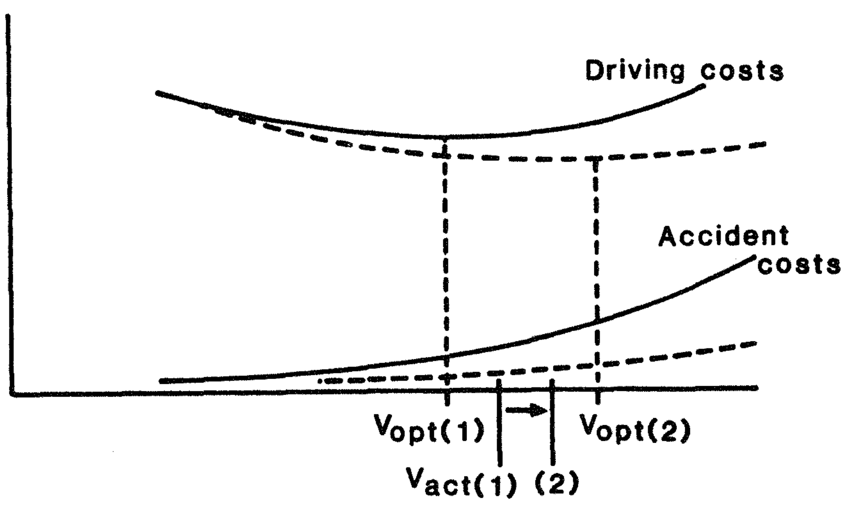

Figure 4. A change from $v_{opt(1)}$ to $v_{opt(2)}$ reduces the driving costs associated with $v_{act(1)}$; a change from $v_{act(1)}$ to $v_{act(2)}$ reduces the driving costs still further.

CONCLUSIONS

Conclusions we may draw from the above include the following.

1. Actual driving speeds cannot be regarded as a problem until a v_{opt} has been laid down by the authorities.

2. Research into the relationship between speed and accident risk should also concern itself with the speeds of both cars and mopeds on urban roads.

3. The v_{opt}'s calculated for parts of the road network that, formally, belong to the same category (e.g. "80 kmph roads" in the Netherlands) could differ considerably. In this case it would be difficult to defend a uniform speed limit for the entire category.

LITERATURE

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THE SAFETY IMPROVING EFFECTS OF CYCLE TRACKS IN URBAN AREAS

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Introduction.

This paper presents the results of eight Danish studies, all of them dealing with evaluation of the safety of cycle tracks in urban areas.

The studies concern different aspects of the implementation of cycle tracks. There is a great variety in the physical design and location of the cycle tracks, in the road user categories focused on in the eight studies, and in the research methods which have been used.

In diagram A the different types of cycle tracks included in the studies are shown. The numbers refer to the photoes shown as figures 1-14, and the names and numbers refer to the list of references. Each type of cycle track and its safety improving effects will be described briefly without going into very many details concerning the experimental design of the studies, and without presenting any tables. This is due to the demand for a short paper.

Cycle tracks have been devided into three main groups: Cycle tracks on road sections, cycle tracks in T-junctions without any traffic signals, and cycle tracks in signalized intersections. At last, safety problems with cycle tracks and bus stops are mentioned.

Road Sections.

Kerbed cycle tracks.

The implementation of cycle tracks with kerbs towards the carriageway and the sidewalk, figure 1, increases the traffic safety for pedal cyclists. Jørgensen and Rabani, 1969, Jørgensen and Herrstedt, 1979, Lauritzen, 1982, and the road Directorate, 1985, agree on that conclusion. The last study however, do not find any effects of the kerbed cycle track on the safety of pedal cyclists in towns other than Copenhagen.

No significant effects have been found regarding accidents involving mopeds. In this connection it is worth while mentioning that mopeds in Denmark in general have to ride on cycle tracks in urban areas if nothing else is indicated by signs.

1. Traditional cycle track with kerbs towards the carriageway and the sidewalk.	*Jørgensen and Rabani, 1969* *Jørgensen and Herrstedt, 1979* *Lauritzen, 1982* *Road Directorate, 1985*
2. Cycle lane separated from the carriageway by a white line of a width of 30 cm.	*Engel and Thomsen, 1983*
3. Non-signalized T-junction with no cycle track. The sidewalk is continued past the minor road.	*Jørgensen and Herrstedt, 1979* *Lauritzen, 1982* *(Jørgensen and Rabani, 1969)* *(Road Directorate, 1985)*
4. Non-signalized T-junction with cycle track.interrupted before the junction. The sidewalk is continued.	*Jørgensen and Herrstedt, 1979* *(Jørgensen and Rabani, 1969)* *(Road Directorate, 1985)*
5. Non-signalized T-junction with cycle track and sidewalk continued past the minor road.	*Jørgensen and Herrstedt, 1979* *(Jørgensen and Rabani, 1969)* *(Road Directorate, 1985)*
6. Non-signalized T-junction with a lateral dislocated cycle track, and the sidewalk continued.	*Engel and Thomsen, 1983*
7. Signalized intersection with cycle track interrupted just before the first pedestrian crossing.	*Jørgensen and Herrstedt, 1979* *Technical Directorate Cop. 83* *(Road Directorate, 1985)*
8. Signalized intersection with cycle track interrupted 30-40 m. before the pedestrian crossing.	*Jørgensen and Herrstedt, 1979* *Technical Directorate Cop. 83* *(Road Directorate, 1985)*
9. Signalized intersection with cycle track as 7. combined with a cycle lane past the intersection.	*Technical Directorate Cop. 83* *(Road Directorate, 1985)*
10. Signalized intersection with cycle track as 8. combined with a cycle lane past the intersection.	*Technical Directorate Cop. 83* *(Road Directorate, 1985)*
11. Signalized intersection with cycle track as 7. combined with a blue lane past the intersection.	*Technical Directorate Cop. 83*
12. Bus stop with give way markings across the cycle track.	*Engel and Thomsen, 1985a.*
13.+14. Bus stop with rumble lines across the cycle track.	*Engel and Thomsen, 1985b.*

Diagram A. The different types of cycle tracks included in the eight Danish studies from 1969 to 1985.
() These studies do not differ between lay out of the cycle tracks.

The study from the Road Directorate finds an increase in accidents between pedal cyclists, moped riders and pedestrians after the implementation of kerbed cycle tracks on road sections.

The two studies from 1969 and 1979 were carried out as comparisons between existing road sections with and without kerbed cycle tracks, while the newest studies from 1982 and 1985 were before and after studies.

Road Sections.
Cycle lanes.

In only one study, Engel and Thomsen, 1983, cycle lanes have been investigated, figure 2. The actual road section was very short however, and even though the before and after periods were of a lenght of three years each, the accident and injury figures were to sparse to produce valid results.

Non-signalized T-junctions.
Type a: No cycle tracks but a sidewalk, which is continued past the minor road.
Type b: Kerbed cycle tracks discontinued past the minor road combined with a sidewalk, which is continued past the minor road.
Type c: Kerbed cycle tracks continued past the minor road together with the sidewalk.

Jørgensen and Herrstedt, 1979, have compared the safety of three types of design of non-signalized T-junctions, one with no cycle track, type a (figure 3), and two with cycle tracks, type b and c (figure 4 and figure 5). Please notice, that figure 4 has a fault. The sidewalk ought to be continued past the minor road, which it is not on this photo.

For pedal cyclists the same accident rates were found in the three types of junctions.

For moped riders it was different. A significant higher accident rate for moped riders was found, where the cycle track was continued past the minor road compared to type a and b.

In this study the effects on accident rates with other road users have not been investigated.

The recommendation was not to continue cycle tracks past non-signalized T-junctions if the aim was to increase safety for both pedal cyclists and moped riders. The study referred was carried out as a comparison between accident rates in existing junctions of different designs.

The study from the Road Directorate, 1985, finds increasing numbers of accidents between moped riders and other light road users in non-signalized T-junctions after the implementation of cycle tracks. The design of the cycle tracks in the junctions was however not specified. The study was carried out as a before and after study.

Non-signalized T-junctions.
A lateral dislocated kerbed cycle track on the major road continued together with the sidewalk past the minor road.

Engel and Thomsen, 1983, made a before and after study on the implementation of lateral dislocated cycle tracks in non-signalized T-junctions, figure 6. Eight junctions were reconstructed. For pedal cyclists there was found an increase in the accident rates after the reconstruction; for moped riders there was found a decrease in the accident rates. The number of accidents were however very sparce, and the traffic data, especially for mopeds, were calculated with considerable incertainty.

Signalized Intersections.
Type a: Kerbed cycle tracks continued as far as the first pedestrian crossing.
Type b: Kerbed cycle tracks discontinued 30-40 meter from the first pedestrian crossing.

Jørgensen and Herrstedt, 1979, have compared the safety of cycle tracks continued to the first pedestrian crossing to the safety of cycle tracks discontinued 30-40 meter before the first pedestrian crossing, figure 7 and figure 8. In the last type of intersection the two-wheelers have to share the area before the intersection with right turning motor vehicles, cf the photo.

For pedal cyclists the same accident rates in the two types of intersections were found.

For moped riders intersections of type b were found to be much safer compared to intersections of type a.

The same results for pedal cyclists were found in a study from the Technical Directorate of Copenhagen, 1983.

The recommendation in the Jørgensen and Herrstedt report was to discontinue the cycle tracks in signalized intersections if the aim was to increase safety for both pedal cyclists and moped riders.

Both studies were carried out as comparisons between accident rates on existing intersections of different designs.

Signalized Intersections.
Type a: Kerbed cycle tracks continued to the first pedestrian crossing and carried on past the intersection as a cycle lane.
Type b: Kerbed cycle tracks discontinued 30-40 meter from the first pedestrian crossing and carried on to the pedestrian crossing and past the intersection as a cycle lane.
Type c: Kerbed cycle tracks continued to the first pedestrian crossing and carried on past the intersection as a BLUE lane.

Only the study made by the Technical Directorate of Copenhagen has been dealing with these three types of intersections, figure 9, figure 10 and figure 11. The three types of intersections were compared to intersections without any cycle lanes carried on past the intersections.

For pedal cyclists no differences in accident rates between the four types of intersections were found. This study did not include accidents with moped riders or other road users.

The study from the Road Directorate, 1985, finds increasing numbers of pedal cyclist-car accidents and car-car accidents in signalized intersections after the implementation of cycle tracks. The design of the cycle tracks in the intersections was however not specified. As already mentioned, the study was a before and after study.

Bus Stops.
Kerbed cycle tracks with different road markings.

In the municipality of Copenhagen and Frederiksberg an increasing number of accidents between pedal cyclists and pedestrians has been experienced at bus stops after the implementation of kerbed cycle tracks. The problem is, that bus passengers have to cross the cycle track when they walk to and from the busses.

Experiments have been made trying to reduce the speed of the pedal cyclists in the area just before and past the bus stop by the means of two different types of markings on the cycle tracks: Give way markings, figure 12, and rumble lines, figure 13 and figure 14.

Engel and Thomsen, 1985a. and 1985b., found no effect at all on the speed of the implementation of give way markings (so called "shark teeth"), while there was a reduction of 10 per cent in the speed of pedal cyclists after the implementation of rumble lines.

These experiments have only been carried out in two streets, and a before and after study on accidents are not yet available.

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Figures:

Figure 1. A traditional cycle track with kerbs towards the carriageway as well as the sidewalk.

Figure 2. A cycle lane separated from the carriageway by a white line of a width of 30 cm. The lane is also equiped with cycle symbols painted on the asphalt, cfr. the photo.

Figure 3. A non signalized T-junction without cycle tracks. Where the minor road meets the major road a slight hump with a different surface has been implemented.

Figure 4. A non signalized T-junction with a kerbed cycle track on the major road, but interrupted when meeting the minor road.

Figure 5. A non signalized T-junction with a kerbed cycle track continued past the junction parallel with a slight hump at the sidewalk. The hump has a surface different to that of the sidewalk and that of the carriageway and cycle track.

Figure 6. A non signalized T-junction with a lateral dislocated kerbed cycle track on the major road continued past the minor road.

Figure 7. A signalized intersection with a cycle track continued to the pedestrian crossing.

Figure 8. A signalized intersection with a cycle track discontinued 30-40 m. from the pedestrian crossing. From the end of the cycle track to the pedestrian crossing, the cyclists have to share the area with right turning motor vehicles.

Figure 9. A signalized intersection with a kerbed cycle track carried on to the pedestrian crossing (figure 7) and continued through the intersection as a lane marked with symbols and a white line close to the carriageway.

Figure 10. A signalized intersection with a kerbed cycle track discontinued 30-40 m. from the pedestrian crossing (figure 8), but continued as a lane marked with symbols and a white line close to the carriageway.

Figure 11. A signalized intersection with a kerbed cycle track continued to the pedestrian crossing and extented through the intersection as a blue lane.

Figure 12. A bus stop with give way markings across the cycle track.

Figure 13. A bus stop with rumble lines across the cycle track.

Figure 14. A close up of rumble lines across the cycle track.

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SAFETY EFFECTS OF INFRASTRUCTURAL PROVISIONS FOR CYCLISTS AND MOPED-RIDERS

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This contribution is written in response to a paper presented to the workshop by Ulla Engel: "The safety-improving effects of cycle tracks in urban areas", an outline of the results of some Danish studies. The results of each study are given separately; the general remarks and conclusions have no doubt been reserved for presentation during the workshop. It is only to be expected that cycle tracks were found to have favourable safety effects as far as cyclists are concerned, but there are doubts about the effects on the moped-riders: these may even be unfavourable.
I come to this conclusion after having read the paper but also because we in the Netherlands have had similar experiences to those of Ulla Engel and her colleagues in Denmark.

What, however, is the value of these results and conclusions? I have my doubts about this, and I hope that we shall discuss them - not with the aim of blaming somebody: if there are people to be blamed, I am certainly one of them.

What have we been doing until now, both in Denmark and in the Netherlands? We have been studying the safety effects of infrastructural provisions, namely cycle tracks and cycle lanes: on sections of road, at T-junctions and at intersections; at intersections with and without signalling; separately for cyclists and moped-riders, and in some cases for the two categories together. In the same way we have been looking at the safety effects of signalling and of priority rules.
We have done this either by comparing different types of locations or using "before" and "after" studies. Most of the studies were based on statistical analysis of numbers of accidents and of certain accident characteristics. In a lot of cases the number of accidents available was small, sometimes too small to enable conclusions to be drawn without jumping ahead or using a creative way of arguing.

Have all these efforts resulted in tools for the road administrators? Are we able to give clear and reliable advice when a police officer or a traffic engineer consults us by letter or by telephone? I believe we seldom succeed in doing this.

Are we able to trace the general effects of the provisions on road safety? On one occasion I found that the construction of cycle tracks in rural areas influenced the severity of accidents with cyclists on the roads concerned (both sections and intersections) during the 1978-1982 period in such a way as to account for an important part of the overall decrease of the lethality of this type of accident in rural areas during the period. Another important contributory factor to this was the construction of motorways during the same period. So the separation of bicycles from cars appeared to have a beneficial effect on the safety of cyclists in rural areas. I did not find an effect of this kind in urban areas; I did not look at other categories of road users at all. The general effect I found was the result not of a local study comparing types of locations or a "before" and "after" study, but of a simple analysis of accident statistics for the whole country. This, unfortunately, does not enable us to trace the general effects of the dramatic increase in the number of locations with signalling during recent years, or of various priority rules. The reason this is not possible is that the relevant accident characteristics are not recorded or not consistently.

Could local comparisons and "before" and "after" studies be a solution for this problem? In my opinion these studies can be building bricks, but we need more to construct a safe building. The method which we have been using in most cases until now is mainly solution-oriented. In addition we need another method, one that is not just directed at one means of transport, one group of road-users, one type of location etc. We need to look not only at road safety but at other aspects of the traffic system too. Here I am thinking in particular of the purpose of that system: mobility.

At the moment we at SWOV are applying a method of this kind. We have selected six groups of road users: elderly pedestrians and cyclists, and inexperienced pedestrians, cyclists, moped-riders and car drivers. We are analysing the problems of each group in as much detail as is practicable. The analysis is based on the idea that road safety can be improved most economically by an integrated approach, aimed at the optimum alignment of the elements of the traffic system (humans - vehicles - infrastructure) to one another and of that system to the social environment within which it has to function. We try to obtain information about why, when, where, under what circumstances and how each group participates in traffic and what kind of problems the members of the group meet. We are not just investigating the problems of the group but also those of the other participants in the accidents in which the members of the group are involved. So summarize, the method used can be described as an integrated, problem-oriented approach.

We have confidence in this method, and the first results are promising. In our opinion we have found a useful approach to investigate road safety in a more or less fundamental way. In the meantime, however, we are expected to improve road safety. We cannot just study, we also have to ensure that others are able to do something to reduce the number of accidents and to make casualties less severe.

Road administrators still want to know whether they should construct a cycle track along a certain road, and it is our duty to help them by giving answers to their questions. From time to time I confronted with a question like this, and sometimes I succeed in applying the approach during the conversation or telephone call. Then we talk about the problems which the construction of a cycle track or cycle lane is supposed to solve. We talk about the users, the pedestrians and the car drivers. We do not talk just about the section concerned but also about the T-junctions and intersections on the route concerned. Not only about accidents and victims, but also about feelings of comfort and safety and about the traffic behaviour of the different categories of road user, and about their motives for travelling and their alternatives as to mode of transport, route etc. We also discuss other possible solutions, such as measures to reduce the speed of cars, modification of the signalling at an intersection, the creation of alternative routes for cyclists or cars, etc. After a consultation like this I often have the impression that my discussion partner is largely satisfied. He (or she) has not been given a concrete solution but has been helped to make a diagnosis in such a way that he can choose a solution on better grounds, whether the original one or another solution. At the same time I am strengthened in my opinion that the method applied - an integrated problem-oriented approach - is a useful one, not only for researchers, but for administrators as well.

Does all this mean that I reject the results of research projects as presented by Ulla Engel and those which I have found and have been working for myself? No, but I do not believe that it is wise to present them in such a brief way, without general remarks and without discussion. In my opinion we must do more with the data gathered for these quantitative analyses: a qualitative analysis of the data is necessary to obtain a better understanding of the problems to which we and the policy-makers want a solution. Soon we shall come to the conclusion that we need more information, for example about other accidents, but also about the behaviour, opinions and feelings of road users. If we want to choose the right solutions we not only need to know the problems, we also have to devise and test theories about the backgrounds to the problems. For example, if we want to know whether mopeds should ride on cycle tracks or on the main road we cannot just compare numbers of accidents. At least we should know the types of accidents moped-riders are involved in, the manoeuvres made by them and their collision partners, and how these relate to the different types of location. We also need information about the circumstances at the time of the accident: daylight or darkness, wet or dry road surface, alcohol consumption. We have to know the consequences for other road users: in this case especially cyclists and pedestrians. When we know all this we can decide to study the behaviour of moped-riders at some selected situations where they apparently have special problems, and we can put questions to a sample of them. When we have studied all the information gathered we may be able to give an answer to the main question, or at least we shall have a better basis for choosing a solution.

I do not have the idea that the things that I am suggesting are new or original. Each of us works in this way from time to time. But it is good to realize this again and again, and to ensure that we can continue to do our job in this way. It is useful, therefore, for road safety researchers to tell one another things like this, and to discuss them so that we can try to do our job to the best of our ability.

ROAD ACCIDENTS IN THE IRISH REPUBLIC; PROBLEMS FOR ACCIDENT PREVENTION WHEN NUMBERS ARE SMALL

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1. INTRODUCTION

This talk illustrates the technical and practical problems of attempting to reduce accident numbers in a country where population is in general dispersed, and where the number of kilometres of public roads per head of population is one of the highest in Europe. The set-up of the problem, and the theoretical considerations, one part of the effort, has been complemented by the work of one of my colleagues. I would hope that the constraints under which the work is undertaken, the small resources at our disposal, the use of what are at this stage standard methods, the effort to follow them through into practice would be of some, if limited, interest to the group here today, which I have been privileged to ask to join for the day.

2. BACKGROUND

The population of the Irish Republic dropped from 2.96 million in the immediate post-war years to 2.82 in 1961, before increasing to an estimated 3.53 million in 1985. The number of taxed vehicles increased from 75,000 in 1946 to 914,000 in 1985.

The number of persons killed on Irish roads increased from 160 in 1946 to a peak of 640 in 1972, with a secondary peak of 628 in 1978. Since then, reported road deaths have declined steadily, to 465 in 1984, and to 410 in 1985. It is likely the figures for 1986 will be around 350, or just 1.0 per 10,000 population.

On the other hand, the ratio of persons reported injured to persons reported killed on Irish roads is one of the lowest in Europe (Table 1). (The figures given in that table are for 1983 - the Irish ratio has improved somewhat since). The net effect of all this, however, is that, in total,

	Killed	Injured
Average for EEC	1	34
Belgium	1	38
Denmark	1	20
Federal Republic of Germany	1	42
Greece	1	18
France	1	25
Italy	1	29
Luxembourg	1	25
Netherlands	1	30
United Kingdom	1	55
Ireland	1	15

TABLE 1: Ratio of persons reported killed to those reported injured: EEC countries

it is 5,500 reported accidents that are made available for analysis every year, on a road network of 92,000 kilometres, or one accident for every 17 kilometres of road per year. That, of course, is overstating the problem - there is a concentration of accidents on certain parts of the network. In particular, in each year, one third of fatal accidents and one half of injury accidents occur in built-up areas, which account for only four per cent of the Irish road network; a further one fourth of fatal, and one fifth of injury accidents occur on rural National Routes, which in turn represent only one-sixth of the road network. It is the work that we have been carrying out over the last number of years on this restricted part of the Irish Road Network that I would like to illustrate in this talk.

3. THE RURAL NATIONAL ROUTES

(a) Mathematical Model Used

Traffic accidents are complicated events, each involving a combination of human, vehicular and environmental factors. On the other hand, the mathematical model used to describe and order the phenomenon are structurally elementary. The initial hypothesis is that each road section can be characterised by a risk parameter, r, such that the occurrence of accidents on a section of road in unit time depends on this parameter.

In particular, in unit time the probability of a section having k accidents is

$$P(k) = \frac{e^{-r} r^k}{k!} , k = 0, 1, 2 \ldots\ldots.$$

Now, it can be argued that the characterising risk parameter for each section depends on a large number of variables. In road directed road safety work, it is generally assumed that human and vehicular variables are not relevant.

Therefore, attention is directed towards differences in accident risk between sections that arise because of the physical characteristics of the sections: certain geometric characteristics increase accident risk, others lower the risk.

As a first approximation the number of accidents occurring on the section is taken to be a Poisson distributed random variable, with characterising parameter r_i, where i identifies the section in question and where r is a linear function of the vehicle miles travelled on the section: the product of the section length by the traffic flow.

If r can be estimated for each section, it is then possible to compare the actually occurring numbers of accidents with the expected to see if they are in reasonable agreement. Since the expected number is derived directly from vehicle miles of travel figures, if the acually recorded accidents are very much higher than the expected number, this implies that the section has very many more accidents than other sections with similar vehicle miles of travel.

There may be many reasons for this, but having identified a small number of such sections, detailed examination of the accident patterns may highlight aspects of design or of geometry which may be causing problems for drivers.

For a simplified model such as the one used here to be useful, it depends heavily on the reliability and uniformity of traffic accident reporting, on the accuracy of the inventory of the national routes, and the completeness of Annual Average Daily Traffic figures.

The success of the model also depends on the extent to which a linear function of vehicle miles travelled on the section is an adequate approximation in quantifying the effect of section length and traffic flow on traffic accident occurrence, assumed to be a Poisson variable.

The usefulness of the model cannot be determined in advance. It provides, however, a uniform way of looking at the most important three thousand miles of rural road in the country with a view to using historical accident data to identify deficient parts of the network. It, therefore, provides an overall frame for systematic accident prevention activity on the roads that in the recent years considered have claimed 1165 lives.

There is a technical point that could be made.

It arises from the use of the standard correlation coefficient in Accident Studies with small numbers and Poisson assumptions.

If it is accepted that the most useful model for accident occurrence in unit time at a site is one based on the Poisson probability distribution, where the underlying accident risk is characterised by a parameter .

Then, it is not sensible to claim that the exact value of the number of accidents can be predicted, but only the value of the underlying risk parameter, since by the definition the scatter of values around this is random, i.e. not to be explained.

The square of the Pearson correlation coefficient can also be written

$$R^2 = 1 - \frac{\text{residual variation}}{\text{total variation}}$$

As a simple illustration, suppose it is attempted to predict the number of accidents at three intersections with underlying risk parameters, a_1, a_2 and a_3. A perfect model will predict the values of a_1, a_2 and a_3 exactly.[2]

Table 2 gives the values of R^2 for four different sets of underlying risk values, where these are predicted exactly.

	Case 1	Case 2	Case 3	Case 4
	a_1 a_2 a_3	a_1 a_2 a_3	a_1 a_2 a_3	a_1 a_2 a_3
Actual values	4 5 6	3 5 7	2 5 8	1 5 9
Total Variation	17	23	33	47
Predicted Values	4 5 6	3 5 7	2 5 8	1 5 9
Residual Variance	15	15	15	15
R^2	0.12	0.35	0.55	0.68
R	0.35	0.59	0.74	0.82

TABLE 2: Values of R^2 for different risk values, assuming a Poisson Distribution and a perfect model

This has implications for road safety work, since in some circumstances this implies that observed correlations of the order of 0.40 are to be expected, even with perfect models, where more usually under assumptions of normality a value of 1.0 would be expected.

(b) Numerical Results

There were 2879 miles of rural national routes considered. On them, in the six year period 1977-1982 1165 persons were killed and a further 12,217 persons reported injured, mainly seriously in 7022 reported fatal or personal injury accidents. The average AADT figure for the period was some 2,650 vehicles per day, although obviously this varies considerably between the busy and the quieter routes.

There were 2,408 subsections with AADT values constant along each and of homogeneous geometric design.

With each subsection is associated its length and its AADT value, as well as the number of fatal and of injury accidents which are reported as occurring in the six year period.

In accord with the simple mathematical model used, it is postulated that the expected number of accidents on subsection i, is a linear function of vehicle miles of travel on the section, so that if Y_i is a random variable - the number of accidents occurring on the section in unit time - and X_i is the vehicle miles of travel on the section, then

$$E(Y_i) = BX_i$$

where B is a parameter to be estimated from the available data, and $E(Y_i)$ is the expected number of accidents on the section.

Maximum likelihood estimates of B were derived using a standard computer program for Poisson regression analysis. The value of B for all accidents was estimated to be 2.262 and for fatal accidents to be 0.328.

The reduction in the sum of squares, using these estimates was of the order of 40% for fatal and injury accidents combined and of 30% for fatal accidents only, implying correlation coefficients between accident numbers and vehicle miles of travel of the order of 0.65 and 0.55 respectively.

While there are difficulties about interpreting correlation coefficients where Poisson distributed random variables are in question, as pointed out above, it is clear that traffic flow figures improve considerably the possiblity of estimating the number of accidents due on a section.

It is now assumed that the remaining variability as measured by the sum of squares is made up of:-

(i) variability due to the geometric or environmental characteristics of the section,

(ii) a residual random variability which arises because of the chance nature of accident occurrence.

While some of the variability in accident numbers - accident occurrence higher than average or lower - can be assigned to factors such as excessive roadside development, it is that site or section specific characterisitcs can be identified, which if modified, would reduce the characterising parameter on the section to average.

The rule was adopted, in accord with standard statistical practice, that this hypothesis - of risk on the section equal to section with similar vehicle miles of travel - would be rejected, if the number of recorded accidents would have arisen less than one in twenty times, were the hypothesis valid. In the case where the recorded accidents were greater than expected, the section was labelled a high-risk one.

Using the techniques described above, 186 of the 2408 sections were identified as high risk sub-sections, sub-sections in total 215.3 miles in length - 7.5% of the total network - on which 230 fatal and 1118 injury accidents occurred - 19.2% of all accidents. The average length of these sub-sections was 1.158 miles, some three per cent lower than the overall average.

The next, and crucial step was to examine accident, traffic, geometric and environmental aspects of these 'high-risk' sections with a view to identifying site-specific characteristics which if modified would reduce traffic accidents.

One hundred sections on the rural National Primary Routes have been designated as "out of control" on the basis of accident occurrence during the period 1977 to 1984 inclusive. Forty-two of these have been studied in detail and a record sheet submitted to the Department of the Environment with detailed proposals for countermeasures. Only in 5 of the 42 studied was no road defect noted.

The record sheet contains a summary of the accident data, a detailed description of the physical charactertistics of the section, an assessment of the relationship between the accidents and the physical characteristics, and proposals for low cost countermeasures.

Section length varied from 0.10 miles to 6.00 miles. The numbers of accidents on sections varied from 2 injury accidents to 46 injury accidents. The average number of injury accidents on a section was 10.

The physical characteristics found to be associated with accidents were as follows:

Poor design of main road in vicinity of junction leading to cars wishing to turn out of main road being struck	7 instances
Poor design of transition section between rural section and urban section on the outskirts of towns	6 instances
Poor design of junction - accidents involving cars entering main road	5 instances
Geometrics of section generally sub-standard	4 instances
Geometric defects leading to loss of control	3 instances
Poor definition in darkness	3 instances
Poor definition in daylight	4 instances
Deceptive appearance on new section	3 instances
Setting-out defect on new section	2 instances
No road defect discovered	5 instances

4. SMALL TOWN STUDIES

A simple ranking system was derived for the towns on the National Routes taking into account the population of the towns and the vehicle miles on the National Routes. The ranking should reflect accident risk: towns high in the rankings having many more accidents than expected in the period.

In outline, the method used consisted in deriving an 'expected' number of accidents in each of the towns using multiple regression techniques, with population size, and travel on the National Routes as the independent variables. The towns were then ranked in accordance with the size of the difference between the actually occurring accidents and the 'expected' or predicted number. The expected number was derived from the multiple regression equation.

At present, studies of five such towns have been completed, ranging in population size from 25,000 to 3,500 persons.

In summary the kind of road factors encountered have been found to vary widely:

(i) In small towns, the main factor identified is the parking practice on the main through routes. In larger towns, a second common factor is defective housing estate design, which allows speeds in excess of 20-25 miles per hour through the estates.

(ii) On approches to towns, the present design practice is unsatisfactory. Design standards need to be developed for the transitional area between rural sections and town streets. A further design problem is the transition between the newly designed motorway standard roads, and the old road network - an example is the roundabout system at Swords, which ignores the existence of pedal-cyclists or indeed motor-cyclists completely.

(iii) On rural sections, design defects and construction defects crop up with equal frequency. In many instances the design defects are matters of fine detail and often relate to the misreading of the road by drivers, especially at night. Surface irregularity and adverse camber from poor setting out are frequently implicated, as are poor maintenance procedures, resulting in potholed hard shoulders on town outskirts, which in turn can lead to pedestrian accidents.

SMALL IS BEAUTIFUL, BUT IT MAKES OUR WORK MORE DIFFICULT

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In addition to the problems that one encounters in normal statistical work, in the field of traffic safety research one has to cope with some problems that have in common that they disappear when the numbers of accidents grow large enough. But happily enough, the numbers of accidents, at least in the Netherlands, don't grow at all. Actually, they have been declining steadily during the last 15 years. So we now have the situation that because of the success of many years of safety policy the numbers one encounters in traffic safety research are so small as to necessitate the development and use of statistical methods that take into account the underlying discrete distribution of accidents. Here we find our first topic for discussion: the Poisson Assumption.

1. The Poisson Assumption

One can without doubt say that the Poisson Assumption lies at the core of traffic safety research. From the theoretical point of view it forms the foundation of the probabilistic treatment of accident statistics.
Without it much work such as before and after studies would be impossible. On the one hand it is considered to be firmly founded on a few simple, plausible assumptions, but on the other hand there exists to my knowledge no experimental confirmation of the Poisson Assumption. Furthermore, from time to time one finds in the literature statements that a distribution of accident numbers is found which is not in accordance with the Poisson distribution. This is an interesting situation: we have a cornerstone of (traffic) safety research: the Poisson Assumption, which appears to be without a firm foundation.
We can first ask ourselves if the assumption can be confirmed empirically at all. This appears to be not the case, for in practice we can never realise the known and constant conditions under which we can repeat observations long

enough to compare an empirial distribution of accident counts with the theoretical Poisson distribution.

On the other hand, the theoretical deduction is very plausible, if we choose the definition of accident in such a way that accidents are independent, so that an accident which is caused by another accident is not counted as a seperate accident, but the two (or more) together as one, complicated, accident.

If we find in practice accident data which have a dispersion which is greater than the Poisson norm we don't have to interpret this as evidence of the non-validity of the Poisson Assumption, but as a manifestation of a mixture of different Poisson parameters. Here we can use the analogy of a tiled side walk when it is raining in a constant way.

After each period of, say, 10 seconds of rainfall, each tile is hit by a number of raindrops. We have to distinguish two derived distributions of numbers of raindrops on tiles. One is the distribution of the numbers of raindrops on a particular tile, if we count them each period of 10 seconds. This distribution is Poisson if the rainfall remains constant over time and the raindrops fall independent of each other. The other distribution consists of the numbers of raindrops on <u>all</u> the tiles counted after <u>one</u> period of 10 seconds. This is only a Poisson distribution if the tiles are all of equal size, given that the rainfall is uniform over space. If on the other hand, the tiles are of different sizes the distribution is not Poisson at all!

If we read e.g. for tiles road crossings and for raindrops accidents it is clear that in the real world the crossings are not equal (and the "rainfall" not uniform over space) so it is not surprising that we find variances greater than the means for the distribution of accident numbers of crossings. But this does not imply that the number of accidents on one crossing (or the sum of accidents on several or a class of crossings) should not be regarded as one realisation of a Poisson process or, in other words, as a sample of size one from a Poisson distribution. And this is all we need to compare the number of accidents in two consecutive years, or before and after some safety measure: we can test the statistical significance of the size of the difference under the null hypotheses that both numbers are independent samples from a single Poisson distribution with unknown parameter. Because under the null hypotheses there is an estimator for λ (the mean of the two numbers) which gives us an estimate for the mean of the distribution as well as of the variance we can test the size of the difference of the two numbers against the standard deviation. If the numbers are large enough (≥ 10) we can derive, using the normal approximation N (λ, λ) to the Poisson distribution, that the statistic

$$\frac{n_1 - n_2}{\sqrt{n_1 + n_2}}$$

is asymptotically normally distributed with $\mu = 0$ and $\sigma = 1$.

2. The Regression-to-the-Mean effect

A second interesting problem that often crops up when numbers are small and people still want to do something about safety is the Regression-to-the-Mean effect (RM). It seems that this effect, which is well known in statistical circles, influences the results of unknowing safety researchers. My thesis is that RM should not play a large role in traffic safety research. Its effects are noticable when one uses the simple scheme of selecting sites for treatment that have a (much) larger number of accidents than average (black spots). (The crusade of E. Hauer against this practice seems to be an overreaction).
As an example of the simplistic attitude to black spots let us consider the influence of, say, totem poles on the traffic safety on crossings. In order to prove they are very effective in reducing accidents, we need to obtain a list of all crossings in the Netherlands ordered by the number of accidents that happened there in the last few years. We then select the top twenty and erect totem poles. Lo and behold, afterwards an enormous reduction in accidents will occur. Hauer* gives the formulas to calculate the size of the effect.) So, we could conclude that totem poles are very effective as a safety measure. However, we could just as easily prove the opposite: we could select all crossings where no accidents took place and put totem poles there. Now most certainly many accidents will happen on the selected sites, so totem poles are harmful.

* E. Hauer. On the estimation of the expected number of accidents. Accid. Anal. & Prev. Vol. 18, No. 1, pp. 1-12, 1986.

ROAD SAFETY EDUCATION AS ACCIDENT COUNTERMEASURE

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Introduction

About 25 years ago the first experiments were carried out which investigated the possibilities of children in dealing with the traffic environment and the possibilities of teaching them to do so. These experiments were on a very small scale, most of them carried out in the laboratory, and did not receive much attention until 12 years later, when the results were published in English in a book which is by now a road safety education classic, entitled "Children in Traffic" (Sandels, 1975). Since then many studies have been carried out to develop and evaluate road safety programs for children and young adults. The recent OECD report "effectiveness of road safety education programs" (1986) lists close to a hundred studies, and it must be clear that it will not be possible to review these studies in any detail. Instead, a few topics are discussed that seem critical to the development of road safety education that indeed does what it stands for, which is to contribute to the traffic safety of the target groups involved. Several models or conceptual frameworks have been developed (e.g. OECD, 1978; Bongard and Winterfeld, 1977) to describe the components of traffic education, but for the development of educational programs it seems more appropriate to use a model describing the process of road safety education. The instructional process as such consists of three components a) defining and structuring the content of instruction, b) presentation of the content to the learner and c) evaluating the outcome of instruction. The components of the instructional process can be represented as follows.

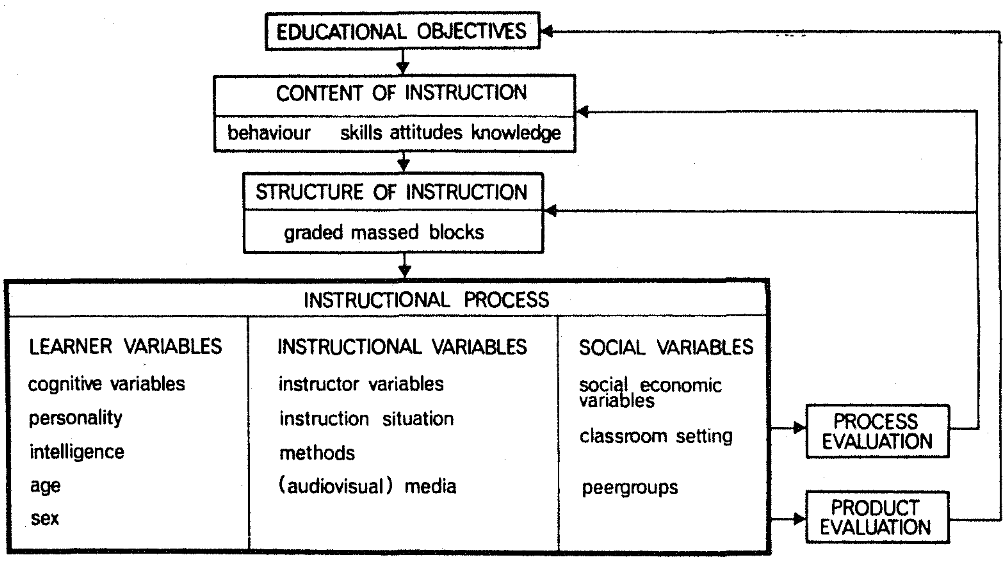

figure 1 . Components influencing effectiveness of road safety education

Formulating educational objectives

Formulating valid educational objectives for road safety education is of crucial importance to the possible effects in terms of accident reductions. The strategy that should be followed in doing this, is a matter of prolonged dispute. Grayson (1981) for example has argued that it is impossible to arrive at safety relevant objectives on the basis of empirical evidence alone, and indeed at times the empirical evidence on which educational objectives can be based is rather shallow or downright contradictory. The strategy that ideally would have to be followed is: a) describe theoretically the normative behavior required; b) describe the actual observed behavior and c) collect for each of these behaviors relevant exposure and accident data. If all these steps are taken then those behaviors, that are observed to be deviating from the normative behavior and are found to be a causal factor in a relatively high proportion of the accidents involving the target group, can be selected as be critical to these road users. However, this is only a first stage, usually termed "problem analysis". A second point that must be considered is the developmental level of the target group of children or youngsters involved. It is obvious that it does not make sense to formulate an educational objective that requires the pupil to learn to take account of a sufficient safety margin when crossing the road, if this pupil is of such an age that he has not yet developed the ability to judge speed or distance of oncoming traffic. The issue of the development of abilities and psychological functions that are relevant for road user behavior has been discussed extensively by Vinje (1985).

In the past ten years normative task analyses have been produced for pedestrian behavior; cyclist behavior, and moped and motorcycle riders' behavior (e.g. Van der Molen et al, 1981; Brookhuis et al, 1985; McKnight and Heywood, 1975). However, the relevant empirical data required to pinpoint the critical behaviors on the bases of these task analyses is in many areas still deficient. Observational studies of moped riders, for example, are virtually nonexistent. Exposure studies often lack data on young pedestrians and cyclists, while those groups are in fact the most vulnerable in traffic and therefore the most likely target groups for educational measures. Accident data have so many shortcomings that it renders them practically useless as a basis for formulating educational objectives.

Although the process of formulating educational objectives based on empirical information seems very cumbersome, there is no other way to ensure that the formulated educational objectives are both relevant and valid for the target group involved. The formulation of concrete educational objectives also enables an exact evaluation of the developed programs in terms of these objectives. Thirdly, it forms the basis for handling another basic problem in developing educational programs; deciding what will not be part of the program. Many programs have been developed that are so extensive that their 8-volume manuals requires three months preparatory study for the teachers and a full year course for the pupils. In order to avoid such unrealistic approaches road safety education must aim to be efficient, and formulating educational objectives on the basis of empirical evidence is a strategy to ensure this.

The content of instruction

Educational objectives describe what should be achieved as a result of the process of education but do not describe what is necessary to achieve this. For example, an educational objective in a cycling course could be that the pupil learns to cycle in a straight line or learns to yield at junctions for traffic which has priority. Unless we assume a totally behavioristic approach, which may in fact at times be very profitable to do, it has to be determined which are the necessary prerequisites for the required behavior. For cycling in a straight line this seems simple, in the sense that this is mainly determined by psycho-motor coordination, which can be regarded as a skill, but yielding for traffic that has priority requires knowledge about priority rules, requires production rules to apply these priority rules, requires psycho-motor skills such as stopping with a bicycle and to a certain extent requires a specific set of attitudes towards the necessary behavior or towards safe behavior in general. Some aspects, such as skills, are more important amongst younger children, other aspects such as attitudes are more important for adolescents, and it may very well be that the behavior displayed by young children and adolescents is ruled by very different mental representations, even though in observation it looks very much the same.

Content of instruction also has to be structured in such a way that it forms a curriculum or course. Essentially two different school of thought exist with regard to curriculum or course design. According to one point of view road safety education should be integrated in education in general and could form a part of subjects such as physics, mathematics or biology. This has the advantage that road safety education would become firmly based in the school curricula within the time available for the different existing subjects and can be carried out by the teaching staff involved in teaching those subjects. A problem in this approach is that the teachers of subjects such as mathematics or biology often do not feel themselves competent to teach road safety education and that integrated teaching may not always provide the possibility to use instructional methods that are effective in changing the road user behavior of the pupils (see Rothengatter et al, 1985). The other approach that can be followed regards road safety education as a type of technical training that should be carried out by specialized personnel (e.g. Valentine et al, 1980). In this view road safety education should be structured in relatively short term courses, which are not integrated with other subjects. The National Cycle Proficiency Scheme, developed in the U.K. (see e.g. Wells et al, 1979) and the Crossing the Road program developed in the Netherlands for young children (Rothengatter, 1982) are examples of such an approach.

An issue, which is recently receiving attention concerns the possibility to structure the educational content in terms of the pupils' mental representations to ensure that the pupils can apply that what they have learned more readily in the real traffic environment. This is for example important in learning priority rules, where it has been found that children cannot apply the rules they have learned when they are in the relevant traffic situations. In this area road safety education may greatly benefit from recent developments in cognitive psychology.
Alternatively, the content of instruction may be structured in accord with the intrinsic structure of the traffic situation or the behavior required. Comparatively, little empirical evidence is available in relation to these issues, and as a consequence, several lines of approach exist at this moment.

Instructional Process

Most research which has been carried out has focused on the instructional variables, in particular the methods of instruction and training, the type of instructor and the instruction or training situation and the audiovisual media that can be used in these situations. Reviews of the relevant literature can be found elsewhere (Rothengatter, 1981; OECD, 1986), here only a few main points will be mentioned.

In terms of achieving improvements in traffic behavior a direct training of the behavior seems the most effective method, unless the behavior required is very complicated. In those cases it is beneficial to include a preparatory cognitive instruction. If cognitive instruction is given, this should be directly related to the behavior involved. The use of audiovisual aids, in particular film or video, can in that case greatly enhance the effectiveness of the instruction. Behavioral training is difficult to realize for teachers within the existing school systems. As a consequence, many attempts have been made to involve external specialists and the parents in road safety education. Both groups can play an important role, in particular parents with young children who start to participate in traffic.
Road user behavior can only be learned in interaction with the traffic environment. Notwithstanding the at times quite elaborate attempts to mimic reality in training grounds or traffic parks, training in normal traffic conditions is virtually always superior to training in other environments. The main exception to this rule is the training for special groups of road users, such as handicapped children, for whom the normal traffic conditions may be too complicated in the beginning of a training program.

Evaluation

The concept of evaluation is surrounded by enormous confusion, which is partly due to the fact that in education in general different concepts are used than in road safety research. A recent attempt to reduce this confusion can be found in the OECD report on the effectiveness of road safety education programs (1986).
Here it is assumed that there are two types of evaluation used for two different purposes. The first type of evaluation, process evaluation, concerns the process of instruction and training and addresses such questions as; do teachers find the content relevant and attractive, do pupils understand the concepts used in the booklets, is parent involvement realized, does the course take too much time etc. The purpose of such evaluation is to optimize the instruction and training process, and results of this type of evaluation must never

be used as an indication for the effectiveness of an educational program. It is most likely that are many programmes that are very attractive and successful in application, but nonetheless do nothing to improve the behavior or safety of the pupils.

The second type of evaluation, product evaluation, addresses the issue of effectiveness in terms of attainment of the educational objectives. Does the program indeed achieve behavioral changes in the required direction; do the pupils indeed have more knowledge, better skills, more positive attitudes etc. are the questions this type of evaluation should answer. Since product evaluation uses criteria that are derived from the educational objectives, it can be carried out on the level of knowledge or skills improvement, on the level of attitude changes or on the level of behavior improvements. However, only when at least traffic behavior is used as a criterion can the effectiveness be considered relevant in terms of safety. Improved knowledge or skills is a good starting point, but irrelevant if no behavioral changes are observed. Unfortunately, evaluations in terms of traffic behavior are scarce, mainly due to the problems arising in such evaluations. These problems concern methodology, for example the site observations and conflict techniques used in evaluating infrastructural measures are rather useless in this case, and statistical problems, due to the fact that the research designs are no more than quasi-experimental at best. Nonetheless, some studies (e.g. Rothengatter, 1981; Van der Molen, 1983) have decisively demonstrated that significant improvements in traffic behavior can be achieved over longer periods of time even after a relatively short period of traffic education.

If behavioral evaluation studies are scarce and difficult to achieve, evaluation studies that concern effects in terms of accident involvement are hardly existent, and mostly have such methodological flaws that it is difficult to draw any firm conclusions. The problems encountered in this type of evaluation can only be solved if accident recording would be greatly improved both in terms of reliability and in terms of detail of description. At the moment this simply means that alternative ways of accident data collection have to be developed.

Conclusions

Road safety education requires concrete formulated educational objectives that are directly derived from empirical data concerning accidents, exposure, behavior and the psychological development of the target group involved. The content of instruction can be deduced from these objectives and should include behavior, knowledge, skills and attitude components. The effectiveness can be enhanced by involving parents and specialists and by direct training of the required behavior in normal traffic conditions, although cognitive instruction can also be effective in particular when audiovisual media are used. Although the methodological problems involved in evaluating educational programs are severe, it has been decisively demonstrated in some cases that improvements in traffic behavior can be achieved, and there are indications that accident involvement can also be reduced. Provided that stringent methods for formulating educational objectives are followed, and the instructional methods are evaluated on effectiveness in terms of cognitive and behavioral improvements, road safety programs can do what they aim to attain, i.e. a reduction in accident involvement of the target groups that are subjected to them.

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THE EFFECTS OF A COMBINED ENFORCEMENT AND PUBLIC INFORMATION CAMPAIGN ON SEAT BELT USE

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Background

Researchers generally agree that seat belt use is effective in preventing (fatal) driver injuries, and that legislation is an effective measure for increasing their use. Nevertheless, legislation alone rarely proves sufficient to achieve anything near universal usage. For example, Fig. 1 shows urban and rural usage rates in the Netherlands for the last eight years. (Legislation was implemented in 1974).
Policy makers can reach for a number of measures to bolster seat belt use, e.g., mass media campaigns, intensive treatment in small groups, incentive programs, and police enforcement. The techniques, however, have met with checkered success, are labor intensive, or have been implemented in situations where seat belt use was voluntary, in which case it is unknown whether they would also be effective in mandatory situations.
Nevertheless, one would think that combined enforcement and public information campaign would be a widely used technique for promoting seat belt use. (Such campaigns are conceptually simple, most road users recognize the value of seat belt use even if they don't always use them themselves, it is relatively easy for police officers to detect non-compliance, there is little a road user can do to protect himself from the risk of sanctions except to comply, etc.) This, however, does not appear to be the case. This may be due to difficulties in achieving the co-operation of police corps, who have their own problems, fear of eliciting criticism from the community, or the reluctance of police officers to enforce a law which they don't always comply with themselves. Even if some police forces rigourously enforce seat belt legislation, the effect of their efforts is rarely evaluated, or if evaluated, the results thereof rarely reach the international community.

One happy exception to this state of affairs is the series of enforcement campaigns in Ottawa, Canada, evaluated by Jonah and his colleagues. (Jonah et al., 1982; Jonah & Grant, 1985.)
In a nutshell, Jonah's results indicate that an intensive enforcement and

publicity campaign results in immediate and impressive improvements in seat belt use and a mild negative public reaction, both of which tend to dissipate in time. Furthermore, repeated (short) applications of these campaigns tend to counteract backsliding. A very recent study in Elmira, New York, (IIHS Report, 1986) tends to confirm the effectiveness of enforcement and publicity campaigns.

This paper will present some of the results of an evaluation of a combined enforcement and public information campaign that was conducted in 1984 in the Dutch province of Friesland (pop. 600,000). In one sense, this study was primarily an attempt to replicate the findings of Jonah et al.; in another sense this study is somewhat more complex. In the first place, this campaign was organizationally more complex, requiring the co-operation of more than 20 different local, independent police forces covering about 4000 sq. km. of a primarily agrarian region; Jonah et al. worked with one major metropolitan area. In the second place, our survey strategy allowed the collection of more information, which would hopefully allow more subtle answers to more complex questions. (Jonah et al. used a telephone survey of households; this study used a written survey of road users whose seat belt use had been observed in the field.)
In addition to the primary question of whether such a combined enforcement and public information campaign could increase seat belt use (and if not, why not?), the following questions will be addressed:
- did the campaign have a differential effectiveness for different categories of drivers or for different patterns of seat belt use?
- did the campaign create a negative public reaction, and, if so, which aspect of the campaign was it directed against and what was its intensity and duration?
- were some sources of information more effective than others in reaching the attention of the public?

The Campaign

The Frisian campaign consisted of a number of aspects: police enforcement, mass media public information and publicity, the handing out of folders and stickers, and public demonstrations of falling cars (!) and collision simulators.

The police invested about 2800 man hours in enforcement activities, controlling about 41,000 drivers and ticketing about 1300 of them in the second half of the campaign. The time actually spent on enforcement was only about 12% of the time originally budgetted, and the actual time spent varied widely from police corps to police corps (taking the size of the corps into account), and from month to month.

The campaign was initiated with a press conference and was, furthermore, extensively covered by regional and local newspapers and the regional radio station.

About 20 demonstrations were given with cars falling from a height of 10 m. and with collision simulators. The intention here was to dramatize the necessity of seat belt use. Police estimated that about 60,000 people witnessed these demonstrations.

The campaign was also supported by local chapters of the Dutch Organization for Traffic Safety (VVN), who distributed tens of thousands of folders and stickers, etc.
It was estimated that the activities around this campaign cost about Hfl. 200,000,- including material and personnel expenses.

One rather important detail is that this campaign was conducted simultaneously with a national seat belt publicity campaign, which also made use of local VVN chapters, and included national mass media coverage. The consequence is that both the treatment and (pseudo) control regions were also covered by this national campaign. The difference between the two regions was then a question of the extent of the coverage as well as the special Frisian activities (enforcement, demonstrations, and the obvious regional tint).

Method

A multiple time series of measurements were made in the "treated" region, the province of Friesland, and a (pseudo) control region, the northern part of the province of North Holland, otherwise known as West Friesland. Both regions were physically separated from each other by the IJsselmeer, which minimized the chance of contamination.

Measurements were made in five waves: several months before treatment (June, 1984), after the first month of treatment (end Sept., 1984), one month thereafter at the conclusion of the two month treatment (end Oct., 1984), six months (Apr., 1985) and twelve months after conclusion of the treatment (Oct., 1985). (A sixth measurement wave is pending, two years after the end of the campaign, the results of which should be known any day now.)

A measurement wave consisted of observations of seat belt use of individual car drivers during work days. Observations were conducted at 16 traffic intersections in Friesland and 16 in West-Friesland. Half of the intersections were inside built up areas, the other half outside. Every other observed driver was handed a written survey, with the request to fill it in and return it via the mail. (Postage was prepaid.)

A total of 28,688 observations were made over the entire project, the number of observations being approximately equal for each region and each measurement wave. 14,012 survey forms were handed out and 46% of them were returned.

Results

Fig. 2 shows the usage rates, broken down by region, measurement wave, and whether the measurement location was inside or outside a built up area. The improvement in belt usage is quite apparent in the treatment region for both inside and outside built up areas. In addition, a residual long term effect can be detected which lasted for at least one year after the end of the campaign activities. No dramatic change in seat belt use is apparent for the control region. In addition to these effects, log linear analysis also found significant driver sex and age effects: male drivers and younger drivers used their seat belt relatively less often. No age or sex interaction with treatment was found: all age and sex groups were equally affected. We could however find no plausible and demonstrable explanation for the apparent dip in seat belt use 6 months after the campaign had ended.

Concerning the written survey, it was already mentioned that there was a 46% response rate; log-linear analysis revealed a clear response bias: seat belt users and, to a lesser extent, male drivers being overrepresented. No interaction with region or measurement wave was found.

The survey itself covered a wide range of topics, including: self-reported seat belt use under varying conditions; reasons for (not) wearing a seat belt; the extent to which one had heard or seen something about a seat belt enforcement and/or publicity campaign; whether or not legislation, enforcement, and public information were an acceptable and effective means of promoting belt use, etc.

In order to get a good handle on this mass of data, and to answer the most general question in such a study, i.e. what the most apparent region specific changes in time in the answer patterns in the survey were, two steps were taken:
- data was grouped into sets of questions pertaining to similar subjects (e.g., self reported seat belt use, the degree to which respondents had heard about a campaign, etc.) and each set was reduced by means of non-linear principal component analysis;
- a discriminant analysis was used to distinguish between (5 measurement waves x 2 regions=) 10 group centroids on the basis of the vectors obtained from the aforementioned PCAs.

The results of the discriminant analysis are shown in Figs. 3 and 4, while the interpretation of the PCA vectors is shown in Table 1. The canonical correlations for the first and second discriminant dimensions were 0.65 and 0.18, the first being very significant, the second being of lesser interest.

The interpretation of this solution is quite simple: the primarily region specific change in answer patterns pertains to the fact that respondents in the treated region during the campaign were relatively aware of the existence of that campaign, and then by means of a great number of information channels. I.e., they had heard about it on the radio, talked about it with their neighbors, read about it in the newspapers, etc. This is just another way of saying that the observed behavioural change was accompanied by an awareness of the campaign itself, and that there was a reasonably good penetration of the target group by a variety of means.

The second discriminant dimension reveals that respondents in the treated region after the end of the campaign were likely to have a higher self-reported seat belt use. They were also relatively more positive about legislation, enforcement, and public information campaigns, and were relatively likely to be of the opinion that there had been a lot of attention paid to seat belts.
Instead of a negative public reaction to the campaign, it seems more likely that a (weak) positive attitude towards the law and its enforcement has been obtained.

Unfortunately, space does not permit going into further detail.

Discussion

This study has quire clearly confirmed the major result of the Jonah et al study. Namely, an intensive combined enforcement and public information campaign can produce dramatic changes in seat belt use which can endure for up to a period of one year. Nevertheless, we were not able to confirm their finding of a temporary negative public reaction to such a campaign. On the contrary, a weak but measureable positive reaction was found which endured up to one year after the conclusion of the campaign. In addition, no differential effectiveness was found for types of trips or types of drivers: there seemed to be a general, non-specific increase in seat belt use for all types of drivers and trips. While it would have been comforting to find that such a campaign would primarily affect high risk drivers (such as young males), we at least don't have to fear that such groups would be untouched by such a safety campaign.

While this paper hasn't considered it in detail, it seems that most respondents were reached by means of the (local) mass media and by word of mouth. Very few respondents admitted to having been controlled by the police themselves or even having seen a police control, even though they estimated that the chances of such a control had increased during the course of the campaign. It would seem that organizing and motivating the police can be a rather difficult problem with such campaigns, and that a lot can be done to improve the visibility of their efforts in the field. Nevertheless, the bottom line may be that it is less important what the police do and the degree to which they do it, as long as road users have the impression that the police are vigorously enforcing the law.

It should be noted that these results indicate that there may be some degree of habit formation with accompanying attitudinal change. It can be hoped that this campaign may result in a more permanent behavioural change, due to the possibility that (some) road users may attribute their increased use of seat belts (which persisted for at least one year) to their own good sense instead of the threat of police intervention. Of course, this remains to be seen and it is hoped that a more recent measurement wave in November, 1986, will confirm these expectations to some extent.

Finally, preliminary calculations indicate that such a safety measure is cost effective: the costs of implementing a combined enforcement and public information campaign are at least equal to the economic savings due to the prevention of premature death and serious injury. Depending upon one's assumptions, an appreciable financial benefit may be obtained. This is, of course, computed without consideration of the benefits of the prevention of human suffering.

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Jonah, B.A.; Dawson, N.E. & Smith, G.A. 1982. Effects of a selective traffic enforcement program on seat belt use, Journal of Applied Psychology, 1982, vol. 67, no. 1, 89-96.

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Fig. 1 Seat Belt Use of Passenger Car Drivers Inside and Outside Built Up Areas in The Netherlands from 1979 to 1985 (Arnoldus & Scholtens, 1986).

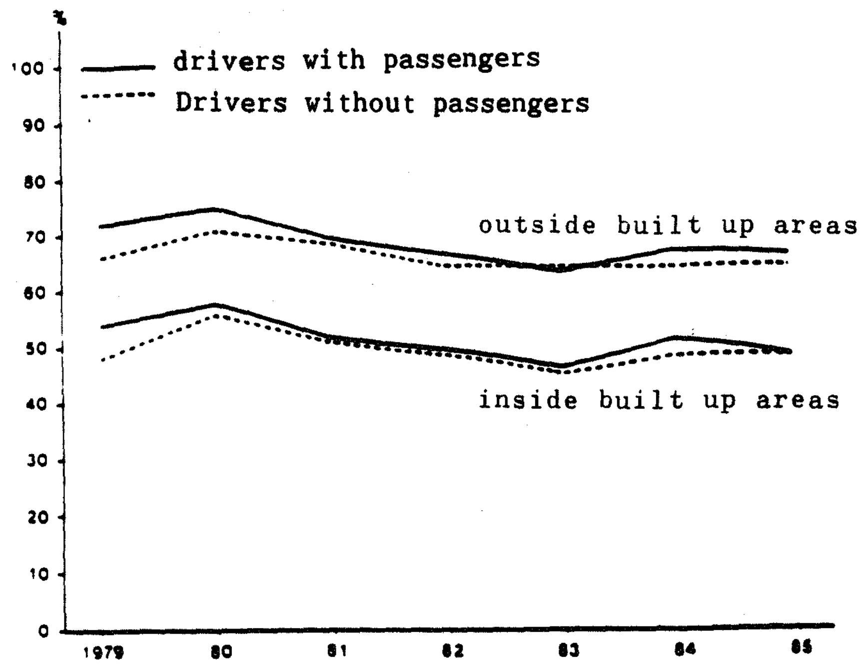


Fig. 2 Seat Belt Use of Passenger Car Drivers Inside and Outside Built Up Areas in Friesland and West-Friesland during Five Measurement Waves

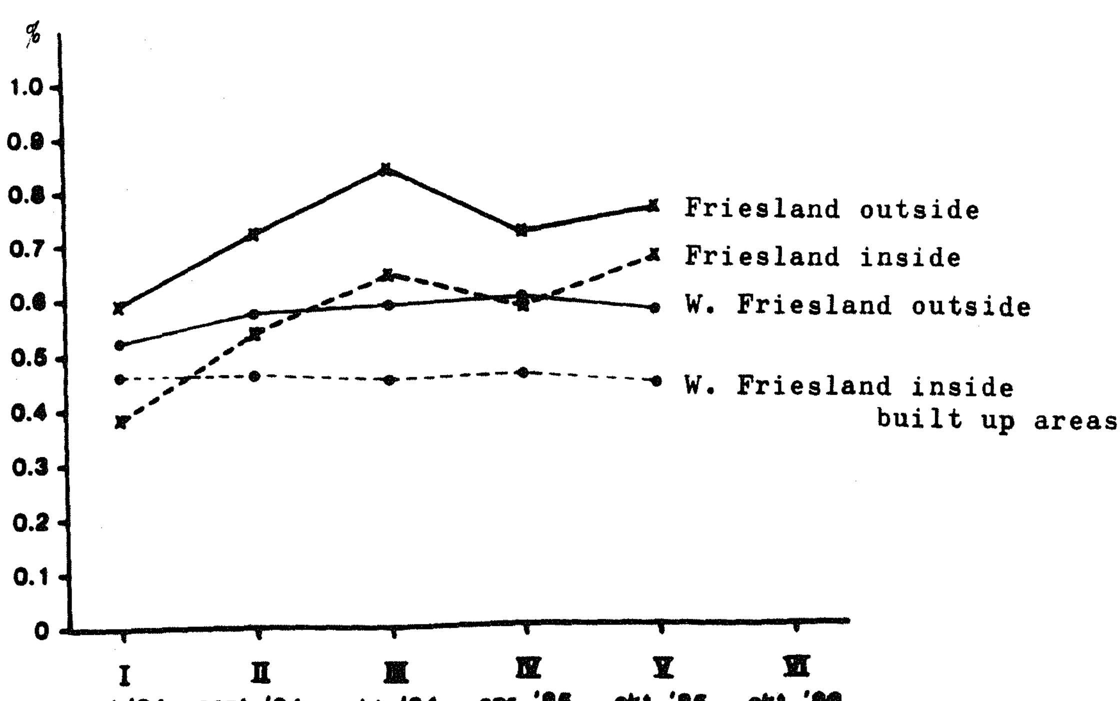


Fig. 3 Centroids of the 10 Groups (2 Regions x 5 Measurement Waves) in the Discriminant Analysis

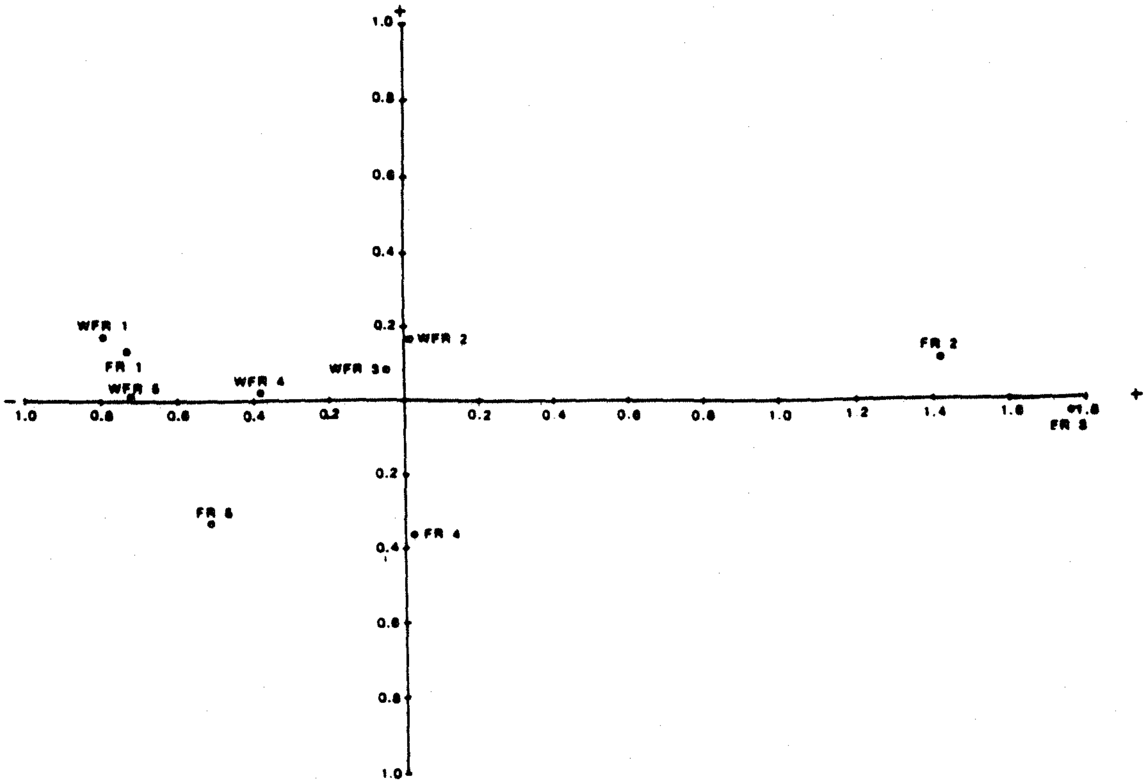
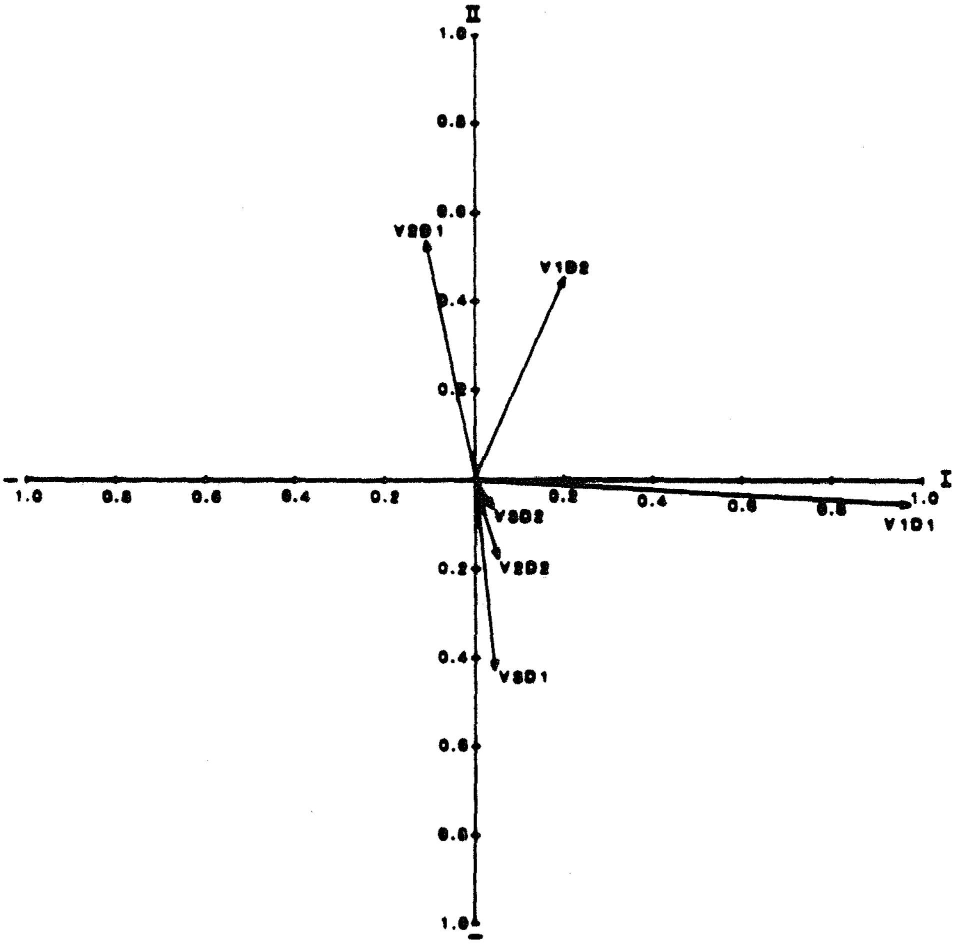


Fig. 4 Correlations of the (Composite) Variables with the First two Disriminant Functions



Tabel I Short Description of the Independent Variables in the Discriminant Analysis, which were created by PCA

V1D1	(+)	respondents are relatively aware of the seat belt campaign
V1D2	(+)	not enough is being done to encourage seat belt use
V2D1	(+)	lower levels of self reported seat belt use
V2D2		difficulty factor
V3D1	(+)	respondent is relatively positive about legislation, enforcement, and public information concerning seat belts
V3D2	(+)	respondent is relatively positive about public information as opposed to enforcement

THE ROLE OF ROAD ACCIDENT SIMULATION IN SAFETY RESEARCH

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ABSTRACT

Numerical simulations are becoming the major tool in passive safety research, i.e. in studies aimed to reduce the hazards of road accidents once they have occurred, whatever the cause.
In the last two decades the trend has been to use experiments more and more as sources of input data and to validate computer simulations; experiments maintain a crucial importance, but their role and requirements are changing.
This paper describes and comments on some of the author's experience in his long cooperation with SWOV of using simulations to design and improve safety barriers and other roadside devices.
Consideration is also given to more recent work on the use of simulations for other safety problems, and finally some new trends in dynamic simulation of road accidents are outlined.

1. CRASH SIMULATIONS: WHY

Numerical simulation, viz. simulation using numerical models, has been enhanced tremendously by the incredibly rapid developments in digital computers. In the last two decades digital computers have shown a cost reduction of more than three orders of magnitude for the same performance, while performance has increased more than four orders of magnitude. This has been the main reason for the rapid growth in the use of numerical simulations.
In turn, such growth has changed the role of simulations and full scale experiments in safety research, experiments having maintained their full cost.
Besides the lower cost, however, what is the value of simulation for road safety research?
In principle a simulation, if carried out correctly, can be viewed as a more or less simplified approximation of an experiment. Two main features of simulations must be observed:
1. ease, viz. low cost, no risk, repeatability, easy access to all variables;

2. one to one correspondence with experiments, i.e. in general, one simula tion reproduces one experiment, and no more than one.
Moreover, one of the major advantages of simulation over experiments is the possibility it offers to study the effects of parameter variation with little effort and at moderate cost.
In fact such parameter variation entails only computer cost; it does not require the high labour cost of developing a new model (one to four man-months).
Parameter variation may also be an effective means of gaining insight into complex phenomena such as crash dynamics.
Another important use of numerical simulation is reliable interpolation, and to some extent extrapolation, of experimental results.

For example, having experimented with roadside barriers using freight vehicles weighing up to 20,000 kg, and having thus validated simulation models, one can reasonably extrapolate to 40,000 kg vehicles with simulation, without the need for further experiments.
Finally, easy and reliable simulations are essential for the design of a crashworthy vehicle or a good safety barrier.
There is no doubt, then, that simulations are useful.

2. CRASH SIMULATIONS: HOW

A crash simulation model is a non-linear structural dynamic model, mostly of the "finite element" type, involving one-sided contact forces, friction forces and other special submodels.
High material non-linearity and large deflections entail frequent reconstruction of the governing equations, which requires a computational effort for each time step no less than a complete static solution.
Since one simulation may easily require several thousand time steps, it demands the computing of several thousand linear static analyses of the same detail (degrees of freedom = DOF).
So, even using the most powerful computers available, a crash simulation with the same detail as a normal static analysis (more than 20.000 DOF) will require an unacceptable computing time, many restarts, and possibly many days to be completed.
Dynamic simulation generally uses a much smaller number of DOF.
Modelling with a limited number of DOF requires a good deal of experience, or a certain "modeling art" as a U.S. author says.

This means, e.g. in a class of collisions of a class of vehicles, that it is often possible to distinguish three different structural areas:

- areas with linear elastic behaviour, that can be modelled as rigid parts or with very few elastic elements;
- areas with moderate plastic deflections, where medium detail is suitable;
- areas with very large plastic deformation, and crumpling, where very (unacceptably) great detail or hybrid modelling is needed.

Hybrid modelling aims to represent one of these areas with one macro-element having complex non-linear force-deflection behaviour, determined with ad-hoc experiments or detailed simulation. This modelling strategy may even be efficient, but it requires a good deal of experience of that particular class of structures in that particular class of collisions.
In other words, a vehicle model developed with this strategy must be used with care, and not beyond its validity envelope; it is not a general model of this vehicle.

All this is likely to change in the future, when the cost and the power of the big vector computers have again been substantially improved.
In ten years the complexity and accuracy of F.E. models currently used in linear static analysis will be adequate for crash simulations.
Modelling difficulty and the need for a "modeling art" will be considerably reduced.
We must be prepared for this, and start working now in this direction.

3. THE ROLE OF EXPERIMENTS

The evolution of numerical simulation has changed the role of experiments, and it will change this role even more in the future.
Twenty years ago experiments were the main tool for studying the crashworthiness of vehicles and the safety of roadside devices. Nowadays simulation is the main tool, but experiments are still needed to acquire the knowledge necessary for modelling. Moreover, experiments are needed to provide data for hybrid models and, at a later stage, to validate the simulations of each class of collision.
The experiments required, even if fewer in number, may have to be more expensive, since they will have to provide accurate measurements of many parameters.

In the future, when simulation uses "pure" or "theoretical" F.E. modelling, experiments will be more basic and more detailed, c.f. those for developing reological material models or for understanding joint failure.
Final experimental validation of complete simulations will still be needed, with even better measurements.
Thus experiments may become even more expensive, if fewer in number, but above all, our capability to design crashworthy vehicles and good roadside protection will be considerably increased.

4. PREVIOUS EXPERIENCE

Previous experience is very useful, but it must not become the cause of excessive conservatism.
My cooperation with SWOV started with the development of a MAthematical Model for Impacts Against Crash barriers (MAMIAC) in 1967. The first mainframe used was less powerful than a present-day personal computer.
That start was really innovative and it was made at the right time. The MAMIAC programme grew up with the computers and with our experience during the next seven years.
It reached a really high level of development: it was used successfully to improve guard rail design and to design a new bridge parapet for heavy freight vehicles (on the Brussels Ring).
MAMIAC was specially designed for metal guard rail constructions and accordingly had a built-in fixed modelling strategy.
The barrier was modelled with true finite elements of moderate size; the only exceptions were the posts, modelled as hybrid elements, as they are likely to undergo very large concentrated deformations.
Figure 1 (1972) is a graphical presentation of one instant of a MAMIAC simulation.
After the completion of MAMIAC a more ambitious project on Vehicle Dynamics And Crash (VEDYAC) was started.
VEDYAC was intended to simulate different kinds of impact; it incorporates finite elements, hybrid elements and one-sided contact forces, but it has no fixed strategy.
It has been used for metal barrier simulation (Figure 2, 1983) with the MAMIAC modelling strategy; it has also been used for collisions with concrete barriers (New Jersey barrier; see Figure 3) and other crashes.
It has also been used for train collisions (Figure 4, 1984) and for bio-

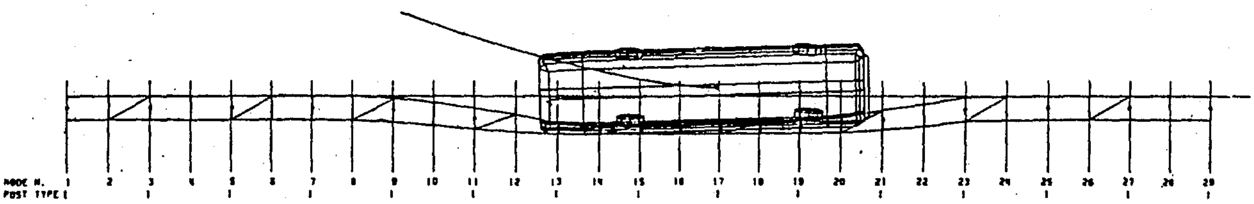
mechanical modelling of humans inside (Figure 5, 1984) and outside colliding cars.

Obviously VEDYAC is more difficult to use than MAMIAC, mainly because the optimum modelling strategy is "a priori" unknown and must be found for each specific problem.

5. CONCLUDING REMARKS

To summarize, the use and value of simulation in road safety design and research has increased rapidly in the last two decades and will increase even more in the '90s.

The role of experiments has changed correspondingly and will continue to change, but they will still remain vital.



MAMIAC

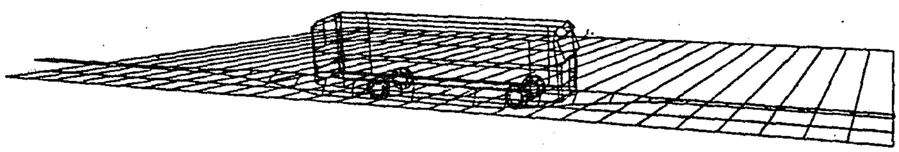


Figure 1 (1972)

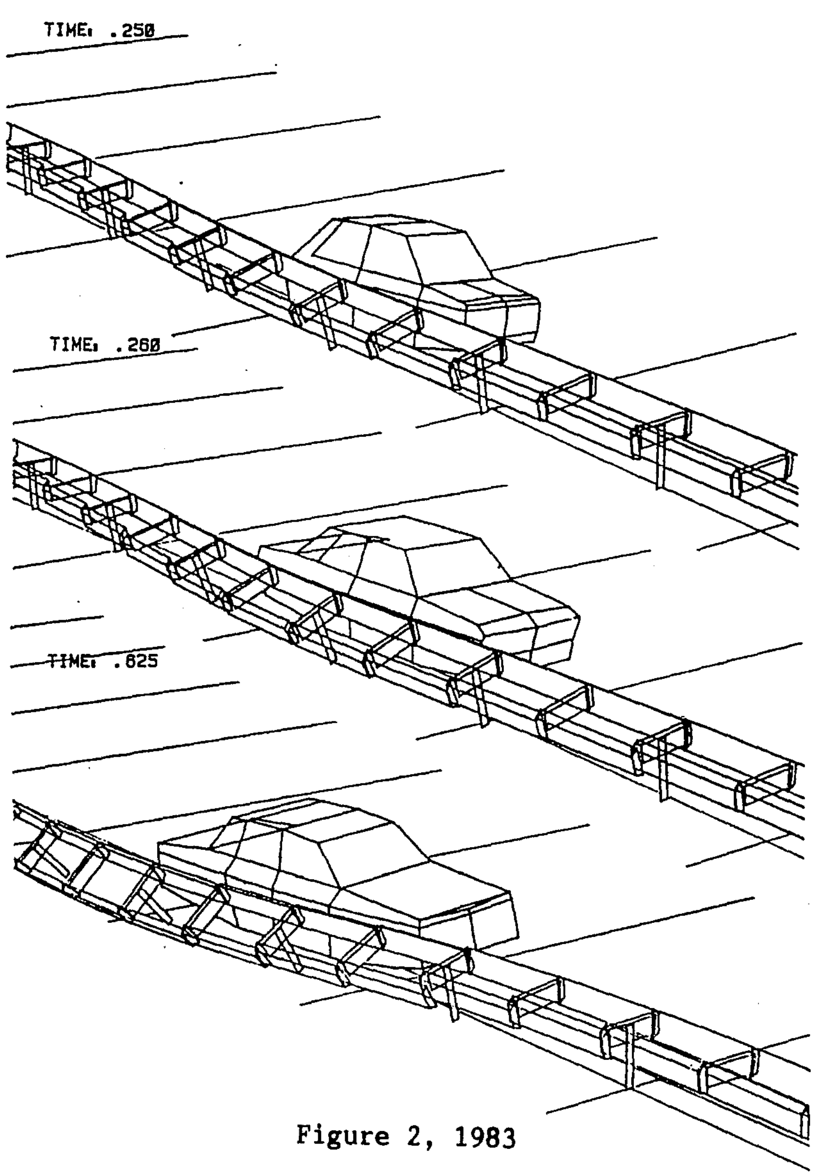


Figure 2, 1983

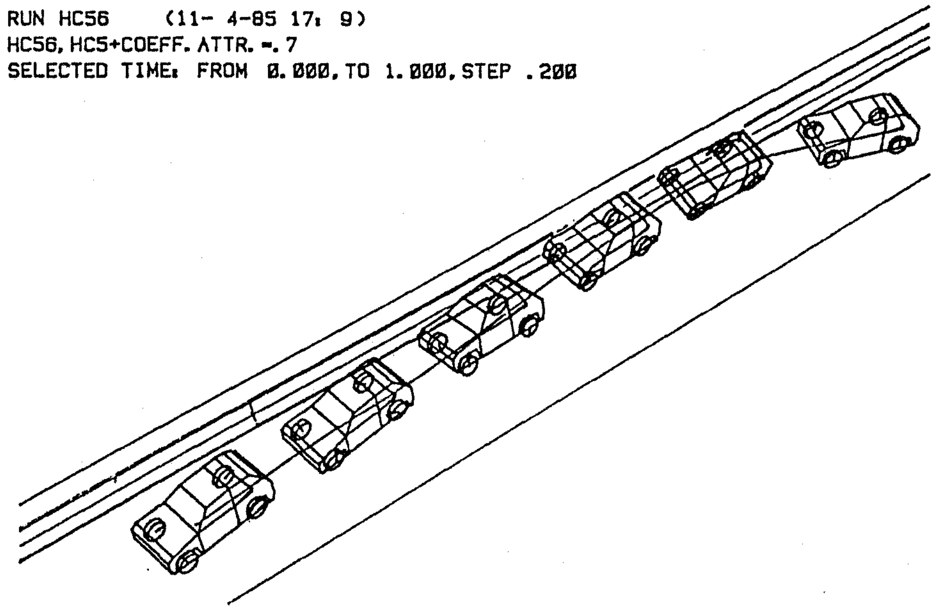


Figure 3

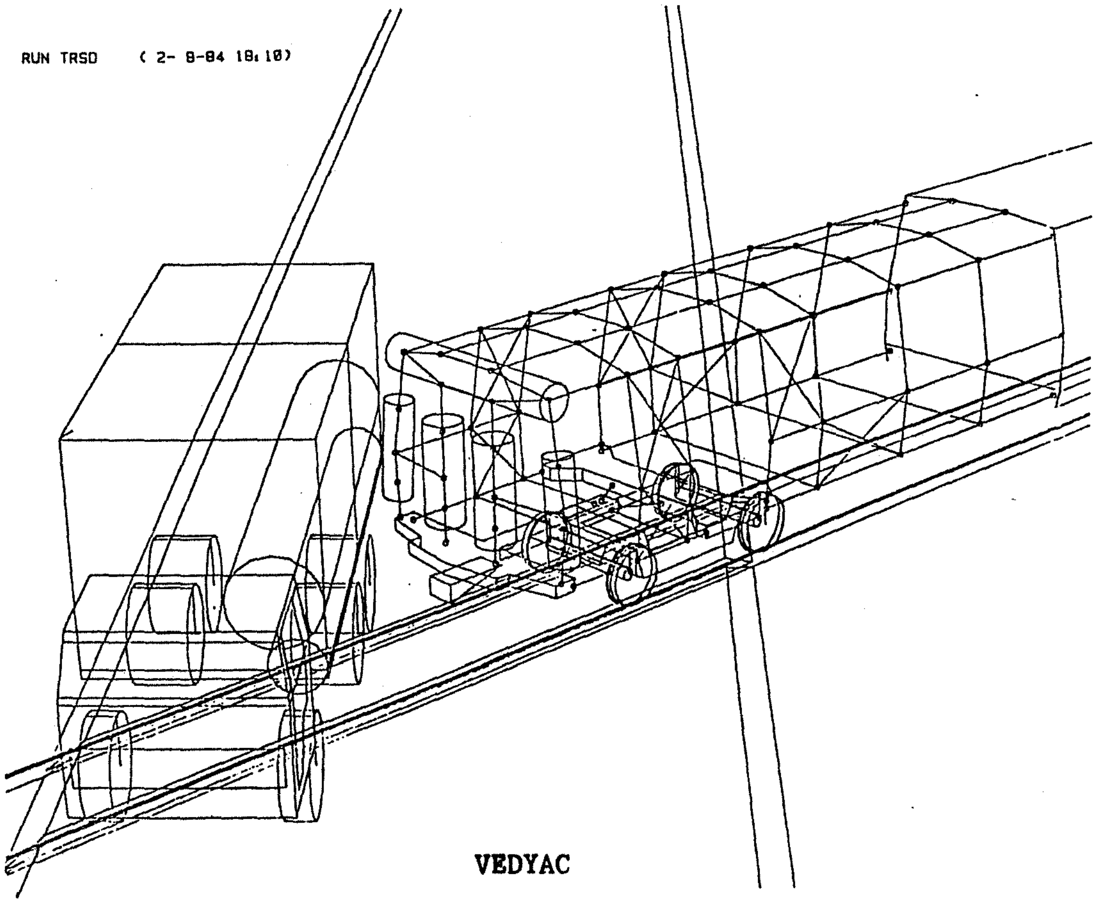


Figure 4, 1984

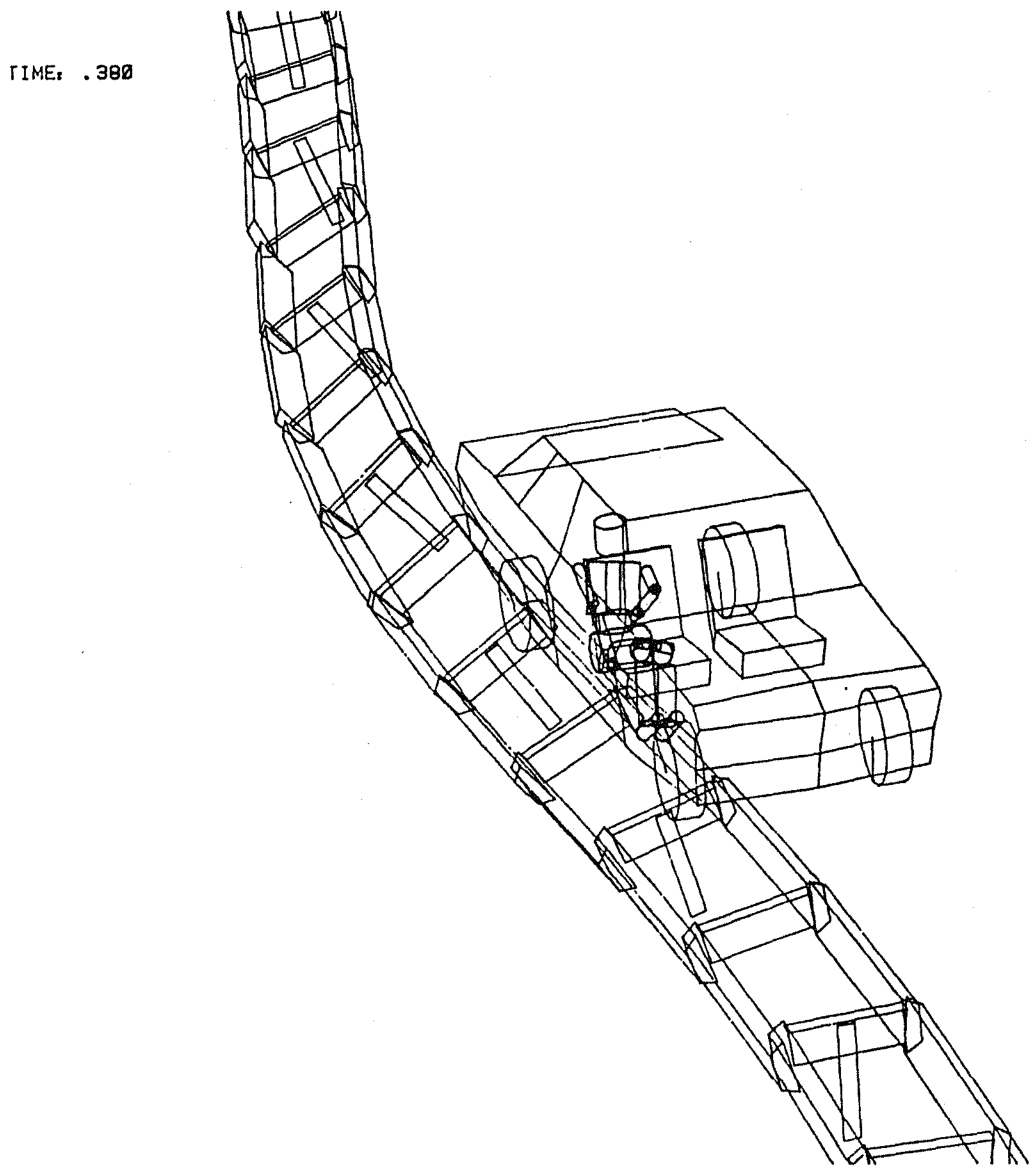


Figure 5, 1984

STATISTICAL RISK ASSESSMENT WHEN USING DETERMINISTIC MODELS

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Introduction

Models like VEDYAC, the one presented by prof.V.Giavotto, have gradually grown into accepted tools in the investigation of crash phenomena and the development of adequate safety measures. These applications are mostly limited to devices located on the vehicle (e.g. crush zones) or on the roadside (e.g. guardrails). The models are usually validated by means of a limited number of full scale tests and generally can be made to comply reasonably with these tests. Thus, the outcome of a great variety of conceivable crash circumstances can be predicted cheaply and more or less accurately, as far as movements, accelerations etc. of vehicles are concerned. Severity of the simulated crash can only be judged in terms of the models parameters, that is, in terms of parameters of the vehicle. In some cases, like VEDYAC, the models capacity also includes the simulation of man-like structures which enables the user to get at least a rough impression of extent of mechanical violence the victims will be exposed to. Although this may provide a better criterion for judging crash severity then vehicle movement and accelerations, the eventual "translation" of violence to actual injuries really determines whether or not a crash must be regarded as absolutely dangerous. Without the possibility of this translation, realistic judging of the severity of simulated events often is to difficult and we must revert to relative indicators, that is, we must judge the improvement or deterioration of results between various simulations.

Extended applicability

The availability of an "injury translator" could extend the use of crash models beyond the computer aided design of crash appurtenances. The (hypothetical) translator enables us to assess the severity of a simulated traffic accident in terms of injury severity (or death) of those involved; the same terms that are commonly used as indicator for traffic safety and therefore more readily understandable. In this way, the models could be used directly to evaluate existing or hypothetical traffic circumstances, new or existing measures etc. Other possibilities include more versatile application in accident reconstruction, more accurate estimation of initial conditions in accident investigation and better insight into mechanisms that cause injuries during crashes.

Profile of an "injury translator"

Given the fact that human beings differ considerably in size, mass etc. and since it is highly improbable that every human being will respond identically to the same mechanical "input" we need to leave the "simple", straightforward way of the deterministic models and allow for statistical variation. This implies that we must allow for differences in vulnerability. It also means that victims of an identical accident may still experience different violence due to their differences in mass and stature (hence different mechanics). Moreover, violence applied to various parts of the body will provoke vastly different types of injury, much more types than we can ever hope to model in fact. So apart from stochastical problems we also face difficulties in selecting relevant injuries. We will now examine the consequences of these considerations:

Differences in antropometry

From general tests, both with mathematical as with physical models (dummies), it is clear that the influence of antropometry cannot be neglected. We must therefore first try to establish in more detail which parameters are relevant (sensitivity analysis) and how they vary together in reality. In the next step, we must select a limited number of combinations of parameters such, that the entire field of the parameters is covered reasonably (a representative sample). The sample must be limited because we need to repeate the same simulation with every selected set of individual properties. Provided that we will be able to properly define these samples, we have thus constructed a set of data representing the variation in exerted violence due to differences in antropometry.

Selecting relevant types of injury

Although there is an infinity of possible types of injury, there is also a number of factors that limit the choice. These factors are:

- limitations of the mechanical model itself due to the level of detail; e.g. internal organs are commonly not included in modelling so internal injuries can only roughly be predicted on the basis of "outside" phenomena
- the translator must rely upon a scoring system of injury severity, e.g. AIS

and is therefore automatically limited to scoreable injuries
- availability of data concerning different types of injury; this proves to be a major difficulty since these data can only be obtained in expensive and elaborate research
- severity of the injuries themselves often determines whether or not they will be significant; most minor injuries can be left out since they occur at low levels of mechanical energy and the models will generally not be accurate enough to predict reliably at these levels.

In practice, the factors limit the number of more or less predictable injuries to less than 100.

Differences in vulnerability

Differences in "injury response" prove to be the most difficult to represent. The differences derive from a potentially large number of characteristics that we may be able to name but probably cannot measure sufficiently. Although this implies that accurate prediction is virtually impossible, there remains a possibility of using proxy variables. This means that we must assume that many of the immeasurable parameters are somehow correlated to a limited number of measurable ones and therefore can be replaced by these measurable quantities. We could, for instance, try to use measurable antropometry like age, sex,mass and stature and maybe some other body dimensions as such proxy variables. After this assumption, there is a choice of statistical techniques to determine whether the variables form a sufficient base for prediction of individual injury response and if so, how this relationship must be defined.

Taking into account the uncertainties, approximations and the complexities of many covariant variables in the reasoning so far, we must conclude that the feasibility of an "injury translator" depends heavily upon the quantity and quality of available antropometrical data and biomechanical experiments.

Realising a translator

In the past 4 year, SWOV has attempted to develop a translator along the lines mentioned above. As the results we very uncertain to start with, it was decided to limit the search for data to relatively cheap literature studies, both for antropometrical data and for data regarding injury susceptibility. The Abbreviated Injury Scale (AIS) was chosen as numerical scoring system for injury severity, together with the related Injury

Severity Scale (ISS), useful for scoring multiple injuries. The ISS also provides a guideline in categorising injuries into 6 different areas of the body, which led us to develop 6 different so called predictor modules. Inside such a module, more than 1 type of injury may be taken into account, the highest AIS score determining the score for the corresponding ISS area. Provided we could calculate a score for each area, we could assign a single ISS-value to any simulated case. Reality is not so simple however. From biomechanical data, it soon becomes clear that, even with the application of proxy variables to account for variance, it is impossible to obtain full certainty about the occurrence of any single injury. There always remains a "gray area" of doubt which, owing to the mostly rather poor quality of available data, can be large. This forced us to introduce the concept of probability in the prediction. This was tried in various ways, but the simplest way turned out to be no more unreliable than more complicated procedures. So we simply fit a normal distribution into the remaining "gray area" from whitch a probability distribution on the AIS-scale is derived as a function of predicted level of mechanical violence . This procedure is followed for each predictable type of injury and for each member of the sample population, so in the end we have a number of samples, each representing a certain portion of the population, and each assigned 6 body areas in which a probability distribution on the AIS scale is calculated. According to the rules of ISS, these 6 AIS-distributions are compounded into a probability distribution on the ISS-scale, again for each population sample. The proces of compounding is not very simple but straightforward (if you are a computer) since it involves calculating a very large number of possible combinations. For this paper, let us be content to conclude that al we have left to do is a weighed summation of all ISS distributions, the weighing factors being the representativity of each member of the population sample. In this fairly complicated way we can arrive at a probability distribution upon the ISS-scale (more or less) valid for the whole simulated population. Assuming a maximum accptable ISS-value of e.g. 17, we can now determine which proportion of the population will be injured below the acceptable limit and wich part will exceed that limit; a good measure for total risk. Neither the collecting of data nor the eventual analysis turned out to be smnooth or simple. Even with a limited number of proxy variables (4 or 5), data turned out to be scarce; to scarce even for most statistical techniques and procedures. Moreover it became clear that biomechanical data from different sources were hard to combine due to inconsistencies in experimental procedures or even simply because one or more antropometrical data were not recorded. So whatever algorithms have been derived, they have always been based upon a relatively small number of datapoints and can hardly be regarded as reliable. In fact, the only more reliable source was a British investigation into antropometry of cardrivers with more than 2000 fully recorded cases. The resulting translator (the computer coding is not finished yet) therefore is but a mere start, to be applied only with much reticence. Still we feel that, by careful comparison and modification, with the aid of test results and accident data, we can eventually arrive at a useful tool, much better suited than separated injury criteria.

PUBLIC LIGHTING AND ELECTRONICS

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1. Generalities

Even if a precise evaluation of the real benefit obtained by a public lighting installation is often very difficult to calculate, the positive influence on general security and traffic safety of such installations has no more to be proved.

The factors which allow the calculation of the photometric characteristics of the installation, in order to make this latter really efficient depend of variable data such as the meteorological conditions or the traffic composition and volume as well as of fixed data such as the geometry or the surroundings of the road.

A lighting installation has obviously to be calculated for the worse conditions that, with a sufficient frequency, can be encountered, and these conditions lead also to the highest lighting levels.

As long as the energy cost were rather low with respect to the other factors of the running cost, the lighting was generally switched on by sunset and switched off by sunrise.

The increase of the energy price as well as the decrease of the incomes of the public administrations in consequence of the economic crisis have lead these administrations to consider with more detail solutions that may be applied in order to adapt, at each moment, the lighting level to that which is really necessary.

A rather rough solution, and already applied for a long time, consists of switching off part of totality of the lamps during the so called slack hours of the night.

But such a solution is of course very imperfect because it doesn't take in account the actual data of the problem.

As in most countries the Belgian road network is divided in urban roads, main or intercity roads and motorways.

The management of the first ones belongs to the local authorities and doesn't allow therefore a general policy.

The main roads and the motorways fall within the competence of the national government.

When they cross builded areas or agglomerations, main roads are practically submitted to the same local constraints as the adjacent urban roads, but motorways with a rather homogeneous type of traffic (only motorized vehicles), the absence of commercial or urban constraints, and their centralized management offer the possibility of implementing a more flexible adaptative solution.

In the case of Belgium the conditions were still more favourable by the presence along the motorways of a permanent physical support for telecommunications.

When the emergency call boxes placed along the motorways had to be connected to the corresponding emergency centers, it was decided taking in account the rather short distances to be considered in our country to realize these connections by means of a telephonic cable. As the increment of the total cost price of such a cable is much less than proportional to its number of wires, it was also decided to incorporate a certain number of spare circuits. As a matter of fact the existing cables contain 64 pairs of wires and two coaxial pipes.

It was then possible to implement with a rather low cost (for less than 0,5 % of the total cost of the motorway) two separate systems.

In the first one counting devices at each access, connected to a center situated in the suburbs of Brussels, allow the processing in real time of the traffic volumes and densities data, with the main objective, beside statistical functions, of detecting quickly abnormal situations in the traffic flow and giving to the motorway police patrols a possibility of quick intervention when necessary.

The second system allows the control of the totality of the motorway lighting. It is probably not necessary to remind that, with a few local exceptions, motorways are lighted on their total length in Belgium.

With this centralized control system it is possible to switch on or off separately each lighting section or lighted signalisation of each motorway. The system allows of course also the supervision of the functioning conditions of the power and lighting sources.

As the data of both systems are processed on the same place it was then quite natural to try to make a link between them in order to establish a more flexible dependence of lighting to traffic. This is what we call in Belgium an adaptative modulation of lighting.

When implementing this dependence following problems had to be solved :

1. How practically control the lighting level ?
2. What is the correlation law between lighting level and traffic ?
3. How can spatial and time fluctuations be taken in consideration in order to avoid undesirable off and on switching for short periods ?

2. Control of the lighting level

The lighting level control can be achieved or by the adjustment of the number of lamps to the necessary luminance level or by dimming each lamp independently.

The first solution allows only a discontinuous adjustment, is more simple and cheaper, but needs, if we want to maintain the uniformities, the use of multilamp luminaires.

The application modalities of the second method depend of the type of lamps in use. Rather simple for high pressure and fluorescent lamps it is, till now, only possible in a restricted range and with a sensible reduction of efficacy with low pressure sodium lamps as very extensively used in Belgium.

In both solutions remain also the problem of delivering the control impulses to the controlled lamps.

In most cases the use of separate energy wiring will not be economical and the classical solution is then of using a separate control cable. But investigations are now in development to deliver the control signal by superponing to the energy network voltage a 30 ... 100 kHz tension. Conversely to what could be expected, the capacity of the usual energy cables do not attenuate the signal in a too high proportion because this capacity is lower for these frequencies than for industrial frequency. Experiments in real installations have shown the technical feasibility of this solution.

The economic approach of the problem is different according as existing or new installations are concerned.

In our case the problem is to know whether it is justified to modify our energy installations to achieve a certain type of modulation. The economy that can be obtained by switching off one lamp out two may be estimated as follows for a 131 low pressure sodium lamp (150 W with ballast losses) ; with 2 000 h yearly switching off time and a kWh price of 0,05 $ we obtain :

$$2\ 000 \times 0{,}150 \times 0{,}05 = 15\ \$/\text{year.lamp}$$

To this we have to add the economy made on the life of the lamp which may be estimated to 10 $ (Lamps have to be replaced every 4 years instead of every 2 years).

With a pay back time of 5 years, this means that the extra cost for implementing a modulation has to be lower than 150 $.

Although this is very low it is not impossible that this can be obtained in new installations but certainly doesn't justify the transformation of existing installations.

For this reason modulation was introduced in Belgium by switching off the complete lighting of the motorway itself (i.e. excluding the access roads and the lighted signals).

The lamps are however not switched off in case of bad weather conditions such as fog, icy roads, heavy snow or rain.

3. Correlation between lighting level and traffic

A study made by G. DE CLERCQ in 1985 on the effect of restriction measures during the years 1981-1983 indicates that one has to be very careful with too draconian solutions. It is then important to limit such total extinction to periods of very low traffic.

Practically no data are available to say, on a well scientifically etablished base, for what traffic volume lighting may from an economic point of view be switched off.

It was assumed in our solution that this limit may be fixed to 200 vehicles/hour and per travel direction. This seems acceptable till now but further statistics of accidents have to confirm whether this is effectively the case.

4. "Continuity" algorithms

As the control of the lighting is done in the feeding power stations, spaced about 4 km, and that the counting devices are placed at the access points to the motorway, a special algorithm had to be worked out for avoiding, along a sufficiently long itinerary (at least of 30 ... 40 km), a succession of lighted and unlighted stretches.

The principle of the algorithm is the following :

a. when at least 10 % of the counting points indicate a unidirectional traffic of at least 400 vehicles/hour, the lighting is switched on or maintained ;

b. when this is not the case, two groups of counting points are considered : those with a traffic volume comprised between 200 and 400 v/h and those with a traffic volume lower than 200 v/h.
   If the first ones are more numerous, the existing situation is maintained. If the second ones are predominant a predecision of extinction is taken. This is turned into a definitive decision when this situation is maintained during two periods of counting of 6 min each.

This system is now applicated since about one year and seems to give satisfaction, but as said above, this has to be confirmed by the follow up of the number of accidents.

5. Conclusion

The present trend in Belgium in lighting of motorway is thus to maintain the CIE recommendations of 2 cd/m2 as the base for the rating of the installation, but to look to possible applications of telecontrol and electronics devices to adjust as close as possible the lighting levels to what is really needed. In this respect we are very interested by studies that can give information upon an objective relation between lighting level (or more generally overall lighting quality) and accidents.

PUBLIC LIGHTING

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1. THE FUNCTION OF PUBLIC LIGHTING

In most cities and on many rural roads, public lighting is used. The lighting has four different functions:

- reduce nighttime traffic accidents
- improve public safety
- enhance economic and aesthetic aspects
- improve amenity.

In most urban roads and streets all four functions are relevant, be it in different degrees. In rural roads, however, usually the function is restricted to the first: improving road safety. Here, we will concentrate on the road safety aspects.

When considering the road safety function of public lighting, one should begin to realize that the lighting is installed in order to make specific objects visible. These objects are specific: their visibility is required in order to be able to select the right manoeuvre. This holds for all traffic participants; as the requirements for drivers of cars usually are the most severe, it is customary to apply the terminology for (car) drivers. So, one may speak of the driving task when discussing the selection of, decisions about, and performance at specific traffic manoeuvres.

The function of road lighting can be described more precisely as: to allow the traffic participant (car driver) to observe the relevant objects in order to come to the right decision as regards the appropriate manoeuvre to be performed: the appropriate manoeuvre in its turn is the one that became necessary by the fact that the (relevant) object is present. Obviously, it is not exclusively the public lighting that may perform this function: daylight at day, and vehicle headlamps on unlit roads may do the same.

Relevant objects may be traffic obstacles: obstacles that may endanger traffic when hit. They may, however, also be markings and signs that are placed on or near the road with the precise aim to improve traffic flow or safety; and finally they may be things that by their simple presence help traffic, e.g. rows of trees. All these objects are called "visually critical elements", signifying that their visibility is essential for safe traffic. Modern research in this area concentrates on the characteristics of these visually critical elements.

2. THE RELATION BETWEEN PUBLIC LIGHTING AND ACCIDENTS

Public lighting is considered as an effective accident countermeasure. This idea is based on a large body of research, that is recently summarized by the Commission Internationale de l'Eclairage CIE. The overall result is that a "good" public lighting as compared to very poor or absent public lighting may be expected to reduce nighttime injury accidents on major urban thoroughfares by about 30%. This result is primarily based on a large body of experiments made in Great Britain in the 'fifties and again in the 'seventies: the result is supported by a considerable number of tests in other countries. Summarizing these results, the 30% reduction may be regarded as a "scientifically proved statement". The statement, however, is restricted to the comparison of "good" to "very poor" public lighting and to major urban thoroughfares. It is not known what "good" means in this respect, nor what result one may expect on other types of road. Finally, the research did not address the question as to which roads require a public lighting installation in the first place. The last question is obvious for rural roads that often have no public lighting at all; it is relevant for urban roads as well as this regards the road safety aspect.

3. RESEARCH NEEDS

Research is needed in two respects:

- in order to be able to assess the precise required quantity and quality of light under different conditions of traffic and environment, further research is needed as regards the visually critical elements as mentioned above;

- research is needed to fill the gaps in the accident study that was mentioned in the last section: it is required to know what is the reduction in accidents (if any) one might expect in other roads and streets; it is required to know what lighting can be considered as "good" for different conditions, and it is needed to know what (rural) roads require public lighting. For this, additional accident studies seem to be necessary. When such studies will have been made, additional statements can be made regarding the calibration of the research results on the visually critical elements, and regarding the cost/effectiveness of public lighting.

It may be expected that the research will benefit from international co-operation. Both research subjects require a wide variation of input data and they both will require extensive means. In some cases a bilateral effort of two countries will be appropriate, as e.g. is suggested by Belgium and The Netherlands regarding a further analysis of the lighting and accident data collected on the Belgian motorways (as described by Mr. Sarteel). In other cases a multinational co-operation may be called for. In this respect, international bodies like OECD, PIARC or CIE might give valuable assistance.

The results of the research will be applied for the definition of specific accident countermeasures. They will play a role in establishing (national or local) policy regarding the installation and operation of public lighting, and they will be the basis for Recommendations, Standards of Codes of Practice on public lighting. At present, these documents are based on practical experience and common sense; results of scientific research will form a much more sound basis for them, so that the reluctance that is sometimes felt in applying them will be taken away.

Presently, research along both lines is considered in The Netherlands. On the basis of several pilot experiments, a larger study will be set up regarding the visually critical elements. The pilot experiments suggested that the notions held until now regarding these elements is not complete and maybe even incorrect. It was suggested that the run of the road is much more critical than the detection of small obstacles (like the object of 20 x 20 cm that is often used) and that on busy roads the detection of the relative position and speed of other road users is crucial. Further accident studies are considered as well; here emphasis will be placed on the minimum required light level for different types of road. The set-up is similar to a study made in Great Britain several years ago; from a number of streets data are collected regarding the lighting and the accidents. Contrary to the British study, in the Dutch study it is proposed to collect accident data from a large number of roads and streets of different class and with different traffic characteristics; furthermore a much larger sample will be used so that the statistical analysis can be made more accurate. In order to restrict the overall research effort, the lighting data will be less complete than in the British study. A pilot experiment in the city of Dordrecht suggests that the approach is feasible.

4. RECENT DEVELOPMENTS

Recently, a number of interesting new developments have been made and applied regarding both installation and operation of public lighting.

As regards installation, new light sources may be mentioned, offering better colour characteristics in combination with higher efficacy. The new family of low pressure sodium vapour lamps (SOX) should be mentioned separately; these monochromatic light sources that obviously do not permit colour perception have reached the border of 200 lumen per Watt!
Improvements in the optical design of lanterns and consideration of the light reflection properties of road surfaces have increased the overall (system) efficiency even further. Improved lantern construction and selection of better materials have decreased the influence of dirt and corrosion. Finally, the application of computers has allowed an optimal design for different conditions. As a result of these improvements, the costs per "$cd.m^2$" did not increase much, or even did decrease in some cases, in spite of the explosive increase in energy costs.
As regards operation, an improved system of cost control based on more effective data collection has led in many cases to a considerable reduction in running costs of public lighting installations. An example of such a system is given by Mr. Sarteel.

5. CONCLUSION

Public lighting is an efficient accident countermeasure. Furthermore, it fulfills several other functions. For major urban thoroughfares, good public lighting may result in a reduction of some 30% in nighttime injury accidents.

Further research is needed in several aspects. It is to be expected that this research will benefit considerably from international collaboration. In this respect, international organizations like OECD, PIARC or CIE could assist. Finally, a number of recent developments did result in a considerable reduction in installation costs, and particularly in running costs.

ROAD SAFETY IN DEVELOPING COUNTRIES

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INTRODUCTION

The fight against road accidents requires considerable and continuous investment in better roads, better vehicles, and - perhaps above all - better trained and informed road users. Developing countries are particularly badly-placed to afford considerable and continuous investment in anything, and there is no shortage of competitors clamouring for their scarce resources. But there is a growing realisation that road accidents are an unwelcome side-effect of the increasing movement of people and goods which accompanies economic growth. Many of the poorer developing countries are now recording death rates, relative to their populations and numbers of vehicles, considerably greater than those of the developed world. How can such countries benefit from the considerable experience in road safety matters acquired by the industrialised countries, and what is the role of road safety research in this process?

BACKGROUND

Some fifteen years ago my own organisation started to look critically at the available data on accident rates in developing countries as part of its wider research programme into the transport problems of the Third World. This early work showed the scale of the problem, and suggested that around one percent of gross domestic product was being wasted in traffic accidents - an early estimate which has been confirmed by more recent studies in countries as disparate as Cote d'Ivoire and Malaysia. This early work helped to awaken the concern of both the national authorities and the international organisations; in 1976 the World Health Organisation (WHO) established a specific global programme for the prevention of road traffic accidents, and in 1981 held its first international conference on the subject in Mexico City. The United Nations Economic Commission for Africa (ECA) organised the first African Road Safety Congress in Nairobi in 1984, and a second Congress is being planned for 1988 in Egypt. The corresponding UN organisation in South East Asia (ESCAP) held a special meeting on accident data collection and analysis in 1985, and further meetings are planned. International organisations whose main activity is in the developed world (PIARC, PRI, OECD etc) are starting to put developing country road safety problems on the agenda.

A GLOBAL VIEW

Figure 1 shows the number of fatalities per 10,000 vehicles in relation to the number of vehicles per 1,000 population for some 60 countries for the year 1980. The first ratio is admittedly a crude measure of exposure, but reliable information on vehicle use in developing countries is generally unavailable. In deference to the weakness of the data, the solid curve is simply drawn in by eye. The data extends from the lightly-motorised countries of Africa to the heavily-motorised ones of Europe and North America, with the intermediate economies of Latin America and South East Asia lying between. The rapidly-developing oil-exporting countries of the Middle East (the seven open circles) stand out above the general trend; a recent Libyan study ascribes this relatively poor performance to the high rates of motorisation experienced by these countries in recent years.

This global view shows that in road safety, as in many other matters, the division of the nations of the world into "developed" and "developing" is a gross, and possibly misleading, simplification. Rather, we are faced with a continuum of situations, and it is presumably the hope of any single nation to progress downwards on the vertical scale of Figure 1 as it progresses from left to right as its economy flourishes - preferably at a rate and in a position better than the "average".

This time-related interpretation of these figures from what is essentially a cross-sectional data set has no real scientific foundation. However, it is interesting to look at the time series data for a country using the same statistics, and in Figure 2 the "progress" of Great Britain is shown over the past 70 years. Many of the industrialised countries could tell a similar story, but this progress has been bought, particularly in recent years, with considerable effort across a whole range of safety measures. It could be argued that motorisation in the developed world has kept pace with other investments (such as medical facilities, the quality of the road network, vehicle improvements) whereas in developing countries the pace is often beyond that which the inherent capacity of a country can contain, even if the organisational and political will is there or not.

SOME BROAD GENERALISATIONS

Apart from the poor economic picture which affects almost every aspect of national life in a developing country, there are one or two general characteristics of the countries on the left hand side of Figure 1 which have an important bearing on the present safety situation and the way in which it is likely to evolve.

Motorisation

General travel demand is known to increase with rising income, and car ownership at the lower levels of existing ownership found in many developing countries increases at roughly double the rate of income growth. Research by the Overseas Unit in Kenya has shown that this high elasticity is accompanied by an increasing willingness to spend a higher proportion of household income on acquiring and using a personal vehicle; together these trends point to an almost explosive growth in car ownership and use in developing countries in the future, a forecast reinforced by the cross-sectional data of Figure 3 which shows national average data of "motorisation" against GNP per capita. These changes can already be seen in some countries; in South Korea there was a quadrupling of vehicle ownership over the decade 1970-80, and a trebling in Indonesia.

Formal statistical analysis of national data from a wide range of developing countries confirmed the dominating association of vehicle ownership levels with both fatality and casualty rates. In these analyses, other indicators of development such as vehicle density per length of road, medical facilities per head of population etc have been examined. In particular, the proportion of all injury accidents which result in a death (the fatality index) has been found to be closely correlated with the number of hospital beds per head of population which, in turn, is clearly related to the general wealth of the country. It must, however, be remembered that the under reporting of accidents, which research has shown to be significant in the poor countries, will tend to increase the apparent fatality index.

Urbanisation

As the numbers of vehicles in use in a country increases, the number and length of journeys made also tends to increase. This is particularly true in the urban areas, with their expanding peripheral settlements swollen by a combination of rural migration and inherent population growth. As with motorisation, the growth rates in developing countries are particularly high.

For example, the urban populations of the traditionally rural countries of Africa frequently double every 10 years, although only about a third of the population overall is currently classified as urban (in contrast to Europe and North America, where the fraction is nearer to three quarters). The World Bank estimates that by the turn of the century there will be twice as many cities with populations in excess of a million in the developing countries than in the industrialised countries, and some of these cities will be very large indeed, with more than 20 expected to have populations greater than 10 million. This suggests that the road safety problem of the developing world will become increasingly urban in character.

It is difficult to predict the effects that these changes will have on accident rates and patterns. Much will depend on the investments in traffic engineering and traffic management, and the success with which safety is incorporated in a positive way in such investment. Similarly, the attitudes adopted towards public transport (ranging all the way from shared taxis to traditional metros) will have a strong bearing on the accident problem. Some preliminary research by the Overseas Unit in Egypt has shown that less one percent of the total accidents reported in three urban districts in Cairo were fatal, compared with 23 per cent on the inter-urban desert road between Cairo and Alexandria. Hopefully, the severity of urban accidents, if not their number, will decrease as road networks become more congested and average speeds fall - although it must be admitted that this is a biased optimism unlikely to be shared by the traffic engineer. Certainly the developing cities have opportunities to engineer and "build in" safety which are often not present to the same degree in the more established urban areas of the industrialised world.

Age structure

A recent study of 19 developing countries showed that, on average, one in five of the fatalities were under 15 years of age, compared with around one in ten for a group of typical developed countries. This is not unexpected in the light of the age structure of typical populations - the table below gives a simple breakdown of age structure for 1983 by different regions of the world.

	Total Population	Under 15	15–64	Over 64	Life expectancy
Europe	492	22	65	13	73
N America	264	22	66	12	75
Latin America	406	38	57	5	65
Asia (exc. China)	1787	39	57	4	57
Africa	551	45	52	3	50
World	4845	35	49	6	62

Table 1: Age structure of the global population (1983)

This shows the importance of countermeasures directed at young people, both as the non-motorised road users of today and the expanding population of motorised road users of tomorrow. It also demonstrates the relative unimportance of measures directed at the very elderly - again in contrast to the situation in Europe and North America.

THE NEED FOR ANALYSIS

Not surprisingly, the classes of road users and the vehicle types featuring in accidents reflect national conditions, and the diversity of these between different countries is itself adequate warning of the dangers of applying general solutions or advocating general policies for the "developing countries" as a whole. For example, the following table shows the distribution of fatalities for some 8 countries, with the United Kingdom included for comparison.

<table>
<tr><th></th><th>Pedn</th><th>Cyclist</th><th>M/Cyclist</th><th>Driver</th><th>Passenger</th></tr>
<tr><td>ETHIOPIA (1983)</td><td>55</td><td>-</td><td>-</td><td>9</td><td>36</td></tr>
<tr><td>TANZANIA (1983)</td><td>39</td><td>6</td><td>-</td><td>11</td><td>44</td></tr>
<tr><td>ZAMBIA (1983)</td><td>46</td><td>5</td><td>3</td><td>14</td><td>33</td></tr>
<tr><td>ZIMBABWE (1983)</td><td>31</td><td>6</td><td>3</td><td>18</td><td>42</td></tr>
<tr><td>SRI LANKA (1980)</td><td>52</td><td>10</td><td>10</td><td>6</td><td>21</td></tr>
<tr><td>P.N.G. (1981-84)</td><td>36</td><td>1</td><td>1</td><td>15</td><td>47</td></tr>
<tr><td>INDONESIA (1977)</td><td>20</td><td>2</td><td>34</td><td colspan="2">44</td></tr>
<tr><td>JAMAICA (1978)</td><td>41</td><td>5</td><td>17</td><td colspan="2">37</td></tr>
<tr><td>U.K. (1980)</td><td>33</td><td>6</td><td>18</td><td>24</td><td>18</td></tr>
</table>

Table 2: Approximate distribution of fatalities by country

Drivers and passengers are not differentiated by type of vehicle, but in the UK are almost wholly private car users, whereas the other countries include a significant number of "other motorised vehicles", including trucks, buses and converted pick-ups used as public service vehicles. Even with private cars, there are far more passengers per vehicle on average in the developing countries than in the industrialised ones. Pedestrians feature strongly throughout the world, but there are other interesting differences, such as the relatively high proportion of two-wheeler users in Sri Lanka and the high proportion of motorcycle fatalities in Indonesia.

Table 3 gives a slightly more detailed breakdown of the fatality pattern in three urban areas. These show the expected differences in vehicle mix and use, and also illustrate that there are vehicle types involved in developing country cities which have no counterparts in the West. A more detailed analysis of the situation in Delhi, for example, reveals some important differences in the use of these vehicles, reflecting local social and economic conditions, which have a direct bearing on the accidents and consequently on any measures adopted to reduce them. The car "problem" is relatively trivial. Motorised two-wheelers are used mainly for commuting and as personal family vehicles: it is not uncommon to see several passengers on a single two-wheeler. Bicycles are used mainly for commuting by the poor and lower middle class, and the fatalities are to be found among the working-age population. A high proportion of the bus commuter fatalities are passengers killed when getting on or off the bus; vehicles are very overcrowded and many commuters travel hanging on the outside.

Road User	Abidjan (c. 1982)	New Delhi (1980)	Built-up areas, UK (1980)
Pedestrian	75	33	50
Bicyclist	4	21	6
Motorised 2-wheeler	-	16	21
Car and taxi	4	3	21
Bus commuter	17	11	1
Goods vehicle	-	4	2
3-wheeler scooter taxi	-	3	-
Other	-	10	-

Table 3: % Fatalities in urban areas

The examples quoted so far show that although the general position of a country on a GNP or motorisation scale can give some general pointers as to its accident situation each country needs to analyse its own accident situation as an essential first step in any remedial programme. There are likely to be very strong local variations within countries, particularly between urban and rural districts. For example, Figure 4 shows the national position of India for 1980/81 in relation to the situation in five of India's largest cities (the figure also shows also the situation in 1961 and the log-linear projection to 2001 predicted by the Indian Roads Congress).

A survey by the Overseas Unit some years showed that many countries did in fact collect, via their police organisations, information on road accidents but this was not in form suitable for scientific analysis or for guiding remedial programmes. A microcomputer and program "package" has been developed by the Unit with the needs of developing countries particularly in mind. Its first application was in Egypt, but the system is being evaluated on a trial basis in Saudi Arabia (Arabic version), Ethiopia, Botswana, Pakistan and Papua New Guinea - French and Spanish versions are also available. In conjunction with pre-coded accident reporting forms, such systems enable accident tables and maps to be easily produced, making it possible to direct scarce resources to where they should have the maximum effect. However, it must be admitted that the amount of hard evidence for the effectiveness of countermeasures in developing countries is, as yet, very limited, bringing to the fore the vexed question of the extent to which developed country experience can be translated - with or without extensive modification - to the road safety situation in the Third World.

REMEDIAL PROGRAMMES AND KNOWLEDGE TRANSFER

Clearly, the industrialised countries have several decades of experience which, in theory, is available to help tackle the global road safety problem. Much of this experience and knowledge, particularly in the area of effectiveness of countermeasures, has to be viewed against the time and background in which it has been gained, and the conditions upon which its validity rests have to be carefully scrutinised. Unfortunately, with the pressing needs and the lack of time and professional expertise found in many developing countries it is tempting to adopt "proven" measures which have been successful (and often quantifiably so) in the industrialised countries. For example, seat belts are universally accepted as a worthwhile safety measure - but they might not be the priority in New Delhi, where only 3 per cent of the fatalities are from car and taxis users. Similarly, most road safety experts would urge continuous and vigorous action against alcohol and driving - but might moderate their advice in Muslim Malaysia (a recent German study identified only 0.2 per cent of all accidents has been caused by the effects of alcohol).

On the other hand, there are clearly many road safety research findings which are relatively universal and in which it would be foolish for the developing countries to reinvestigate - for example, the mechanics of seat belts or the basic properties of visibility and conspicuity described by Professor Rumar at this meeting. The challenge probably lies in being able to absorb the vast amount of information from the developed world (see, for example, the recent synthesis produced by the OECD) and distinguish that which is applicable from that which is adaptable. This is a task in which we can all help, while encouraging fellow professionals in developing countries to collect their own data and be prepared to experiment, monitoring their own field trails before making large-scale investments with long-lasting effects.

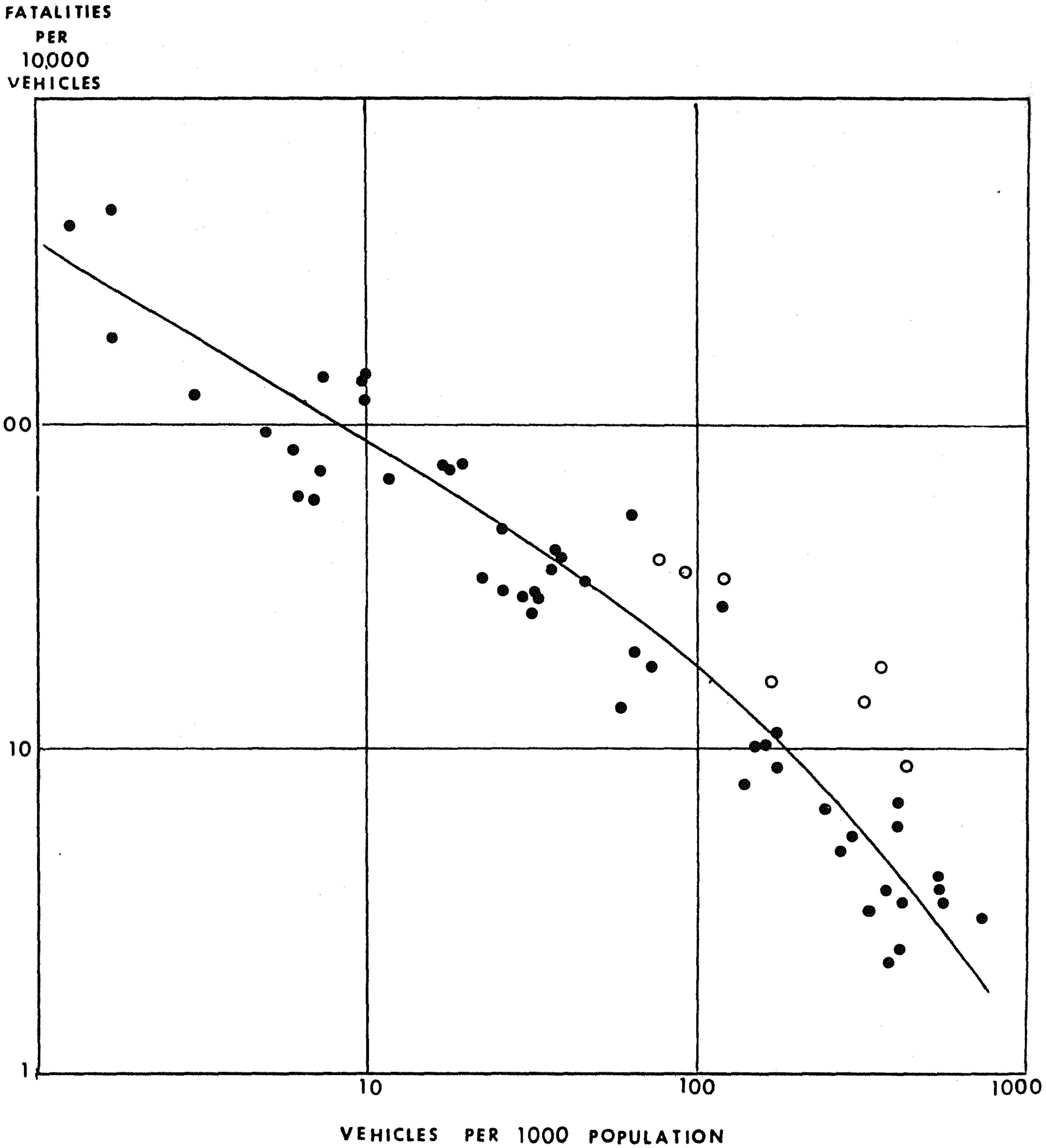

Fig 1 FATALITY RATES AND MOTORISATION,
DEVELOPED. AND DEVELOPING COUNTRIES, 1980

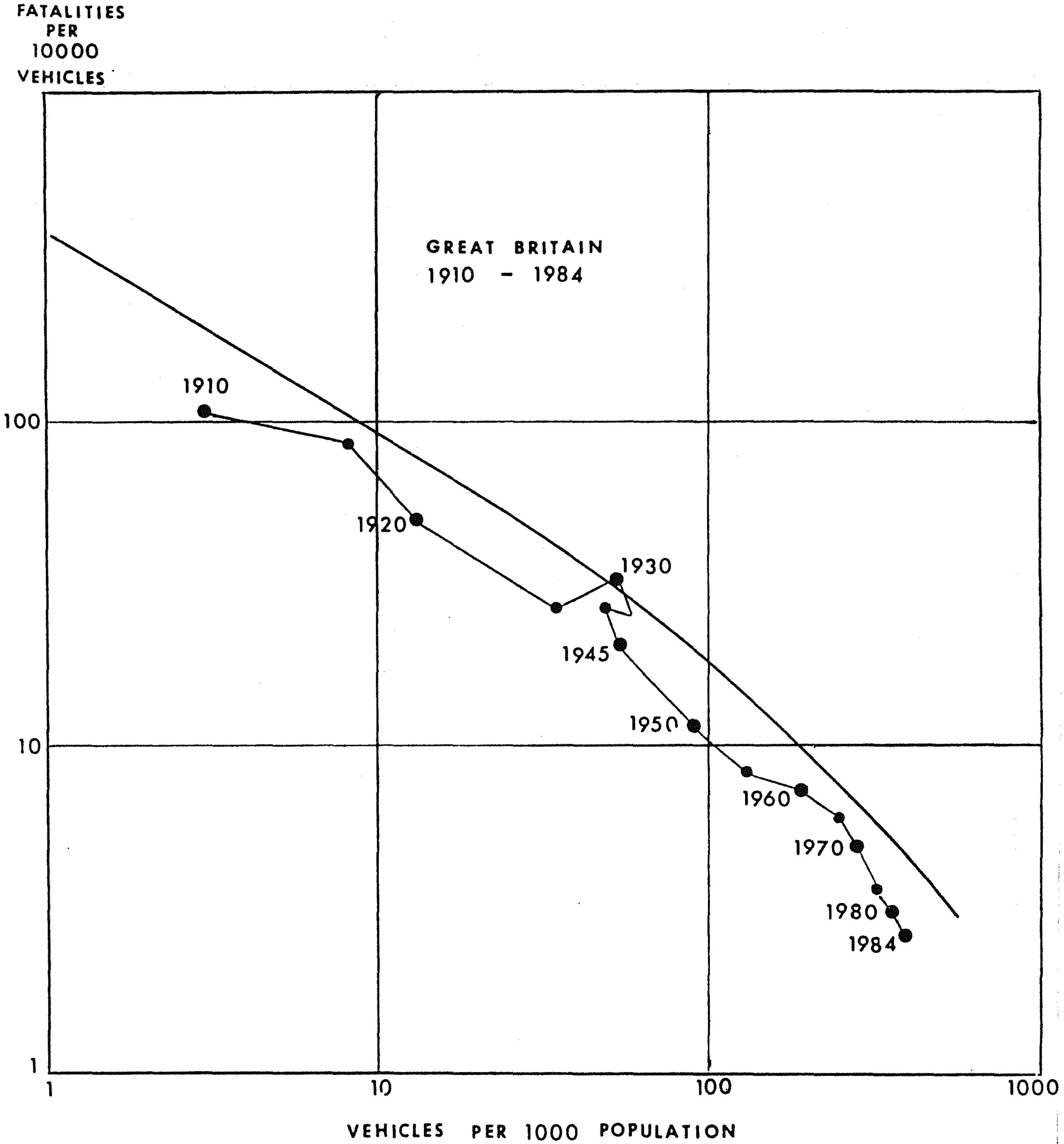

Fig 2 FATALITY RATES AND MOTORISATION,
GREAT BRITAIN 1910-1984

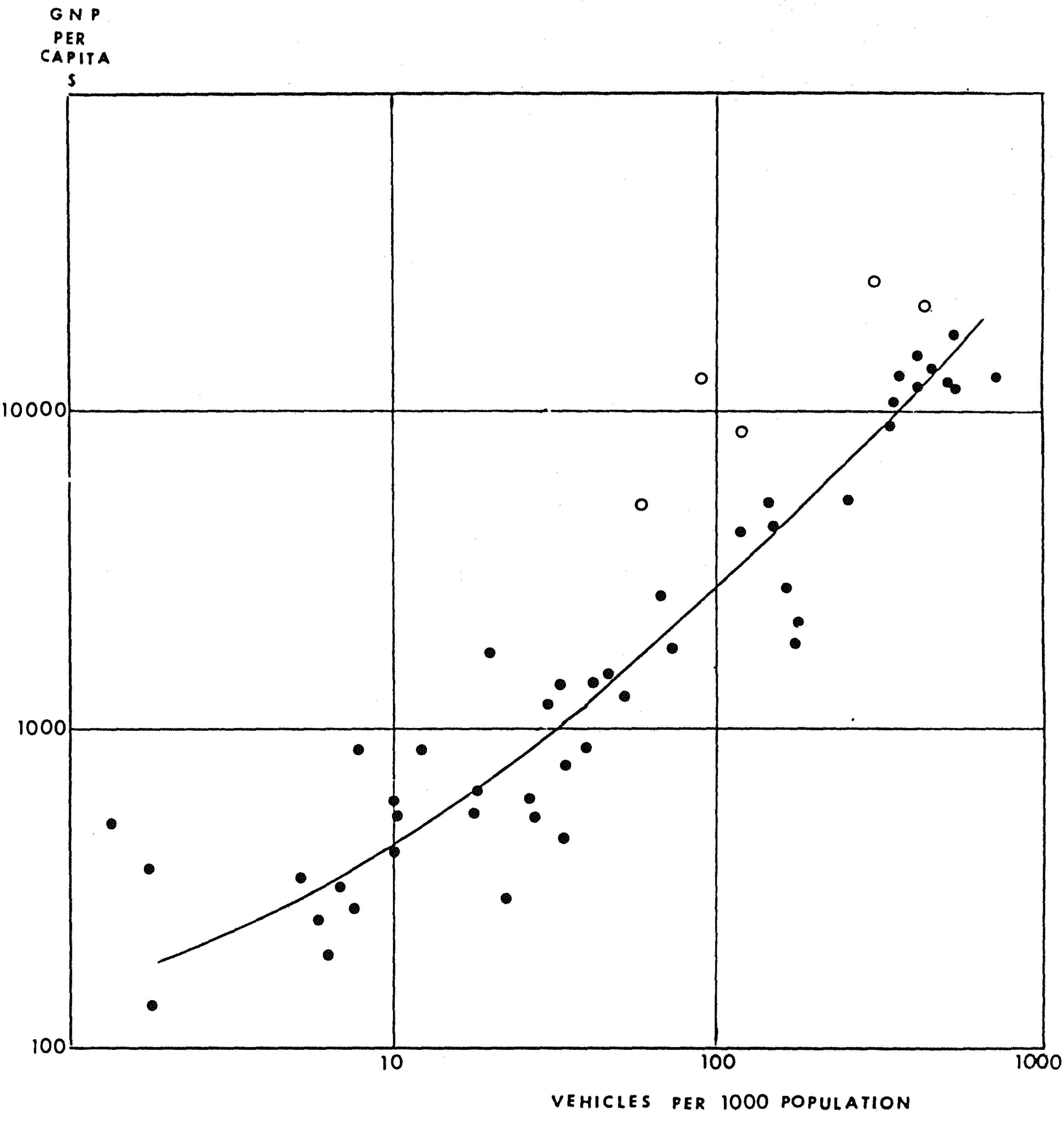

Fig 3 MOTORISATION AND GNP PER CAPITA

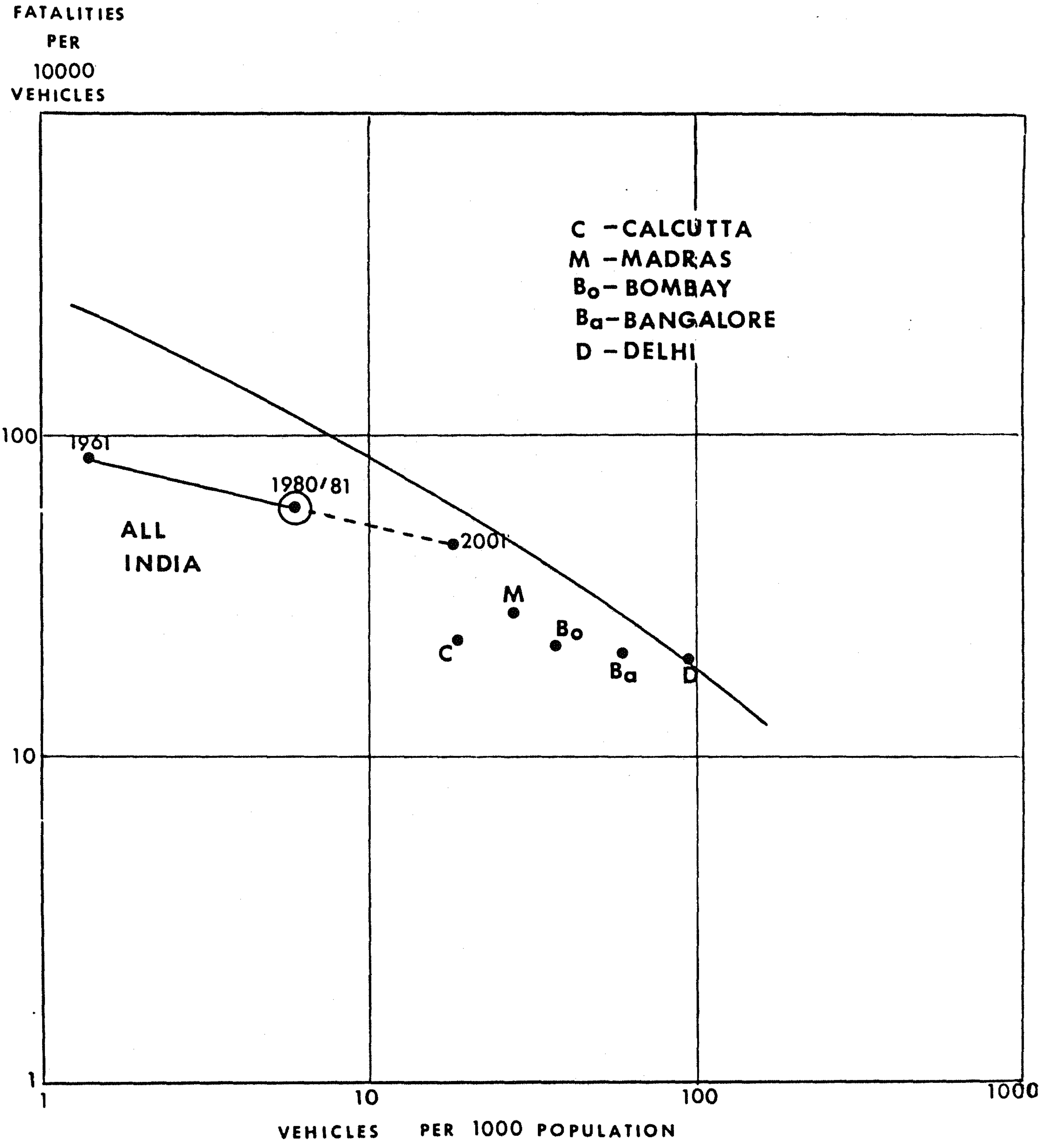

Fig 4 FATALITY RATES AND MOTORISATION,
SOME INDIAN DATA

ROAD SAFETY IN DEVELOPING COUNTRIES: THE ROLE OF RESEARCH

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1. INTRODUCTION

Road accidents are a continuous burden for all countries, developing and developed alike. There are reasons, however, to pay special attention to developing countries as the situation often seems to be even more unfavourable as in developed countries, and as the consequences of road accidents, even individual accidents, can be much more far-reaching. As an example, consider the results of a fatal accident involving a hydrological expert in a developing country and its consequence for the food situation! In this note the situation in developing countries will be discussed, the role of developed countries in improving the situation, and more in particular the role of scientific research.
First, a general discussion of a number of concepts will be given.

2. DEVELOPING AND DEVELOPED COUNTRIES

2.1 Indicators

Usually, the Gross National Product (per capita) is used as a measure for the economic situation in a country, as most of the activities that may be used as predictors or descriptors for the degree to which a specific country is developed, correlate fairly well with the GNP. It is, however, a crude measure that cannot take into account the specific situation of a specific country, more in particular regarding its cultural development. Further, it is primarily a "moment exposure", as most general developments particularly in the fields of technology (e.g. vehicles) and in information sciences (e.g. computers) are worldwide and affect developing countries in the same way as developed countries.

2.2 Degrees of economic activity

When considering questions of road safety, the distinction in developing and developed countries is not accurate enough. A finer subdivision shows five degrees of economic activity, more in particular five degrees in growth rates of economic activity.

- Post-industrial countries: the economic growth rate is small or even negative, whereas what growth may be found is nearly exclusively in consumer (luxury) goods. (Example: Sweden; USA).
- Industrial countries: the economic growth rate is positive and is primarily determined by growing activities in high-technology industry. (Example: Singapore; Taiwan).
- Expanding countries: the economic growth rate is considerable; its major contribution is from heavy industry and half-products involving the local raw materials. (Example: South Korea, Mexico).
- Stagnant countries: the economic growth rate is small, whereas the level of economic activity is low. The economic growth that may be achieved is used primarily for buying raw materials, particularly oil. (Example: Egypt, India).
- Impoverished countries: the level of economic activity is low and further declining. In most countries the production is not enough to ensure the basic needs of the population; foreign support is required in order to avoid actual famine. (Example: Sudan, Ethiopia).

It should be noted that the examples are given only to illustrate the degree of economic activity. The more common distinction between industry countries and third-world countries can be put at about the border between the second and the third class as given here.

2.3 Geographical and political spread

The industrialized countries are concentrated in the moderate climatic zones of the Earth, particularly at the Northern Hemisphere. The developing countries are located mostly in the tropics and the subtropics. Historically speaking, nearly all industrialized countries are "old" countries: they are independent in roughly their present borders for a long time, mostly several centuries. The countries having stagnant or impoverished economies are mostly young countries that have been colonies of Western industrialized countries until quite recent times. Their boundaries often do not correspond to natural limits of e.g. peoples or languages; the borders usually have been set up on the basis of the needs of the colonial governments. As a result, many of these countries do not have reached the phase of stable social and political structure. At the other hand, they often show vehement nationalism. The process of acquiring a national identity, that took centuries in most European countries, is often forced upon the developing countries in only a few decades. In such developments, the road accidents do not always receive the national priority they might seem to deserve in view of the national urgency for safe and reliable transport. The expanding countries show a situation more or less in between.

The relation between many developing countries and the industrialized world often is rather strained, particularly the relationship with the former colonist countries. At the one hand national pride is easily injured, particularly by these countries, whereas at the other hand many ties of education, language and military history would suggest a more close relationship. More in general, it seems that most developing countries have another approach towards the acquisition of knowledge as compared to the industrialized world. Both acquisition by trade and by support have two sides: they both may be regarded as honorable, but also as degrading as an aspect of neo-colonianism.

2.4 Psychological factors

The GNP is only a momentary value; psychological speaking it is important to note that the rate of growth of traffic and transport in general is much higher in developing countries than in industrial countries. It took the industrialized world nearly two centuries to reach mass motorization from horse-drawn carriages; in many developing countries this process took only one or two decades. One important consequence is the fact that the population, particularly the middle-aged and the elderly, did not have the opportunity to get accustomed to traffic, and to the fast-moving motor car more in particular. Another is the rapid urbanization that is simultaneously a cause for and a result of the mass motorization. Still another factor is the level of education, and the rate of development of it. In most developing countries the level of university education is similar to that of the industrialized world; the penetration, however, (the number of universities and the number of students) is much lower. In many developing countries a college education in the former colonising country represent high value. The education of the middle groups (technicians etc.) often is sparce and of low quality. The level of workmanship of the labour force usually is adequate, be it traditional and old-fashioned. These observations are relevant both for the traffic participants in general and for the authorities that have to implement road safety measures.

3. CONTRIBUTIONS OF THE INDUSTRIALIZED WORLD

3.1 General

When considering the road accidents in developing countries, the industrialized world seems to be in a more favourable position. Data are given in the contribution of Mr. Yerrell. There seems to be room for a stream of expertise from the industrialized world towards the developing countries, expertise that relates to complete products (cars, computers), systems (road design, information systems), expert knowledge (scientific data) etc. There are three distinct ways in which this expertise can be channelized towards the developing countries: trade, support and co-operation.

3.2 Trade

Road safety expertise can be traded just like any other commodity. The industrialized countries supply the merchandise and the developing countries pay for it. In theory this could be on the basis on equality between trading partners; in practice, however, the transactions often are in the advantage of the industrialized world. One reason is that in many cases the developing countries pay with raw materials that are exported back to them as finished products. The priorities usually will be dictated by the stronger partner; thus, it is not guaranteed that the priorities reflect the need of the developing country. In this respect, a market analysis might be of help. Financing the schemes usually offers no specific problems as the financing is usually done by the same institutions that agree on the trade. In conclusion: in some cases a trade might be useful for the developing countries, but it is more likely that primarily the industrialized world will benefit.

3.3 Support

Support to developing countries is a much more delicate matter. At first it might seem favourable for developing countries, particularly the poor ones. However, support often hurts national feelings and often is organized by non-professionals. Further, there is a risk that economic requirements or political ideologies will influence the support programmes. The financing of support usually is difficult. In some cases international bodies will guarantee the finances (e.g. the World Bank). Finally, support usually is aimed primarily at the dissemination of knowledge: the difficulties of implementing that knowledge is often underestimated.

The way the support may be realized depends upon the problems to be solved:

- the specific problems of developing countries, or the problems of one specific country. Here the economic and cultural situation are predominant; in order to assess what is the best support, these factors must be known in some detail. In most cases, this involves particular study, and also the assessment of local traffic and accident data. These factors require a flexible frame-of-mind of the researchers. An important advantage of this type of support is that the national priorities of the particular developing country will be prevalent;
- the general problems of road safety. This approach is the more common to take: it is assumed that the developing countries have the same problems as the industrialized countries, and furthermore that (by consequence) the same countermeasures are effective. As long as the decision making process is presented to the developing countries and not the final solution, this approach may lead to favourable results. A major disadvantage is that also in this case the priorities usually are not those of the developing country;
- preventing that the same errors are made. It is often felt that a major contribution in road safety support could be to help the developing countries to avoid the mistakes that were made in the industrialized world.

It seems that this approach is more relevant for matters of environmental protection and of urban planning than directly for road safety measures.

As a conclusion it can be stated that support may be a valuable help for developing countries to reduce road accidents, particularly if the local economic and cultural situation is taken into account and if the priorities are those of the developing country.

3.4 Co-operation

Co-operation presupposes a notion of being equal partners: all members of the great family of man, independent of race, religion, politics or economy. It suits best the idea that the distinction between developing countries and developed countries is an arbitrary one: in reality it seems that there is a continuum of states. Considering that all countries essentially have the same problems of road safety - be it in different degrees - it is logical to try to solve them in similar - if not identical - ways. In this respect exchange of expertise, support for education and training for the general public and support for specialized schooling for policy makers and authorities seem to be the most effective. Financing might pose a problem; many industrialized countries have, however, considerable budgets for support to developing countries. It could be considered to use these budgets also for improving road safety.

4. DATA COLLECTION AND HANDLING

In para. 3 three different ways were discussed where the industrialized world might assist the developing countries to improve the road safety. In a number of cases, further research is needed. Many of these research needs have one aspect in common: the need to collect reliable data regarding traffic, accidents, and other - e.g. demographic - data. As indicated in the paper by Mr. Yerrel, the collection of data is often difficult and sometimes virtually impossible under the local situation. An essential contribution towards the improvement of the road safety is therefore the assistance in setting up data bases in developing countries. The experience of doing so in industrialized countries may be of some help, but practice did indicate that the problems one faces in doing so in developing countries really are different, not only larger, as compared to the industrialized world. There seems to be a need to establish a system for setting up data banks. A further step is assisting the developing countries in handling the data from these data banks; data are useful only to the extent they can be processed. Here again it seems that a system is needed that can give the developing countries a guideline how to set up processing systems, particularly as regards the extent to which these data can be used in forming and maintaining road safety policies.

5. ORGANIZATION OF RESEARCH

In order to be effective, the research needs to fulfill several requirements:

- A first consideration is that the research is truly international. Not only are the developing countries many and manifold; also the knowledge that can be used and the facilities for research are distributed over a number of countries, each of which is specialized in some respect.
- Secondly, the research should be coordinated or even be initiated by international and supranational organizations. This is required by the need to take into account the national identity; further this is needed to safeguard the research from national and/or commercial interests in the industrialized world. At present there is a number of international organizations that may play a role, both of a supranational nature and of a private, nonprofit nature. Examples are: United Nations with various divisions and subdivisions, such as e.g. World Bank, WHO, UNESCO etc.; further organizations like OECD, PIARC, IRF etc. In fact, it seems that the number of organizations that might have a role in international research on the road safety of developing countries is considerably larger than actually needed; this implies that at least some coordination between all these organizations is required.
- Thirdly, it is advisable that several countries - preferably a small number - take the lead in organizing such research. The countries most suited for this seem to be the countries that have experience in research in developing countries. Within these countries the actual research can be undertaken by national (governmental) research establishments or by private consultant firms. Working under the auspices of the international organizations will guarantee independent research. It seems to be preferable that

these establishments and firms do not undertake actual consulting work at the same time, as commercial consulting and research might easily confuse the developing countries.

- Fourthly, the research activities should start by establishing an international programme that is applicable for the majority if not all developing countries, taking into account the differences in economic and cultural situation. The programme should start with designating a small number of research subjects with the specific aim to found and increase trust from the part of the developing countries in the programme. For this, these initial subjects should represent aspects having the highest priorities, permitting wide application between and within countries, leading to directly applicable results, and assuming international approach. Examples are the set-up of systems for data collection and data processing as indicated in para. 4; systems for establishing priorities in possible road safety measures, and training and education of government and local authorities in practical aspects of road safety management.
- Finally, the financing of the research should be organized in a better way. Both international and national budgets designated to support to developing countries could be employed; the conditions should be different, however, from those needed for technical support schemes. More in particular, it should be avoided at the one hand that conditions include the supply of material or expertise explicitly from firms in the industrialized world, and at the other hand the financing should be flexible enough to allow research programmes for which the results cannot be guaranteed explicitly at the outset.

GENERAL REMARKS: "ON PROGRESS IN ROAD SAFETY RESEARCH"

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As most of you, I had a request from our chairman to prepare some statements, in this instance introductory to a general discussion, and center my remarks around these statements. In doing so, I've put a number of constraints on their formulation, apart from them being general, of course.
Firstly, since we are here to talk about developments in road safety research, something should be said about progress in road safety research.
Secondly, they should tie in with the papers and the discussions we had today.
And thirdly, they should not be too serious, since we would probably run out of time - as we do - and any discussion will probably have to take place at Erik Asmussen's reception in a quite different atmosphere. But maybe there should be a more or less serious argument behind them.
The first statement is more or less triggered by the topic Safety in urban areas, but may have a wider application. It reads as follows: "Very little research has been done into questions of effectiveness of road safety research."
The argument behind it runs somewhat along the following lines: Rather then being part of a research community - as we sit here together - we are all part of (national) problem solving communities. Research progress consequently has to be measured in terms of (its contribution to) problem solving potential and ultimately in terms of reduction of losses on the road.
As part of such problem solving communities, researchers have a responsibility for the effective utilization of knowledge and the development of strategies to that end. Achievements in this respect will be dependent on an understanding of the political and social environment in which safety management takes place, preferably an understanding that goes beyond speculation or informed opinion.
So some of all that analytical power might be well spent in determining the conditions under which research results are, or are not, effectively put into practice.

The issue is most prominent with respect to the subject of safety in urban areas. I refer to questions of integrated safety programmes and cooperation between research and practice as we discussed this morning. One might hold that in this particular area a lot of progress has already been made in terms of cooperation between researchers, practitioners and policy makers, when compared to other problem areas, progress in the sense of effort put in information utilization. Analytically, however, in such situations of close interaction the problem becomes even harder. In the Netherlands, for instance, with respect to the development and application of the woonerf-concept, cooperation has been such that it would be very hard indeed to establish what exactly has been the contribution of research and what has come from other sources.

The second statement relates on the one hand to the paper of Mr. Yerrell and questions of validity of research results obtained in Western countries for developing countries, on the other hand to the discussion we had on theory. It reads as follows:
'We know most about the problems we don't solve'.
The argument behind this statement runs along the following lines:
Generally, a change of focus in road safety research may develop because a certain problem is solved, because conditions change, or because constraints on solutions change. The last point may need some clarification. One might hold, that the way in which a problem is to be defined is to some extent dependent on the contraints on solutions, be it financial, social, or otherwise. With respect to nighttime visibility, for instance, as discussed by Mr. Rumar, financial constraints on the application of public lighting may change the problem to one of vehicle lighting, with consequences for the sort of analysis made of the visual environment.
Returning to the statement, it stands to reason that, if conditions and constraints on solutions do not change and a problem is not solved, we continue accumulating knowledge on that problem and consequently know most about those unsolved problems.
The more serious point here is, of course, that of specificity or generality of knowledge and transfer of knowledge from one problem situation to another, which is essentially the same one as we raised in our discussion on theory development.
Having heard this discussion, I think it would be safe to state that road safety theories are thought to be on the one hand so general as to become

practically meaningless, on the other hand so specific as to have practically no transfer to other problems than the ones designed for. Of course, I would not pretend to have a solution for such a major problem but some suggestions might be made, just taking the above statement literally.
If theories are thought to be either too general or too specific, the obvious third choice would be to move to intermediate levels. This would then mean that on the one hand a continuous effort should be made to generalize from specific research results or theories/hypothesis formulated in relation to specific problem areas. On the other hand, general theories such as 'risk homeostasis' or 'risk compensation' should then be broken down in the sense that conditions are specified under which the theory is, or is not, valid, as well as degrees to which the theory is valid for specified conditions.

POSTSCRIPT by PROFESSOR ERIK ASMUSSEN

To the organizors of and contributors to the workshop

Now that the hustle and bustle surrounding my retirement from SWOV has died down, I feel the need to express my gratitude to you all. Those were an unforgettable few days for me! I was deeply moved by the many tokens of recognition and warmth elicited by my departure.

The presence of so may foreign colleagues, both at the Workshop on 19 November and at the Seminar on 20 November, proved to me again that SWOV still occupies an important position internationally and that its research, views and approach are still widely regarded as pioneering. I am certain that SWOV will retain this position: the quality of the staff and, in particular, the new Director will ensure this.

Research is normally the fruit of collective brainwork. New ideas and discoveries, on the other hand, are usually produced by individuals. Any new development is usually preceded by a mutual fertilization period, a kind of cross-pollenation. A research organization is in some ways similar to a hothouse: how well things grow there depends to a large extent on the climate. I am convinced that a good deal of the rapid growth of SWOV and the scientific authority it has acquired, both nationally and internationally, have been due to the good climate and the freedom for the cross-pollenation of ideas to take place.

International contacts like those at the Workshop on 19 November should be expanded, so that more use can be made of the results of research and the quality of the research improved. This will benefit the theoretical side, as I have been urging for many years.

Once again let me thank you all for all your hard work and contributions and wish you every success in the future.