A century of automobiles: Past, present and future of automotive safety

Scientific meeting of the research institutes:
Bundesanstalt für Straßenbwesen BASt (Federal Republic of Germany)
and SWOV Institute for Road Safety Research (the Netherlands)
The Hague, October 7th 1988.

SWOV Institute for Road Safety Research, The Netherlands

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WELCOME AND INTRODUCTION SPEECHES

M.J.Koornstra, Director
SWOV Institute for Road Safety Research

Ladies and Gentlemen,

It has been three years since the BASt invited the SWOV to visit their institute in Bergisch Gladbach. It provided a fruitful exchange of knowledge for us, and we remember the fraternal atmosphere of those days very well.

Since about one houndred years ago, the horse, horse-drawn cart and horse tram have been replaced by the automobile on an increasingly larger scale.

Institutes such as ours have been active for some twenty to twenty-five years, studying the negative aspects of traffic and transport systems and proposing measures to improve the situation. But I think our approach is too autonomous; we are too isolated from each other.

Swapping experience, know-how and products from studies of that past, about what is relevant today and what we want to achieve with future developments through our shared concern for traffic safety would benefit both parties.

In the past, bilateral contacts have been more frequent than contacts at institutional level. Nevertheless, I believe that visits between institutes, such as the one today, are important for the exchange of scientific information and to stimulate scientific cross-pollination.

I sincerely welcome our neighbours from the Federal Republic of Germany and hope that today's renewed acquaintance can give you a better picture of a number of studies presently being conducted by the SWOV.

K.-H. Lenz, Director
Federal Highway Research Institute (BASt)

Dear Mr. Koornstra,

Ladies and gentlemen,

Colleagues,

At first many thanks to our hosts for the invitation to Holland. It was a great pleasure for us to come here and the large number of German participants, making up more than three football teams, is a demonstration of the great attraction of your invitation. I am also very pleased that we are not only pursuing sporting aims to strengthen the element of friendship in this second joint gathering, but have come together also for a scientific exchange. SWOV is renowned all over the world for the efforts it invests especially in the theoretical support of the information and data it obtains. Our strong points lie more in the empirical and pragmatic sector. I believe that an exchange of knowledge will enrich both parties, and in the coming years when Europe will be growing together this type of exchange is actually an urgent requirement on an international basis. If inadequacies still persist in this sector, especially as regards the scope, this is among other things also due to the financial restrictions under which we all suffer. Just going to Leidschendam still means for us a trip abroad and is therefore more difficult to accomplish than a trip to Munich which lies further away and requires more travel time. It should not come as a surprise therefore that normally only one BASt staff member can participate in a meeting of this nature. The fact that so many of us have nevertheless been able to come here today is because each of us is paying part of the travel expenses and because a normally unusual flexibility on the administrative side has come to our assistance. All this, I should say, is already enough of a victory, regardless of the outcome of the football game. So let me conclude by wishing all participants in this meeting many new impressions stimulating both in the professional and personal area. In addition, I wish you all a very pleasant and memorable time together. I trust this meeting will bring fruitful results.

G. Riediger
Federal Ministry of Transport

ROAD SAFETY ASPECTS 1988

In 1982 the "*Höcherl Commission*" made the following statement in its analysis of the road safety situation then prevailing in the Federal Republic of Germany:

"What would happen if
- the air traffic authorities reported an air crash with 250 dead every week? or
- a ship with 1,000 people on board sank every month? or
- a town of 11 - 12,000 inhabitants were to be wiped out by a catastrophe each year?

The result would be a national scandal!
However, there is almost no public interest shown in the fact that every day in the Federal Republic 32 people are killed and 1,300 injured in road accidents. This disinterest is clear evidence that too little attention is paid to road safety in public discussion."

In 1984, the Federal Government passed a road safety programme which, amongst other things, called on <u>everyone</u> to play their part in improving road safety by assuming greater responsibility for their actions. It also called for an increase in the importance which society attaches to road safety.

Unfortunately, there has so far been little noticeable change in this unsatisfactory situation. Enhancing the role of road safety in public discussion continues to be one of the major goals in road safety policy.
A number of revisions in the road traffic regulations and road traffic licensing regulations have become law on October 1, 1988. Most of these clearly illustrate just how much work is still needed before we arrive at a situation where road users become fully aware of their responsibilities. Although the Federal Government has emphasised that better behaviour cannot be enforced simply by extending and expanding prohibitions and legal regulations ad infinitum it saw no way in which it could avoid these regulations by making further appeals to the responsibility of the individual. The new regulations cover a wide range of aspects, including, for example, fights for

parking spaces, a ban on overtaking at zebra crossings, forming an emergency lane on multi-lane roads, and precise instructions for vehicles wishing to overtake or those entering traffic from lowered pavements. These and other provisions would be superfluous if the greater majority of road users were to show a greater safety awareness in traffic situations. One aspect which is particularly disappointing following the conclusive results obtained from the compulsory use of seat belts over recent years is the fact that we once again have to use legal provisions to convince parents that they should also use safety devices to protect their children in vehicles.

The Federal Government believes that such a clear lack of responsibility must be eliminated. It wishes to set new standards and has earmarked DM 3 million for 1987 for planning a national road safety campaign. This campaign will run from 1989 to 1992 and is intended to increase the awareness of both the individual and society as a whole in matters relating to road safety. The importance of road safety must be set at a much higher level.

The national campaign has the aim of changing behaviour in road traffic to produce a greater sense of responsibility and caution amongst road users in order to reduce the number of road accidents and their consequences.

The campaign is to concentrate more on the feelings and motives of the road users, rather than improving their knowledge:

(1) It has the goal of creating a greater sense of personal involvement by setting the road user in true-to-life situations and showing him the consequences which can result from incorrect driving behaviour. Motorised road users in particular must be shown that they not only bear a responsibility for themselves, their families and their friends, but also for other road users. They must also be made to understand that their mobility must not be exercised at the expense of other road users' mobility.

(2) The campaign should be addressed to all sections of German society, to all associations, to all organisations active in the field of road safety, to all levels of the administration and, in particular, to all road users. We therefore want to see this campaign as a "national" campaign.

(3) We use the word "campaign" since, in line with the original sense of the word, we wish to involve the entire country right down to the local authorities. We believe work at local level is an area which promises considerable success since individual road users can be best addressed in an environment they are familiar with.

Finally, allow me to use this opportunity to make two further remarks. Research is one of the essential prerequisites for efficient, well-planned road safety work. And research requires an exchange of information, also, and in particular, at an international level. This is reason in itself for the Federal Minister of Transport to welcome this event. However, in the same way as practical road safety, research work and an exchange of information can only thrive if we exhibit personal responsibility and conviction. This is something which everyone here has clearly demonstrated and I would like to congratulate everyone for this, both guests and hosts alike.

R. Roszbach
SWOV Institute for Road Safety Research

A CENTURY OF AUTOMOBILES

Introduction to the SWOV-BASt mini symposium on
Past, Present and Future of Automotive Safety

"Accidents will happen
..I know, I know, I know"
elvis costello*

People impose constraints on solutions, when solving problems. Sometimes such constraints are unneccessary, self-imposed, and may seriously hamper finding a solution. You can find some striking examples of this phenomenon in many an elementary psychology text
It is from this perspective, that we have chosen the rather pompous title for our mini-symposium. Meaning it, for our informal get-together, as an incentive to move somewhat out of our daily frames of reference, taking the long and/or broad view, and maybe come up with some interesting (or funny) new ideas or angles.
Generally speaking, this message seems to have come across. Although I must confess that it appears to be better understood by our distinguished guests from BASt than by our colleagues from SWOV. But then, long-distance communication does have it's advantages. The relations between distance, frequency and signal-to-noise ratio of communications are not easy ones.

In the same vein, this introduction provides me with an opportunity to give you some personal views and observations on the theme as such, without bothering too much about the evidence.

Firstly, I would like to talk about

THE AUTOMOBILE

as a machine and it's development in approximately a hundred years. Although it is somewhat dangerous to distinguish between basic and secondary characteristics, my first proposition would be that there have been

NO BASIC CHANGES

in it's characteristics since just after it's early and experimental stages. (With such statements, one can easily get rebutted by the remark that there have been no basic changes since the invention of the wheel and the fire. The automobile, however, would seem to be a creative combination of "wheels on fire".) The operating characteristics -speed, position and engine control- of this horseless carriage have remained essentially unaltered, while, at the same time, the machine allowed for considerably greater speeds than those performed by man or horse. The changes that do have taken place can be summarized as

IMPROVED PERFORMANCE

*from the album 'Armed Forces', 1979 Riviera Global Rec. Prod. Ltd.

Which is, on the one hand, improved engine efficiency, on the other hand, higher speeds while allowing for comfort and lateral control.
At the same time we realize that something did change. That change can be characterized as

UNCONTROLLED GROWTH

in numbers.

Taking today's weather as the best prediction for tomorrow's weather we can now come to a

PROJECTION

of what will happen to the development of the automobile in the foreseeable future. Which is, in my case, maybe forty or fifty years. (There seems to be some relationship here with possible lifespan, in order that such statements have at least the possibility of falsification in one's own lifetime. Too many old people make predictions.) The first prediction naturally is that

THE AUTOMOBILE
in it's basic characteristics
IS HERE TO STAY

This prediction is not altogether meaningless. It means, for instance, that we should stop dreaming about automated vehicles. The vehicles we will know, will be operated by a driver. We may learn, however, from trying to simulate what exactly it is, that such a driver does.
The second prediction is, that our automobiles

WILL CONTINUE TO IMPROVE IN PERFORMANCE

This is something which is probably already obvious to everyone. Consequences may be, that we will need "super" motorways with design speeds of up to 160 or 180 km/h. Of course, not many accidents will happen there, but when they do, they will be terrible.
The most significant prediction, however, is that the automobile

WILL CONTINUE TO GROW IN NUMBERS
but
SOME LEVEL OF SATURATION COMES IN SIGHT

The basic proposition here is that the growth in numbers can't be stopped, but, realizing that no one can drive two vehicles at the same time, there is some natural ceiling to the number of vehicles per person. Considering the present state of affairs, this saturation level might be reached in the not too distant future.

From the automobile 'an sich' we can now naturally move to

THE TRAFFIC AND SAFETY PROBLEM

posed by it's numbers. Basic to these problems is that they are

INTERTWINED; SAFETY EFFECTS BUT
NOT NECESSARILY SAFETY MEASURES

have resulted in the steady decrease of risks on the road: safety effects from measures which may be primarily or even singularly aimed at improving flow and speed - as in motorway construction - or at conflict-management and flow - as in traffic lights on intersections. With the exception of measures in the area of

INJURY PREVENTION

which can be characterized as more or less pure safety measures and have as such been more, and demonstrably more succesfull than safety measures in the area of accident prevention.
What has been bothering us is that we have been

DEALING WITH UNCONTROLLED GROWTH
but have a
LIMITED CAPACITY TO DO SO

Simplified, we have the capacity to reduce accident rates under conditions of growing mobility by a couple of percentage points yearly. What number of accidents actually happens, then depends on the rate of growth of that mobility, which is beyond our control.
The instruments we have to influence accident rates do seem to be modest. One way or another they usually boil down to specifying

CONDITIONS AND REQUIREMENTS

Conditions under which traffic participation takes place and requirements for the vehicles and people involved. That is, design specifications for roads and intersections, vehicle standards and inspections, driver licenses etc.
Apart from the usual quality or validity of such specifications (or lack thereof) this does not constitute much more than some form of

elementary control

over the traffic system.
After this incisive diagnosis of the state-of-the-art in traffic safety we can now turn to a

PROJECTION

of likely developments in this area.
First of all, we should make a distintion between conditions of

GROWTH versus SATURATION

After reaching saturation in terms of mobility, we will have a much more stable system which will be much more manipulable than the present one. It would go too far, however, even for this presentation, to try to predict what sort of manipulation that could be or even, what sort of system it will be at the time of reaching that level, maybe fifty years from now. A first step towards more stability can be found, however, in

CONTROLLING GROWTH

of mobility, thereby controlling the rate of change of the system and ultimately, accidents as a function of both decreasing risk and increasing mobility.

This is something which may not only be useful from a safety point of view but may even be strictly necessary from other angles. If not, we might be facing several decades of increasing congestion on the roads. A rather unpleasant prospect.
Furthermore, we may expect what can be described as

OPTIMIZING 1st GENERATION MEASURES

The notion of a first generation of safety countermeasures (to be found in Trincal et. al.,1988*)is an interesting one, implying that most motorized countries have developed and implemented -albeit to some extent sub-optimal- a set of similar, conventional countermeasures and are, to some extent, experiencing diminishing returns on safety investments. There would be some room for improvement, however, in terms of devising optimal packages for local conditions. Also, one might assume that

public acceptance

of measures, known to be effective, leaves some room for improvement, as for instance in the wearing of protection by cyclists.
The fundamental question, however, is what our second generation of countermeasures should look like. Of course this story now gets to be really pretentious:
on the one hand, one might aim for

ABSOLUTE SAFETY LEVELS

for some traffic conditions. This would mean such a combination of controlled low speeds, energy absorbing vehicle materials and protection of the potential victim that no serious injury will arise. This would apply to residential area's and such, where apart from speeds, limited control over traffic movements will be exercised. Accidents will still happen there, but the consequences will be minor.
On the other hand, for other traffic conditions one might aim for

PROCESS CONTROL

of traffic movements. Essentially this would come down to registering vehicle movements on some level of detail, predicting "problems" and feeding this information back to the drivers involved in some appropriate form. Requiring quite a bit of processing power for large scale application but moving one step up the ladder leading to a controlled traffic system.

*G.W.Trincal, I.R.Johnston, B.J.Campbell, F.A.Haight, P.R.Knight, G.M.Mackay, A.J.McLean, E.Petrucelli (1988) Reducing Traffic Injury - A Global Challenge. Royal Australasian College of Surgeons, Melbourne.

Postscript:
as a courtesy to the people who, at the time of presentation seated in the middle or back rows, were unable to read the overhead sheets, I incorporated these in the present text, in order that you may yet fully enjoy them, as well as probably make more sense of the contents than the people who were able to read them at the time and now get their second chance. Godspeed.

R.

SWOV-BASt MINI SYMPOSIUM

Statement 1

THE PHENOMENON OF ROAD ACCIDENTS - REVIEW AND PREVIEW

Jürgen H. Klöckner
Federal Highway Research Institute (BASt)

Traffic accidents are not a product of motorization, for people were losing their lives in traffic accidents even before the invention of the motor vehicle. The number of deaths increased, parallel to spreading motorization until about 1970 and then fell in the following years in spite of further growth in motorization. To account for this development, we have evolved an explanatory model with the determinants "exposure" and "risk", which should help us assess future trends.

Where there is traffic and where there is movement, accidents will happen, inflicting physical damage and injuring, even killing people. And although traffic accidents are not a direct product of motorization, the latter has turned them into a phenomenon that attracts very much attention. Even before the first motor vehicle reached the roads, people were causing and becoming victims of traffic accidents. A look at Berlin as a case in point shows that accidents were an everyday feature of road traffic there over 110 years ago (see Table 1).

As a rule, accident statistics only mean something if correlated with other figures. These include: population, number of vehicles, vehicle mileage. If the number of fatalities is viewed within the context of vehicle mileage, we obtain a very instructive "fatality rate" of particular importance for comparisons over prolonged periods or between countries. Table 2 shows the fatality figures, reference variables ties and the fatality figures relative to these reference variables for four selected years in the last half century.

If we focus our attention on the last few decades, it can be seen that more than half a million people lost their lives in the last 35 years. In the 50s and 60s,

Year	Pop.	Motor Vehicles	Fatalities
1874/76	1 mill.	0	168[1]
1925	4 mill.	35,000	143[2]
1985[3]	1.9 mill.	740,000	150

[1] from riding and driving
[2] without subsequent deaths

Table 1: Selected Accident Data in Berlin

	1936	1953	1970	1986
Fatalities[1]	8,975	11,449	19,193	8,948
Population (mill.)	67.35	51.35	60.65	61.07
Motor vehicles (mill.)	2.47	4.34	17.84	33.03
Vehicles/1000 inhab.	37.00	85.00	294.00	541.00
Vehicle*km (bill.)[2]	34.00	48.20	234.20	384.40
Fatalities/100,000 inh.	13.3	22.3	31.6	14.7
Fatalities/100,000 veh.	363	264	108	27
Fatalities/bill.veh.*km	247	238	82	23

[1] 1936, projected to 30-day period (1.07)
[2] 1936 estimate (as upper limit)

Table 2: Characteristics in Development of Fatality Figures for selected years (1936 territory of former German Reich; from 1953: Federal Republic of Germany)

the number of fatalities rose almost continuously and peaked in 1970 with 19,193. Since then, total fatalities have been falling; the 1987 figure of 7,963 was only 42 % of the 1970 value and 70 % of the 1953 figure. In its structure, this trend is not a specifically German phenomenon, for it can be observed in most highly motorized European countries.

A consideration of this trend suggests the following questions:

- o Why was the previously rising trend reversed in 1970, so that, in spite of a rapid rise in motorization, the fatality figures have been declining since then?
- o Will the falling trend continue, and where will it lead?

The number of fatalities to be expected in road traffic can be estimated from the product of death risk and exposure. For practical applications, exposure can be operationalized by vehicle mileage <in kilometre terms: veh. * km>, and the risk of being killed by the fatality rate <fatalities per 1 bill. hours * km>. This means that the number of fatalities to be expected is a product of fatality rate and vehicle mileage.

Risk and exposure are not constant in time. A look at developments in vehicle mileage and in the fatality rate during the last 35 years shows a nearly continuous rise in the former and a nearly continuous fall in the latter. This is true both of the total road network and of the three segments: urban roads, rural roads and autobahns. For simplicity's sake, the situation in the total network is discussed in what follows.

Total vehicle mileage (exposure) is now nine times as high as it was in 1953. Taking the average of many years, it has increased by 10 bill. veh. * km per year; growth brought a relative increase of 12.5 % per annum in the 1950s, 7.8 % in the 1960s, 3.8 % in the 1970s and only 2 % p.a. since 1980. This means that relative growth in the exposure has been falling over the years. Developments in vehicle mileage/time can be described quite well with a function setup; for the regression setup, the Gompartz function has proved to be very serviceable; the data from 1953 to 1987 provide a certainty rate of 99.4 % for the regression setup. Corresponding setups also exist for the three segments of the road network mentioned above.

Today, the fatality rate (risk) is only a fraction of the 1953 value. A look at the past few decades reveals that the falling trend, in terms of absolute figures, is bottoming out. If we show the development on a logarithmized y axis, the curve ends in a straight line; this means that the relative decline in the fatality rate, e.g. expressed as a percentage, can be interpreted as a constant. A regression setup on the basis of an exponential function shows that the fatality rate has fallen by 6.5 %, taking an annual mean. Put another way: the risk of being killed is down 6.5 % p.a. The certainty rate for this regression setup amounts to 98.6 %. As in the vehicle mileage discussed earlier, corresponding setups apply for the segments of the road network.

For the two variables risk and exposure we now have two different developments in their relative change. The change in the risk is a constant (for the total network -6.5 % per year), the change in exposure is degressive, with high values in the 50s and low values in the 80s. If we plot the relative changes over time, we can identify two stages. In the first, the exposure increases more rapidly than the risk, and the number of fatalities rises in these years. In the transition from the first to the second stage, the growth in traffic is just as great as the decline in the fatality rate, and the number of fatalities peaks in that year. In the second period, growth in the exposure is less than the fall in risk, and the number of fatalities logically falls in those years.

This explains, structurally at least, why fatality figures rose for two decades and why, in spite of a further growth of motorization, they subsequently fell for many years. This does not rule out divergencies in individual years owing to special factors. So there were some years in the growth phase with declining figures, e.g. 1957/58, and some years with growing figures in the decline phase, e.g. in 1988. To counter any misconceptions: the regression functions represented do not describe any situations subject to natural laws; they merely plot the real situation in recent decades. Thus, the fall in the fatality rate was not due to a hitherto unknown law: the fall reflects the sum of all the developments and all the efforts made to improve traffic safety, whether obtained specifically, or implicitly as an incidental effect of other action taken. Which particular measures were concerned cannot be established unequivocally.

If the question is to be answered as to whether the general downtrend in the fatality figures will be continued in the years to come, we must clarify how exposure and risk will develop in future. Although it is still an open question how vehicle mileage and fatality rate will evolve, the following can be said for the future: as long as the growth in traffic is less than the growth in safety (i.e. the decline in risk), the number of fatalities in road accidents will decline.

The estimate below for future fatality figures is based, for simplicity's sake, on the following scenario, the time horizon chosen being the year 2000:

- Total vehicle mileage (exposure) will continue to increase, and already discernible tendencies to bottom out become more marked.
- There will be no let-up in the efforts to increase traffic safety, and these will, on the whole, continue to be as successful as they have been in the past. The percentage annual fall in the fatality rate (risk) will be at the same rate as the average of the past 35 years.

For this scenario, it is possible to estimate vehicle mileage and fatality rate in a future year for the three part networks: urban roads, country roads and autobahns, using the above regression setups. Linking exposure and risk, we obtain an estimated value for the number of fatalities to be expected, viz.:

urban roads	1,103 fatalities
rural roads	3,597 fatalities
autobahns	406 fatalities

Summed up for all roads, this means: if traffic safety work continues to be as successful as it has been in recent decades, and if traffic still increases a little, the year 2000 may be expected to see approx. 5,100 fatalities in road traffic in the Federal Republic of Germany.

Statement 1
OPPONENTS REMARKS

Peter H. Polak
SWOV Institute for Road Safety Research

Central in mr. Klöckners paper is the formula:

$$F = R * E \qquad (1)$$

in words: **Fatalities** equals **Risk** times **Exposure.**

In this opposition I want to state that on the one hand this equation has no meaning, being a mere tautology; and on the other hand that it has so many possible interpretations that it can mean anything you want it to mean, which makes it meaningless too.
To conclude I want to start a discussion on the conditions under which a sensible meaning can be given to this equation.

I

As is obvious, only two of the variables that enter into the equation can be measured, i.e. the number of fatalities F and the exposure E, in Klöckners paper vehicle mileage. With the formula we define a third quantity, called Risk, as the quotient of F and E:

$$R = \frac{F}{E} .$$

If we substitute R in (1) we obtain

$$F = \frac{F}{E} * E = F$$

which is not surprising.

II

The surprising thing which happens in many countries, when we regard the three variables as functions of time, is that F and E vary quite wildly with time but R approximates rather good an exponentially diminishing function. On a logarithmic scale it is a straight line! This beautiful dream is lost when we realize that E, seen as the cause of the fatalities, is a mixture of very different types of traffic, large parts of which don't even mix. If we split up E and F in parts, like different modes of transport, different road types, it follows that the corresponding R-curves are not straight any more. Even worse things happen if we realize that vehicle mileage is not the only way to define exposure. Distance covered is not the aim of transport. The real aim of a user of the traffic system is to go to work, to go out, to go on holiday etc. It is obvious that with the advent of mass motorization the distances travelled per journey have risen because the speeds increased, but the time spent on the road per journey hasn't changed very much. If this is true the risk in terms of people killed per hour in traffic is now in the Netherlands the same as in 1950. So with the same formula you can prove that the risk to be killed in traffic has been reduced by a factor of 12 since 1950 or prove that it remained equal!

III

Now what we need is a discussion on the conditions under which formula (1) in its aggregated form has a clear meaning. One important condition is that it should have a causal interpretation. For this it is necessary that E and R have an independent meaning, apart from their role in (1). Most important is that R should be derived from other variables describing the traffic process. Also the formula should stand up to disaggregation. When split up into its constituent parts it should stay meaningful. And most important, it should be possible to extrapolate it in a meaningful way to parts of reality outside of its defining base, e.g. the future, or other countries. Let's start with answering the question: which is the most meaningful way to define exposition in an aggregated way.

Statement 2
MACROSCOPIC MODELS FOR TRAFFIC SAFETY

Siem Oppe
SWOV Institute for Road Safety Research

Recently there has been an increased interest in the application of macroscopic models for the description of developments in traffic safety. At SWOV this new interest was initiated in the early eighties by the discussion on the causes of the sudden decrease in the numbers of fatal and injury accidents after 1974. Before that time these numbers had increased steadily over the years. A satisfactory explanation for this decrease could not been given.
Two mathematical curves are suggested and from this is estimated a total of 1080 fatal accidents in 1990 for the Netherlands. This approach will be described together with the results of application to the data from the Netherlands, the USA, Federal Republic of Germany and Great Britain.Consequences of this application for the theoretical background of the developments in traffic and safety will be discussed.

Introduction

Recently there has been an increased interest in the application of macroscopic models for the description of developments in traffic safety. At SWOV this new interest was initiated in the early eighties by the discussion on the causes of the sudden decrease in the numbers of fatal and injury accidents after 1974. Before that time these numbers had increased steadily over the years. A satisfactory explanation for this decrease could not be given.
Blokpoel [1982] presents data for the development of traffic volumes, accidents and accident rates in the Netherlands (see Figure 1a). Independently the same data was given by Appel [1982] for Germany (see Figure 1b).

Fig. 1a. Traffic volume and traffic safety data for the Netherlands according to Blokpoel (1982).

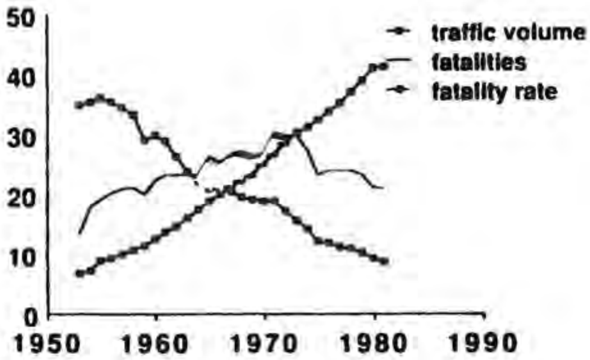

Fig. 1b. Traffic volume and traffic safety data for Germany according to Appel (1982).

Figures 1a and 1b support the assumption that the development of the accident numbers follows from the combination of two more basic processes,

the development of the traffic volumes and of the accident rates. The first curve is monotonically increasing, the second monotonically decreasing, and the rise and fall of the accident curve is then supposed to result as the product of these two monotonic curves. The rise of the number of accidents up to 1974 is part of the same process as the fall after that year, and there is no specific explanation needed for the turning point in this curve. The combination of these basic curves may be used to predict developments in the number of accidents in the future. Several approaches start from one or both curves in order to describe or predict safety results. Oppe [1984] suggested two mathematical curves and estimated from this a total of 1080 fatal accidents in 1990 for the Netherlands.
This approach will be described and applied to the data of the Netherlands, the USA, West Germany and Great Britain. These data are collected from the various national sources. The US-data are from Accident facts 1974 and Traffic accident facts 1986. The data for West-Germany are from SBA Verkehrsunfälle 1986. The data for Great Britain are from Road Accidents G.B. 1985. The data for the Netherlands are from CBS, stat. verkeersongevallen op de O.W. (statistics of traffic accidents on public roads), and additional data from SWOV.

The model

The model is based on the above mentioned assumptions that:
- there is a monotonically increasing S-shaped saturation curve with regard to the development of the number of vehicle kilometers per year;
- there is a monotonically decreasing curve for the development of the fatality rates per year, to be called "the risk curve";
- as a consequence, the number of fatalities per year follows from these curves by multiplication of their respective values.

Two very simple mathematical functions turn out to fit the data rather well. A negative exponential according to model 1 is used for the fatality rates.

Model 1:

$$\log\left(\frac{f}{v}\right) = \alpha t + \beta \qquad (\alpha < 0) \qquad (1)$$

With f the total number of fatalities for a given year, v the total annual amount of vehicle kilometers, t the respective year and α and β the scale-parameters to fit.

This means that the decrease of the ratio between the number of accidents and the number of vehicle kilometers is proportional to time.
The decrease is supposed to be the combination of all efforts made to improve the traffic system, such as the improvement of the road system, vehicle design, crash measures, legislation, education and individual learning [SWOV, 1986]. The traffic density as such may also have had a direct effect on the decrease in the fatality rate.

For the description of the amount of traffic, a good fit was found from simple assumptions. First it was assumed that this development starts from zero and rises through time to a certain saturation level. A simple model of this kind is the S-shaped logistic curve. A generalization of the function for y-values between 0 and some arbitrary but positive value, instead of y-values between 0 and 1 results in

Model 2:

$$\log \left(\frac{v}{vmax-v} \right) = \alpha' t + \beta' \qquad (2)$$

The assumption is, that the rate between the traffic volume already realized at time t and the remaining traffic volume potential to be realized in the future increases proportionally to time. The value of vmax is not given in advance and will be chosen in such a way that the fit of model 2 is maximized.

Results

Both models fit the data rather well. As was already known before, the decrease in the log-rates for the fatalities per vehicle kilometer over the years, turns out to be fit indeed by a linear function for all four countries.
A maximum value for the annual amount of vehicle kilometers is found from the best fit of the linear function to the data according to model 2. Using this proportionality factor vmax, the fit for model 2 is, generally speaking, slightly better than the fit for model 1.
Furthermore an empirical relation has been found between the parameters of model 1 and 2, suggesting the combination of both models to.

Model 3:

$$f_t = c\sqrt{v_t.(vmax - v_t)} \qquad (3)$$

where f_t is the number of fatalities in year t, v_t the total amount of vehicle kilometers in that year and c is a given constant.

Koornstra (1988) noticed that this function is of a particular form. If we rewrite model 2 in its ordinary form as:

$$v_t = \frac{v_{max}}{1 + e^{\alpha t + \beta}} \qquad (4)$$

then it follows that the first derivative of this function with regard to t is:

$$v_t' = \frac{-\alpha}{v_{max}} v_t (vmax - v_t) \qquad (5)$$

(see also Mertens [1973])
This shows that the functional relationship between the number of fatalities and vehicle kilometers as suggested by the empirical data analysis can be written as $f_t = g(v_t') = c(v_t')^{½}$.

Statement 2
OPPONENTS REMARKS

Ekkehard Brühning
Federal Highway Research Institute (BASt)

We have now heard two presentations which model the interrelationship of mileage, the number of fatalities, and death rates over the long run. Some of us may have been surprised to learn that a continuous decline in the number of fatalities seems to be an automatic process.
I want to discuss Siem Oppe's presentation in more detail here. His method tends to be more forecast-oriented, he already used it to make a forecast for 1990.

Minor problems occur if one depicts the long-term development of the number of kilometers travelled in an S-shaped logistic curve. Its application on the German data for the years 1953 - 1986 fitted best with a saturation level of 407 billion v.kms. Exactly this figure has been reached in 1987. However, this remark is not intended to be a criticism that questions the validity of the whole work.

More interesting, from my point of view, is the interpretation of the results of the model:

- Are they a manifestation of those laws that describe how the process of learning works? Are they national learning curves, or, just to the contrary,
- do they show the success of continuous traffic safety efforts or
- is it an interaction of factors, which go together with time and motorization, as, for example, traffic density?

Do these interpretations imply causality?

What is the philosophy behind this model?

- The model is a fatalistic one, if one considers time itself as the explanatory element.
- It is an optimistic one, if one assumes that the effectiveness of safety measures will be continuously the same in the future as it was in the past.

But we all know, the most promising safety measures (e.g. safety belt) have already been employed.

What do we learn from the models?

1. no explanation of the causality but
2. probably correct forecast figures

Even though it is only a partial success, the importance of forecast figures may not be underestimated.

Statement 3
PROGRESS IN VEHICLE SAFETY

E. Faerber
Federal Highway Research Institute (BASt)

In the past occupant safety in frontal impacts was considered to be most important. A lot of improvements in vehicle construction were introduced in car production. Some examples: three point automatic seat belts; rigid passenger compartment; padding and the capability of energy absorption of the car interior.
Today further topics in vehicle accidents are gaining more importance: pedestrian/two wheeler impacts; side impacts and vehicle compatibility in different accident situations.
Car manufacturers, research institutes and government authorities cooperate to establish legislative requirements to improve vehicle safety in these types of accidents.
Unfortunately, it must be observed that in Western Europe and the United States of America different requirements and standard tests are in discussion to be introduced into legislation. All efforts should be concentrated on the aim that a worldwide harmonization of vehicle safety standards can be achieved.

The aim of this paper is to provide an overview of the development of safety legislation in the United States and Europe. The contents of three important legislative proposals, which are still under discussion, will be presented.

History

In the sixties and seventies, the United States introduced legislation imposing standards for the testing of safety systems and their interaction in a rigid barrier impact test with a vehicle ready for the road as a means of increasing vehicle safety. In the following period, the ECE (Economic Commission for Europe) and the European Community introduced safety standards (in the form of ECE regulations and ECE directives) initially only for the testing of vehicle subsystems. Table 1 summarizes important regulations and their key elements as well as the dates of their introduction as legislation.

Table 1: Selected Regulations and Their Effective Dates

Item	ECE-Regulation		EC Directive	USA	
	No.	Date	No.*	FMUSS**	Date
Doors: Locks and hinges	11	6/69	70/387	206	1/68
Steering System	12	7/69	74/297	204	1/68
Seatbelt Anchorages	14	4/70	77/541	210	1/68
Seatbelts	16	12/70	76/115	209	3/67
Seats, Seatbacks	17	12/70	74/60	207	1/68
Vehicle Interior	21	12/71	74/60	201	1/68
Headrests	25	3/72	78/932	207	1/68
Passenger Compartment	33	7/75	74/60	208	1/72
Fuel System	34	7/75	70/221	301	1/68

* first two digits: year of introduction

** Federal Motor Vehicle Safety Standard

After several years of consultations in various bodies, France had introduced a proposal for a frontal impact test at the ECE in 1984. Because there are still points in question, the proposal is withdrawn at present. Over the last 2 - 3 years increased efforts have been made in Europe to introduce a standardised side-impact test using a vehicle ready for the road. The United States are also working towards the introduction of a standardised side-impact test into safety legislation. The fact that various international bodies have established different test procedures makes agreement on a common, internationally-recognised side impact test extremely difficult.

At the end of 1985, the United Kingdom presented draft regulation for the protection of the passenger car driver against facial injuries in collisions, taking into account the changes in kinematics of vehicle occupants in frontal collisions which have resulted from increased wearing of seat belts (despite use of the seat belt, the driver's head often hits the steering wheel in serious accidents).

The key elements of the draft regulations will be described below under separate headings.

Global Test Frontal Impact

The ECE draft regulation for the protection of vehicle occupants in the case of frontal impact [1], who is postponed for the time being, is intended for vehicles primarily designed for passenger transport, suitable for carrying more than 3 persons and whose total weight does not exceed 3,500 kg. An impact test against a rigid, fixed barrier is planned as acceptance test.

The impact speed should be 50 km/h. The front of the barrier should be at an angle of 30° so that the vehicle side with the steering column hits the barrier first. There are detailed specifications regarding the positioning of the dummies in the front seats. If the rear seats are fitted with restraining systems, dummies do not need to be used in the rear seats.

The following protection criteria to be measured should not be exceeded when using anthropometric test dummies:

- the head protection criterion HPC[1)] should be lower than 1000; because of scatter in measured values in impact tests, a scatter range of + 250 is permitted [2], cut off frequency is 600 Hz [3],
- the thorax protection criterion ThPC[1)] should be less than 60 g except for acceleration peaks with a total duration not longer than 3 ms,
- the femur protection criterion FPC[1)] should be less than 10 kN; 8 kN should not be exceeded for force peaks with a duration of 20 ms,
- the abdominal protection criterion requires that, in a restraining system with pelvic belt, this belt should not slip over the pelvic bone iliac crest during the test.

New features in the above protection criteria - particularly in relation to the current American regulation FMVSS 208 - are the introduction of a scatter range for the HPC and a time limit for forces in the FPC, as well as the introduction of an abdominal protection criterion.

[1)] HPC = Head protection criterion, calculated like HIC (head injury criterion), but only for the duration of any head contact; the HPC is met when there is no head contact

$$HIC = \max \left[\left(\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a_{res}\, dt \right)^{2.5} \cdot (t_2 - t_1) \right]$$

the acceleration of the centre of gravity of the head is measured

ThPC = Thorax protection criterion
The acceleration of the thoracic vertebra is measured

FPC = Femur protection criterion
The femur longitudinal forces are measured

Global Test Side Impact

Various institutions have developed draft regulations and test procedures for the protection of vehicle occupants in the event of side impact. The three key proposals which will be discussed here are:

- the European governmental committee on safety vehicles EEVC, further developed by the ECE and today by the Commission of the European Communities
- the American vehicle safety administration NHTSA
- and the Common Market Association of Vehicle Manufacturers, CCMC.

While assessment of the protection of occupants in frontal impact collisions with a rigid barrier allows conclusions to be drawn about behaviour in collisions with other objects, in the case of side impact, all draft regulations require a "test device" to collide with the vehicle under test. In initial investigations mobile barriers were used which had a rigid impact surface and corresponded in width and height to ordinary passenger cars. These rigid, mobile barriers had the advantage of being of simple design and thus easily reproducible for test operation. Due to their rigidity, however, they could not themselves absorb any deformation energy. The disadvantage was that acceleration and damage in the vehicle concerned did not correspond to the situation in a real accident. The last five years have seen the development of various barrier types with deformable attachments, adapting the test machine to make it more similar to a real car. In order to develop these deformable barriers, the relevant data for a large number of car types were collected to determine a standard car front. The key data for such deformable barrier are: the geometry - width and height of the deformation element as well as its height above the ground; its energy absorption capacity, definable by means of the force/distance characteristic (rigidity) and the mass as a parameter influencing the kinetic energy [4].

The requirements of the EEVC draft side impact test procedure are as follows:

The 950kg heavy mobile barrier is fitted with six deformation elements whose geometry is shown in Fig. 1. Four different force/distance characteristics are prescribed for the the six elements (max. total impact force 205 - 255 kN) [5].

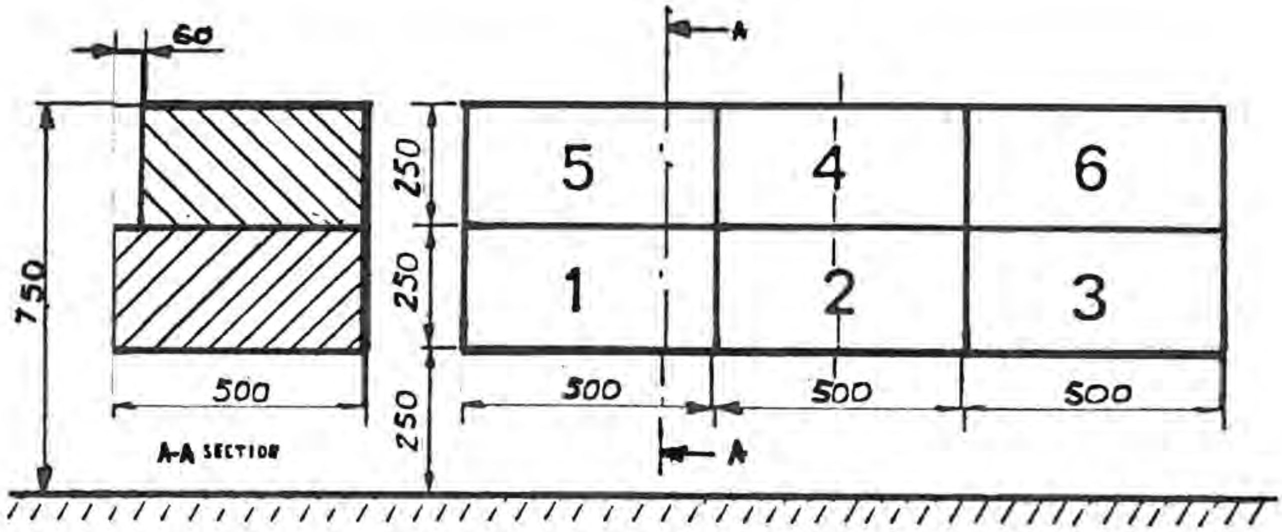

Fig. 1: Geometry of the EEVC deformation elements (material: PU foam)

The most important criteria in the test procedure are as follows:

- test vehicle standing
- collision angle and angle of impact 90°
- collision speed 50 km/h (+ 0, - 2)
- central axis of the barrier hits R-point[2] (driver's side)
- one dummy on the front seat on impact side
- restraining system in use (e.g. seat belts fastened).

The main differences between the proposals of the CCMC and NHTSA and those of the EEVC are as follows:

[2] R-point - fixed point in vehicle: hip joint pivot of a special dummy on front seat in furthest back position

- the rigidity of the deformation elements increases from the EEVC elements to the NHTSA elements (max. impact force: EEVC = 255 kN, CCMC = 350 kN, NHTSA = 490 kN)

- the frontal dimensions of the deformation elements are similar in the three drafts; however CCMC uses deformation blocks, NHTSA uses an aluminium honeycomb block

- CCMC and EEVC specify the same mass for the mobile deformable barrier (950 kg), while the NHTSA barrier is to have a mass of 1360 kg (corresponding to the average for American cars)

- for the purposes of simulating the speed of the vehicle which is hit, the American draft regulation requires crabwalk of the mobile barrier, see Fig. 2

- NHTSA provides for a special side impact dummy (SID) for measurement of protection criteria. A recently completed European side impact dummy (EUROSID) who is currently being tested is intended for the regulations in Europe.

The CCMC now favours a composite test procedure. This requires quasi-static pre-deformation of the side of the car under test up to the seat of the dummy. Then the dummy torso must also be pressed quasi-statically against the pre-deformed structure from inside. In the third phase, the dummy is fixed in place and the car is further deformed from outside. The parameters evaluated in this test will be fed into a computer simulation and the vehicle behaviour will thus be compared with the specified performance criteria limits.

The United States Department of Transportation (DOT) presented its draft regulation on January 25, 1988. Comments on this New Proposed Rulemaking must be received on or before 270 days after publication in the Federal Register (24.10.88). The effective date is 30 days after the date of publication of the final rule.

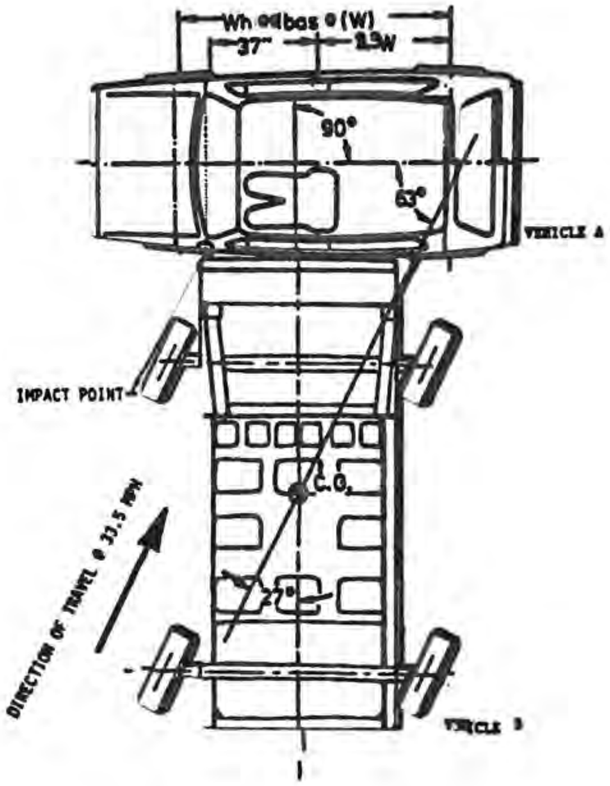

Fig. 2: Mobile deformable barrier with "built-in" impact angle of 63°: barrier with "crabwalk"

A number of different problems remain to be discussed before the draft regulations for the protection of vehicle occupants in frontal and side-impact collisions can be introduced into European legislation. The key questions which remain open are:

- Which existing regulations for component testing are satisfied by the performing a full scale frontal test with an vehicle ready for the road?

- Does the impact geometry - particularly the ground clearance of 300mm of the barrier elements of the side impact test procedure - correspond to that in the real side impact accident situation?

- Which protection criteria should be specified? The development of further improved criteria is possible in the frontal impact test, while the criteria for the side impact test are determined, the assessment of the limit values still remains open.

This draft regulation for the Side Impact Global Test, and the steering wheel impact test described in the following chapter, are the two main points of disagreement at the latest meeting in September 1988 of the ad hoc Group of the Commission of the European Community which was established three years ago under the title: Evolution of Regulations in a Global Aproach (ERGA).

The task of the ERGA group is to tighten up the existing regulation structure and to bring it up to conformity with state-of-the-art developments in vehicle safety. The discussions are due to be completed in 1988.

Subsystem Test Steering Wheel

With the increasing use of seat belts, the injury types suffered by drivers in frontal collisions is changing. In the case of head injuries, impact against the steering wheel, which is still fairly frequently observed in real accident victims despite the use of 3-point seat belts, appears to be gaining in importance. Chest injuries as a result of impact against the steering wheel are becoming less common.

The first version of the draft regulation stated that car steering wheels must be tested at at least five points with an impact test. The impact object must be 6.8 kg in weight and have a diameter of 150 mm. A 50-mm high aluminium honeycomb structure must be attached to the front of the impact object. The impact object must hit the hub and three points on the steering wheel rim at right-angles to the steering wheel plane and at a speed of 24.1 km/h. A fifth point of impact can be stipulated at the request of the testing authority. The acceleration values of the impact object must not exceed 80g/3ms. Deformation of the honeycomb structure must not be deeper than 2 mm on the inner face (100 mm diameter).

When loaded in longitudinal direction, the specified honeycomb structure exhibits an initial force peak and is then deformed under an almost constant force when compressed further. If the honeycombs are pre-deformed (e.g. over the entire surface for 5 mm) this unwanted force peak is avoided. The maximum surface pressure value for the honeycomb structure was laid down as 148 N/cm².

The surface pressure value of approx. 150 N/cm² was calculated from the results of biomechanical tests carried out some years ago on the heads of corpses by dividing the limit force by the diameter of the impact object. These calculations produce values lying between 150 N/cm² (nose) and about 800 N/cm² (forehead). The lowest resistance was taken as a basis for the draft regulation.

Examination of the resistance values of the aluminium honeycomb to be measured quasi-statically showed that the values indicated by the manufacturers and required by the regulations were not reached. It was also discovered that the resistance values of the honeycomb test objects vary greatly within one production batch. This also led to widely differing results in the steering wheel tests. This negative effect combined with the fact that only very few of the steering wheels produced today could pass the test requirements led to massive criticism of the British draft regulation, even though its basic premise was regarded as correct.

As a means of improving the safety of steering wheels in the medium term, the Spanish Ministry for Industry and Energy presented a modified draft regulation for the protection of car drivers in the event of a frontal collision. This proposal provides for the deformable impact object to be replaced by a rigid semisphere with a diameter of 165 mm. The deformation criterion would accordingly no longer apply. To prevent future steering wheels being too hard, an upper limit for peak acceleration is planned to be set (a value of around 120 g is under discussion) in addition to the 80g/3ms performance criterion limit.

The Spanish draft regulation combines ECE 12 and 21. ECE 12 requires a test with a "body block" against the entire steering mechanism.

The body block impact against the steering mechanism requires a high degree of energy absorption at a high level of force, while a steering wheel tested under the draft regulation would only have to absorb much less energy at a lower level of force. Countries with high belt-wearing levels and consequently infrequent cases of chest impact against the steering wheel would like to see this dispute solved by dropping the body block impact.

The following conclusions can be drawn:

The introduction of legally-binding safety regulations should be linked to an increase in road traffic safety. The number of impact tests to be carried out should kept to a minimum and, where possible, reduced by combining different tests in regulations in existence today. The aim should be to achieve only one globally recognised test procedure for each type of impact (front, side), so as to prevent test regulations varying from country to country.

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Statement 3
OPPONENTS REMARKS

Jan Tromp
SWOV Institute for Road Safety Research

The title of your lecture: "Progress in vehicle safety" responds to the question: Progress, but for whom and how; Is every progress an improvement. I admit that a considerable progress in safety of cars has been made: nowadays occupants of cars have a far better chance to survive accidents. But there is still concern about side-impact protection of occupants of cars and the protection of two-wheelers and pedestrians. The difficult negotiations over the application of safety provisions and their harmonization still require a lot of work: the difficult passage along the international bodies, with matters hardly related to traffic safety, requires much effort.

I don't want to go any further into this, but would like to discuss some related matters.
First, some words about heavy goods vehicles:
I tend, especially on cheerless and cold days, to state that there haven't been any safety developments for these vehicles. The number of fatal accidents with heavy goods vehicles decreases much slower than that number for cars and it could even be possible that this decrease has been caused by improvements outside the heavy vehicle. One of the main problems of heavy vehicles is the adaptation of other road users. It would be a progress to install provisions such as lowered front bumpers, and side- and rear-end protection, so that cars could use their crush zones. Side protection could also offer benefits for two-wheelers and pedestrians.
The rear-end protection prescribed nowadays by the EC is too weak and too high: cars has been lowered considerably at front because of the streamline fashion.
A second point is the use of cars:
It is very human to explore possibilities and limits of acquired goods. Aggressive advertising points out a certain feeling of safety inside the car. The result is a loss of safety profits by the way in which cars are used.
Because of the streamline fashion nowadays even small cars can reach such speeds that their drivers should need a license for low-flying. Very recently I could again see what that means in practice on the German "Bundesautobahnen". I was not very amused.

Ridiculous in this respect was the information of a well-known German car manufacturer that the maximum speed of his top-of-the-range model was set at two hundred and fifty kilometers an hour because of safety. You should realize what a set of provisions railway companies regards as necessary for safe operation at such speeds.

A lot has been written about the safety profits of some developments, like four-wheel drive. And not only in advertising, but also in scientific journals. The next story shows how things can be:

A short time after the introduction of the four-wheel driven Audi Quattro, the factory couldn't supply enough replacement front spoilers, because the proud owners discovered that even when the vehicle performed fantastic, it braked as lousy as usual. Anti-lock braking systems do also have this other side: drivers have to learn their handling and should be aware of possibilities and impossibilities of such systems. Who knows that the brakes shouldn't be applied intermittently but as hard as possible to activate the system.

Safety provisions in cars do have more adverse sides: the car is more expensive and heavier and the maintenance is more complex.

As far as I know, nobody has yet posed the question how second and third owners will handle these safety provisions, and how these will perform at the end of life of the car.

A remarkable example of unthinkingness from car manufacturers is the construction of brake-pad wear indication: If the brake pads are worn, a staff makes contact with the brake disk, thus lighting a lamp in the panel. If the mechanic at the garage forgets to reconnect the wire after replacement, the brake pads will last forever. A simple two-wire connection at constant tension will not only indicate wear, but also interrupt connections. Costs: A few guilders.

I also ascertain that safe cars are very expensive, and often heavy: mass alone will offer more protection in crashes with lighter cars. This difference in mass is also an adaptation problem. A lot of safety provisions for common cars are sometimes years later at hand and relatively more costly. This means that somebody with enough money can protect himself at the expense of others.

This social aspect takes me to another point:

Since long the car is not just a means of transport but loaded with addiction, erotica and mysticism. The so called freedom of this means of transport prohibits a realistic approach and the awareness of disadvan-

tages, for example unsafety. As long is this seems to be the reality, any progress in safety will not to be find in only technical developments of cars but in an approach in which use and misuse of cars is the main theme. The behaviour of human beings, not only driving, but maintaining their vehicles, for example, is then important. But also the adaptation of cars to the possibilities and limitations of their users.
The study of behaviour only is the same way too limited.

Statement 4
VEDYAC - A POWERFUL AID IN CRASH RESEARCH

Tom Heijer
SWOV Institute for Road Safety Research

The name VEDYAC is an acronym for VEhicle DYnamics And Crash. It pertains to a computer program capable of simulating a large variety of vehicles, vehicle manoevres and crash conditions in equally variable surroundings.
The main features of this model include:
- simultaneous simulation of the movements and interactions of a large number of independantly moving systems (vehicles or otherwise)
- flexibility in the modelling of deformable structures: there is a choice between simple and fast modelling ("pneumatic cylinders") and detailed and slower modelling ("discrete elements")
- simplified manipulation of input data
- extensive three dimensional graphic postprocessor

In this presentation, these main features will be adstructed and some results of recent work will be shown.

The VEDYAC model

This model has been originally set up as a general purpose computer program to simulate both vehicle manoeuvres and vehicle crashes. The basic tools, that the program offers the user to define and describe the vehicles and moveable or fixed obstacles to collide with, are so versatile however, that the simulations are not confined to simulation of road vehicles only: the program can be used to simulate dynamics of man-like structures, trains, helicopters, lighting poles, guard rail etc. Moreover, the number of simultaneously moving and interacting objects is not specifically limited and so it is possible to simulate a crashing car having occupants colliding with its interior at the same time. The model has been used extensively in the development of new or improved types of guard rail, research of slope accidents using various types of passenger cars and trucks, development of crashworthy helicopter parts and may be used to investigate train crashes. The model has proven a cheap and versatile replacement of often too costly full-scale tests. However, these high costs have also prevented an extensive validation of the model on "real world" data, which sometimes makes the results of the simulations uncertain. Still, verifications with the aid of smaller scale mechanical models in laboratory tests have been carried out successfully.

Characteristics of the program in brief

The basics of the model are simply the Newtonian laws of reaction and motion, applied to an unlimited amount of freely moveable rigid bodies. To these bodies, deformable shapes (cylinders or plane elements) can be attached in specifyable places to describe the outward shape and to enable forces to be generated upon contact with other (moveable or fixed) bodies. In order to model vehicles, several types of suspension are available (independant wheel movement, rigid axle, swing axle, steering gear) that can also be attached in any place to moveable bodies. Bodies may be coupled in one or more places by means of deformable joints, the characteristics of which (elastic-plastic-frangible deformation, damping) can be specified for each point separately.

Thus articulated vehicles (truck-trailer) can be modelled, but also more continuously deformable objects like guard rail beams can be described by dividing the beam into a large number of coupled elements of finite length: in such fashion, the program allows the use of "finite elements" to provide for deformation of complex constructions. Simple finite element shells can also be attached to moving bodies to enable modelling of more complex deformation properties than planes and cylinders would allow. The program solves the equations of motion of each body separately in a large number of small timesteps with the aid of a simple predictor- corrector algorithm.
Results can be presented in the form of tables (time series indicating position, rotation, speed and acceleration of all bodies), graphs or 3 dimensional drawings.

Applications
As already mentioned, the program is extremely flexible and applicable in a great range of dynamic problems ranging from simple manoeuvring on hard or soft soil via cars impacting pedestrians to impact of complexly structured train fronts against heavy trucks. The program has also shown some potential in dynamic analysis of assembled steel structures (vibration of networks of girders and beams). Some examples of recent applications of the program are illustrated in Figures 4, 5 and 6.
Figure 4: Comparison of full-scale test results and model output in case of a slope accident on a 1:2 slope at a speed of 100 km/h
Figure 5: Simulation of a truck, loaded with a 5 ton steel roll, colliding at 80 km/h with a concrete median barrier
Figure 6: An example of a finite element structure: an aluminum train body colliding at 70 km/h with a 30 ton truck.

Simulation of structural deformations

With these programs the vehicle's structure can be optimized and the structural behaviour can be predicted. They are based on finite element and finite difference techniques. With the current general purpose finite element and finite difference computer programs problems such as static crushing and low and medium velocity impact can be dealt with. By the appearance of supercomputer systems these problems can be of rather extent. However, to perform a simulation of a full vehicle crash, a very complicated and cpu consuming model is needed. Specialized computer programs for crash analysis have been derived from existing advanced packages by unifying their respective virtues and by adding new features. In this way, special purpose crash analysis packages have been developed. Until now, application of such programs in the automotive industry is not common use. Composing the model and defining the input parameters require specialized knowledge on engineering and computational mechanics [8]. As an example, in Figure 7 the difference is shown between an overall structural analysis mesh and a special front-end crash analysis mesh.
For type approval a road vehicle must undergo a series of tests. One of these tests is a frontal collision with a velocity of 50 km/h with a rigid wall. During this collision certain parameters must be measured which should not exceed prescribed values. A simulation of this test is presented here.

During a real crash, the kinetic energy (1/2.m.v2) is dissipated by the structure and transformed into deformation energy (F.s). Normally, the deformation length is of order 0.5 m, which results in an average deceleration of 20 g. The total impact has a duration of about 100 ms.

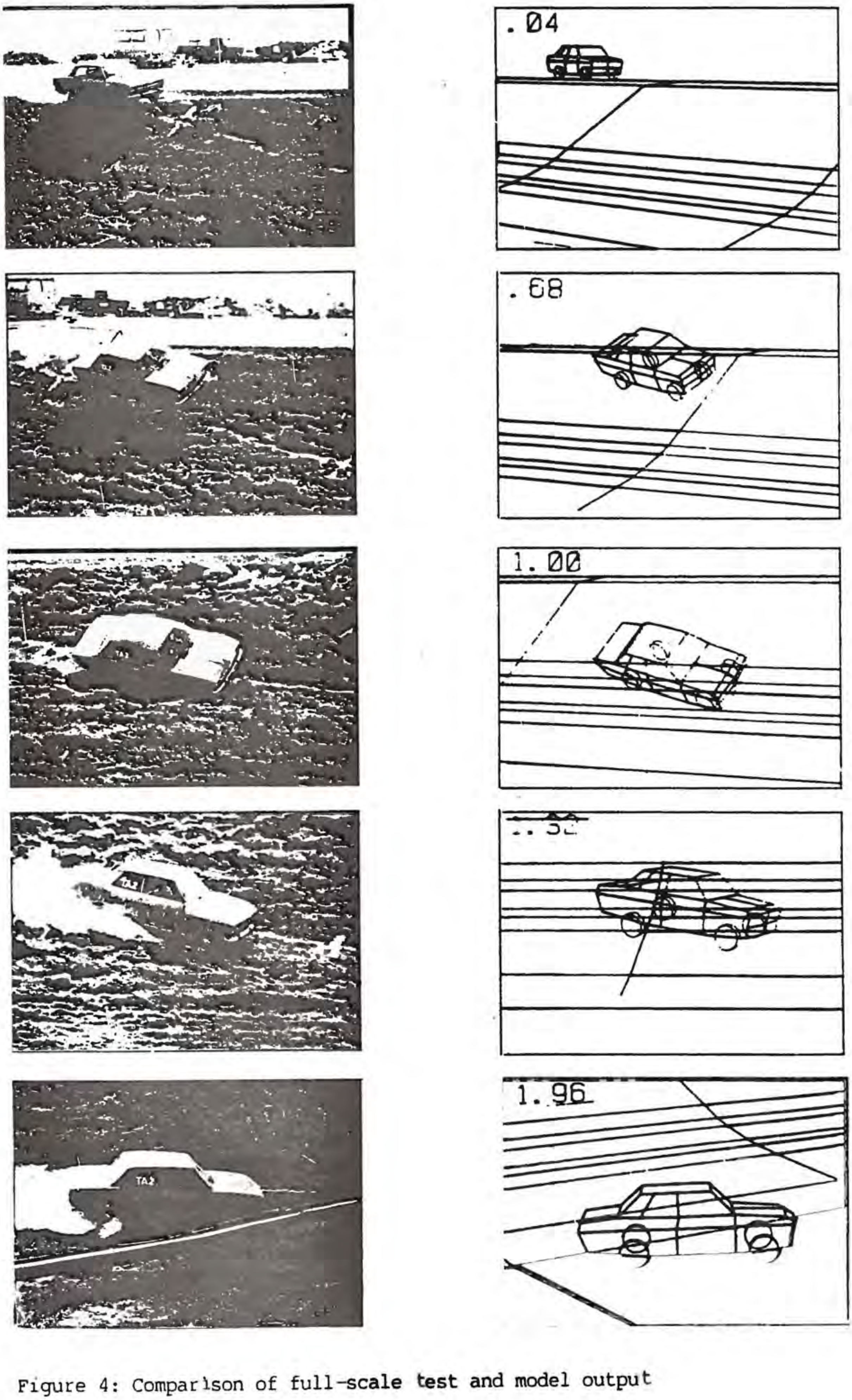

Figure 4: Comparison of full-scale test and model output

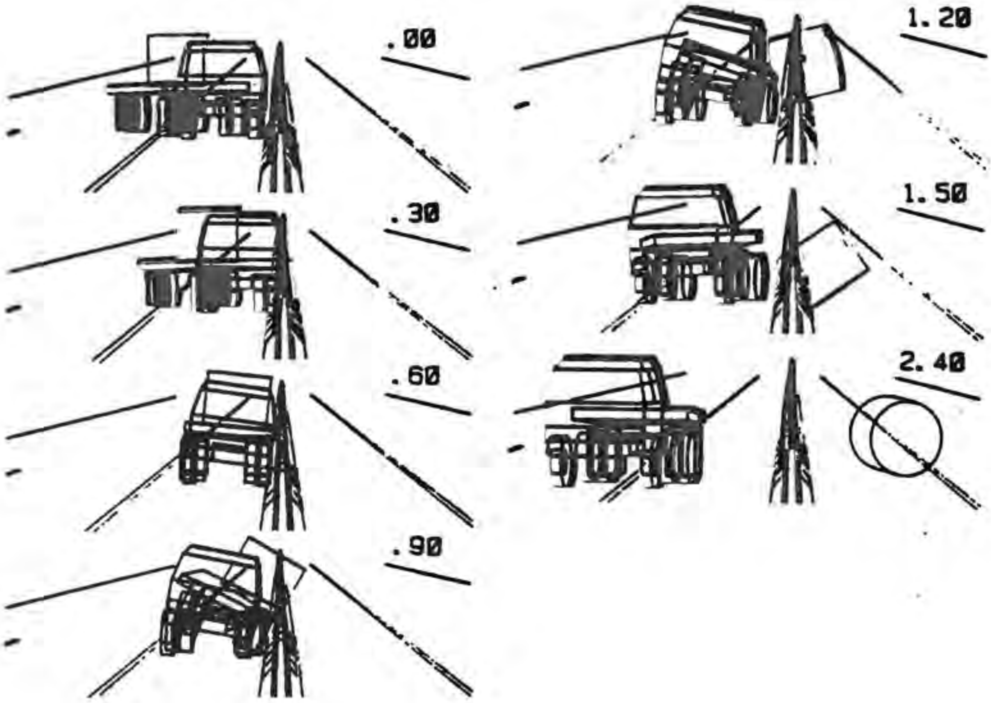

Figure 5: Truck, loaded with a 5 ton steel roll, colliding with a concrete median barrier

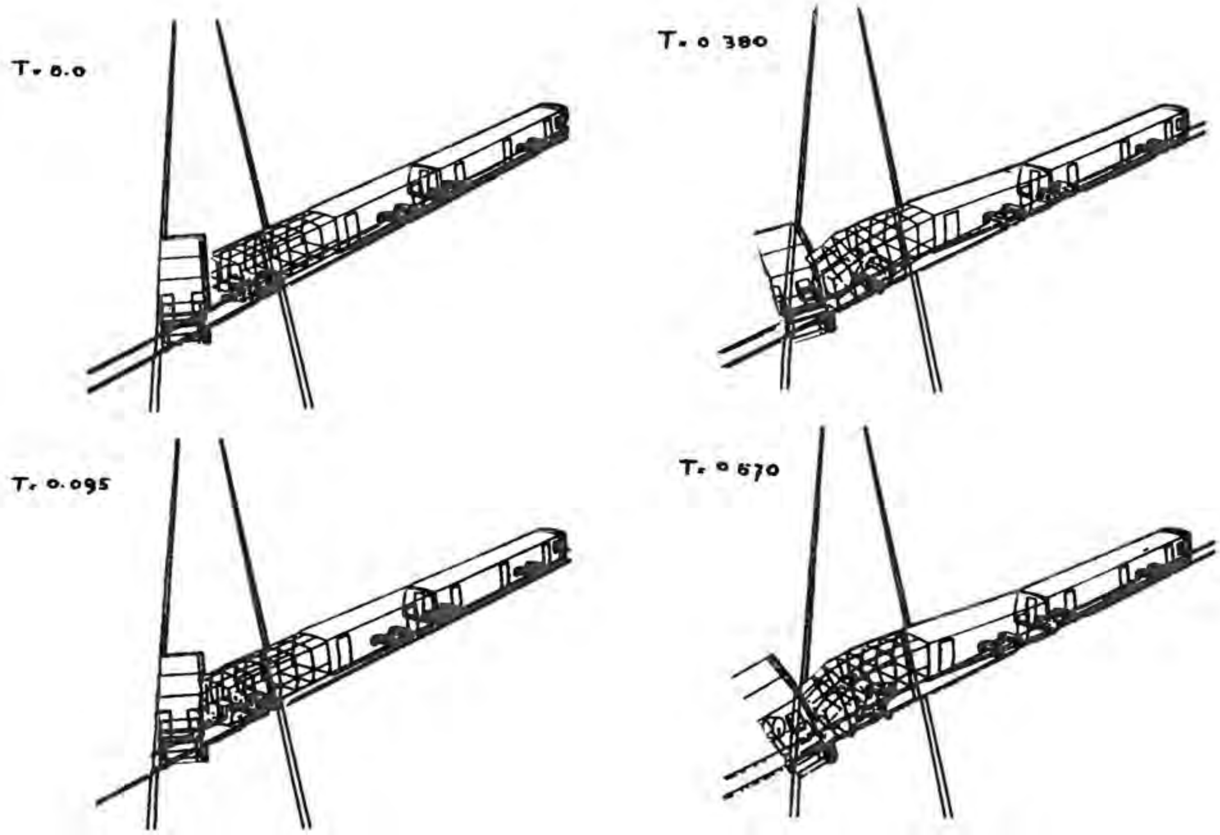

Figure 6: Aluminum train body colliding with 30 ton truck

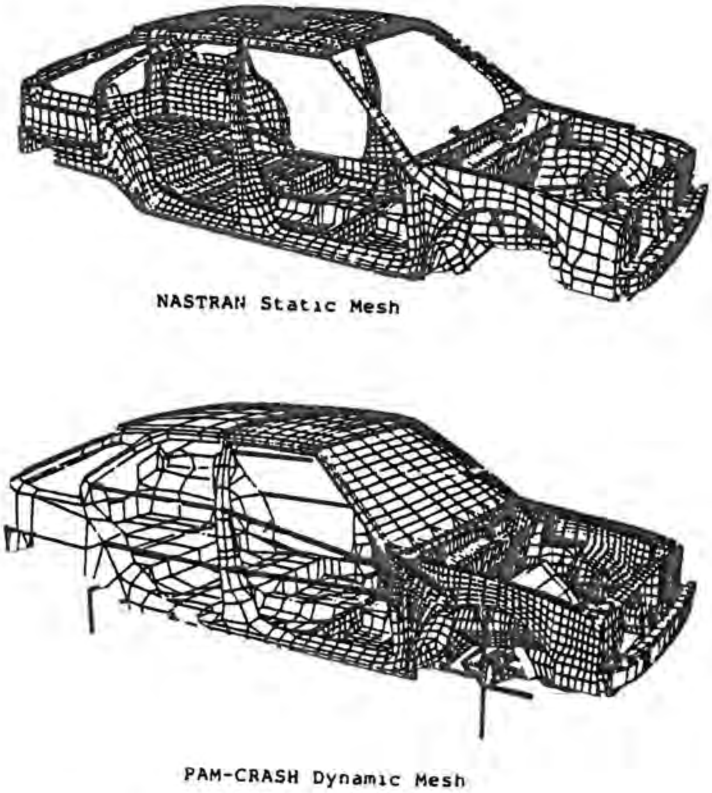

Figure 7: Static structural mesh and dynamic local impact mesh

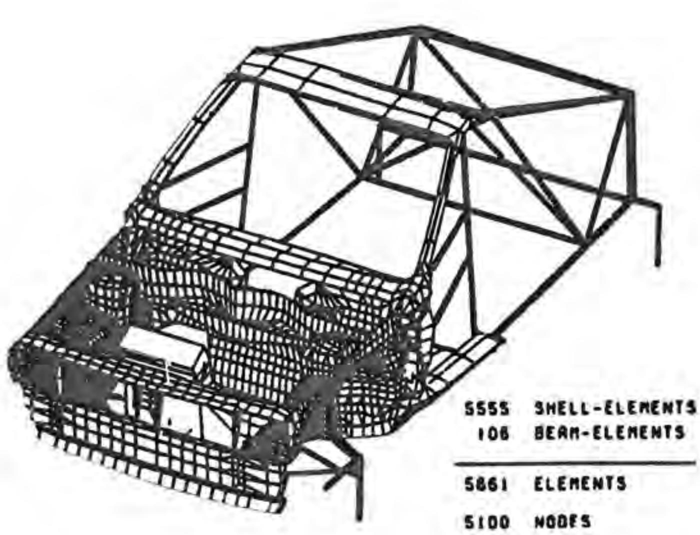

Figure 8: Finite element model

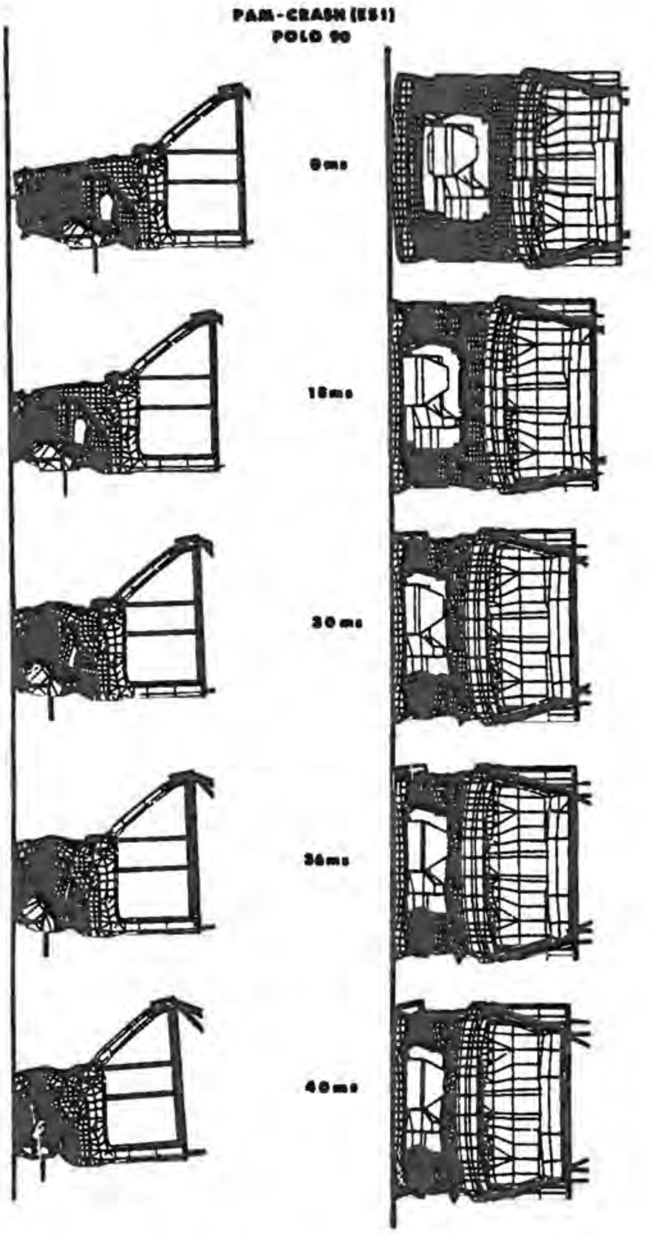

Figure 9: Finite element crash simulation

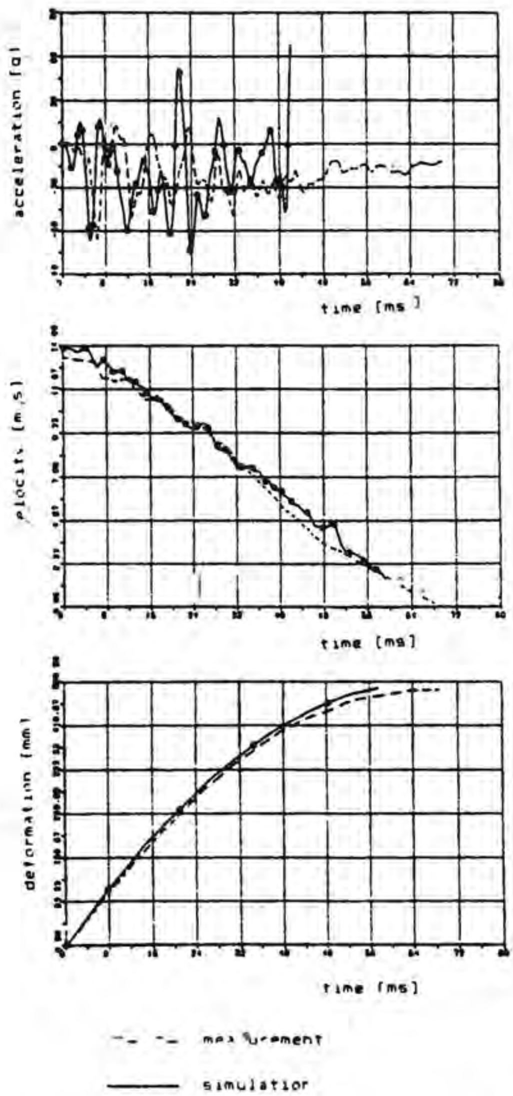

Figure 10: Acceleration-, velocity- and deformation-time relationship of a rear vehicle point

A finite element model of the front structure of a Volkswagen Polo is shown in Figure 8. It consists of 5555 shell elements and 106 beam elements, representing the structural and physical properties of the vehicle.
Only 60 ms of crash time have been simulated. This simulation took 4 hours of cpu time on a CRAY1 supercomputer. The results are shown in Figure 9.
In Figure 10 some comparisons are shown from simulation and a full-scale test. The results are in good agreement.

Simulation of human whole body response

This type of models has been developed to describe the dynamic response of a vehicle occupant involved in a collision event. However, they also can be used to study for instance the motions of a pedestrian or a cyclist if impacted by a vehicle [1]. The human body in this type of models is described by a number of rigid elements connected by hinge or ball and socket joints. The dimensions and the mass of the body usually can be changed to represent an actual accident victim. The earlier programs were two-dimensional models developed to study frontal impacts. Later models, however, have fully three-dimensional capabilities. A review of various models developed in the past is given by King and Chou [2].

One of the most recent programs available now is the MADYMO crash victim simulation program [3]. This program has been developed at the TNO Road-Vehicles Research Institute in the Netherlands in co-operation with the Institute for Road Safety Research SWOV. The program is widely used by car companies and research institutes for instance in computer aided design applications and for biomechanical analyses. Advanced graphics possibilities are available which allow visualization and animation of the motion of the body during a crash event. Special submodules allow for the simulation of the human body with the vehicle interior and crash safety devices like an employing airbag. The MADYMO program has been validated in the past in numerous studies by comparing the predictions with results of experimental crash simulations. Illustrations of the possibilities offered by MADYMO are given in Figure 11. Results are presented for the reponse of an occupant in a frontal collision, a side impact and the motions in a pedestrian impact.

Simulation of human body segments

The final type of crash models to be discussed here are the body segment models where the model representation is restricted to a specific organ or structure. They particularly have been developed to study injury mechanisms in the most frequently injured body regions like the head, neck, spine and thorax. For a review of this type of models see Ward and Nagendra [4].

In these more detailed models the distribution of the forces inside the tissue and bone is studied and internal stresses and strains are calculated.
Due to the complex geometry involved and the non-linear and elastic properties of biological tissue in mostly finite element or finite difference representations are used. However, many of the significant parameters of biological material are not or only partially known and consequently the realibility of the predictions of such models appears to be still rather limited if correlated with experimental test data. Figure 12 illustrates a typical example of this category of model namely a finite element representation of the human brain developed by Ward [4].

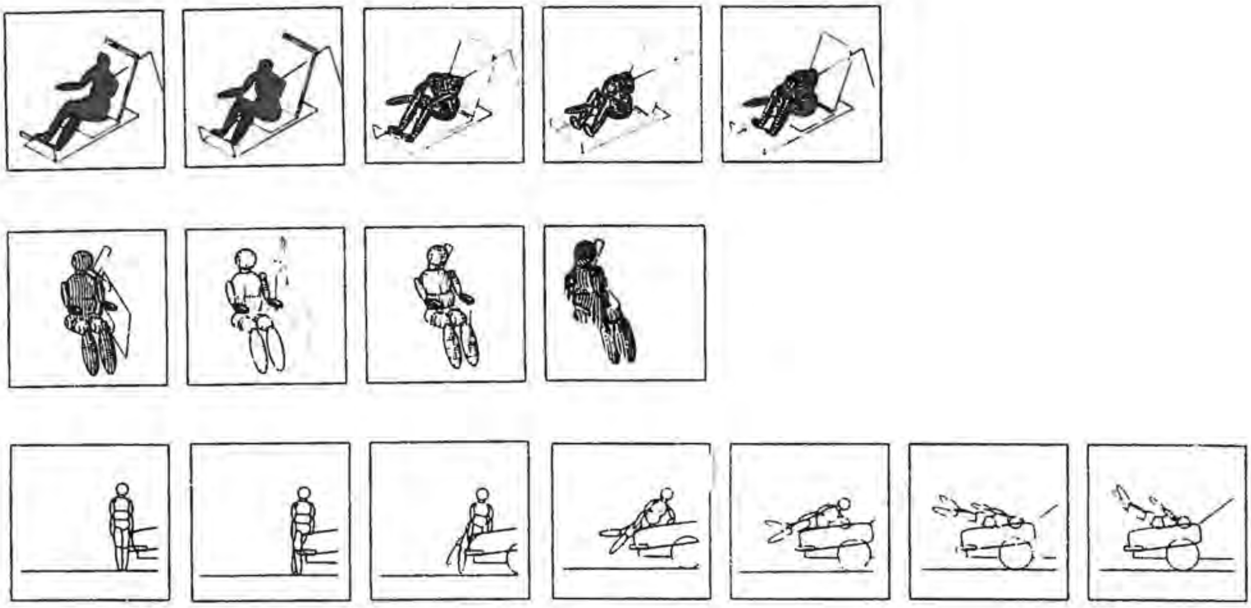

Figure 11: Examples of model simulations with the MADYMO Crash Victim Simulation program.

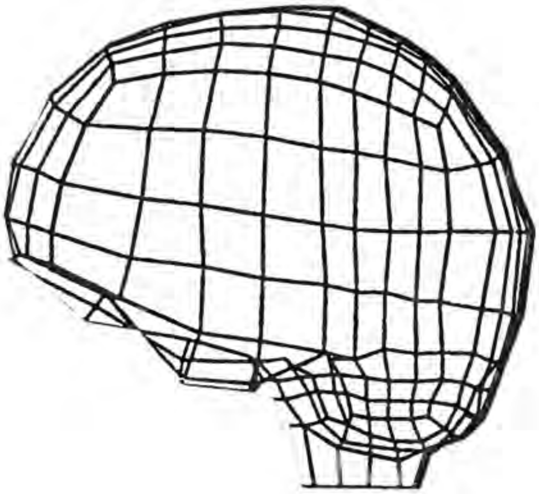

Figure 12: Finite element model of the human brain used for head impact simulation.

Discussion

In the past years application of crash models in traffic safety research has shown a rapid growth. To a large extend this is due to a strong increase in features offered by software packages. But also more powerful computer hardware systems have become available which have contributed significantly to this trend.

In this paper the most important categories and applications of crash models have been reviewed. They vary from relatively simple lumped mass models to study vehicle trajectories during a crash to very complicated non-linear finite element programs to simulate the vehicle deformation in a crash or the response and injuries in a specific body segment like the human brain. Practical application of this last type of models (i.e. human segment models) is still rather limited mainly due to the lack of information on material properties of biological tissue.

In the field of accident reconstructions, particularly for litigation purposes, models have been applied in the past years extensively. Also in vehicle design more and more use is made of crash models (computer aided design). Though these analyses are not common practice yet in automotive industries, it is expected that simulations will be of increasing importance during the design period of a vehicle. However, these simulations will never superfluit the need of testing, because it is not possible to take account for or to model all phenomena which may be of influence during a real crash test. By applying simulation techniques in an early stage of the design, a considerable decrease in the number of prototype crash tests can be expected. As a result, in a shorter time and a more effective way a vehicle can be designed with optimal safety features.
A final development which is expected to contribute significantly to the acceptance of simulation programs for crash analysis is the increasing use of technical graphical workstations. Most recent developments in this field allow real-time animation of the dynamics during a crash which appears to be a real advancement in understanding the complex mechanisms involved in a crash.

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Statement 4
OPPONENTS REMARKS

E. Pullwitt
Federal Highway Research Institute (BASt)

I congratulate you to the successful presentation of such an interesting theme.

Before I answer, I'll give you an idea of what I'm dealing with, I'm a test engineer in the area of passive car safety and I have not very much experience in computer programming. Therefore, I can't give you any hints for doing your job better, but, nevertheless, I was able to widen my experience by preparing myself for this answer.

My opinion about mathematical simulation is as follows:
Advantages are, first, to set up a computing model, you must be sure about the crash mechanism, that means the rules and laws of the real world behaviour of the acting objects.

Second, if a simulation program describes the behaviour in a special test in large conformity to reality, one can use it to vary single items of the vehicle or its surrounding characteristics and find an optimised result in a kind of step by step evolution.

A disadvantage is to my mind that at the moment no program and model system exists which is capable of simulating different car types without an adjustment coming from data of real crashes.
So, I think you are right when you say, that detailed and reliable results require a large amount of structural data and sometimes approximations.

From my experience in crash tests I know about the wide scatter of test results. This scatter combined with limitations of a simulation program can't lead to a 100% prediction of test results.

If we consider the use of simulation programs in the field of car type-approval tests, we get a greater complexity of the simulation program by installation of occupant models.

Taking these disadvantages into account the use of simulation programs should be restricted up to now to the development of vehicles or road equipment.

Actually, there exists a proposal to use a kind of simulation program in car type-approval, more details on this are included in the statement by Mr. Faerber.

This simulation program is a very simple one. The dummy is simulated only by two interacting masses. But there is one feature which I think to be an improvement compared to other programs, that is the character of the input data for the crash behaviour of the vehicle. This program doesn't need a big amount of single elements with their own characteristics but gets force and stiffness data from a real deformation produced in a quasi-static load. In a further step we need only a model which is able to transform quasi-static loads into dynamic ones.

The way to further development of mathematical simulation should not be cut off. The technical development on the computer sector will open further possibilities to get reliable results from simulation models with decreasing expenditures on computer hardware and costs.

Statement 5
EINE PFLASTERSTORY

H.H. Keller
Federal Highway Research Institute (BASt)

Just as absolutist France revived the old paving techniques of ancient Rome - neglected for 1.500 years - on a grand scale over 200 years ago, all the world is now following up the concrete and asphalt era with clinkered roads in the "Dutch manner": in Kei, Platkei, Dik, Waal, Tegel and other formats. Brickworks, quarries and the old paving handicrafts are beginning to flourish again. But we will have to relearn much that we have forgotten, from ancient times as well ?

Zusammenfassung

Wie das absolutistische Frankreich vor mehr als 200 Jahren die alten, vernachlässigten Pflastertechniken des antiken Rom in großem Stile wiederbelebte und damit zu einer Blüte in Europa führte, so folgt alle Welt nach der Beton- und Asphaltaera nun der "Niederländischen Manier" des Straatklinkerns in Kei, Platkei, Dik, Waal, Tegel u.a. Formaten. Ziegeleien, Steinbrüche, das Pfasterhandwerk beginnen wieder zu florieren, aber wir müssen Vergessenes neu lernen ... etwa von der Antike?

Die erste Renaissance des Pflasterns von Straßen und Plätzen erlebte Frankreich im 18. Jahrhundert in großem Stil. Alles blickte gebannt auf den Glanz von Paris, wo die Prachtstraßen nicht in Staub und Schlamm versanken.

Die zweite Renaissance ging im 20. Jahrhundert von den Niederlanden aus, sie kam mit der Verkehrsberuhigung. Hier bei Ihnen hat das Pflastern ungebrochene Tradition, Straatklinkern blieb immer ein florierendes Handwerk und beschränkte sich nicht nur auf Verkehrsberuhigung. Die ruhigere, sichere Wohnstraße nach niederländischem Vorbild erstrebend, wurden Verkehrsberuhigung und Pflaster in Deutschland fast zum Synonym. Jede Bürgerinitiative für eine verkehrsberuhigte Wohnstraße verlangte nach Pflaster, jeder Stadtplaner restaurierte Plätze mit kunstvollem Pflasterornament.

Aber bei uns fehlte geeignetes Material und kundiges Personal. Klinker aus Ziegeleien, Pflaster aus Steinbrüchen und das ehemals stolze Pflasterhandwerk waren im modernen Straßenbau lange nicht mehr gefragt gewesen.

Der Zementbetonverbundstein prägte zunächst das Bild, preiswert, von angelernten Hilfskräften schnell verlegt, ob im Neubaugebiet oder in einer historischen Straße. Wo blieb damals der Aufschrei der Denkmalpfleger gegen die Entstellung gründerzeitlicher Stadtgestalt? (Bild 1) Wer geißelte die neue graue, oder - noch schlimmer - zart-gemusterte Monotonie - wenn nicht der Spieltrieb per Farbpinsel? (Bild 2)

Wir hatten alles gründlich verlernt. Aber keine Sorge, wir versuchen aufzuholen. Straßenbaufirmen heuern Kolonnen von Pflasterern in Ungarn und anderswo an. Schönes altes Natursteinpflaster wird massenweise von der DDR bezogen. Dort kursiert schon der fatalistische Spruch: "Ach wär' ich doch ein Pflasterstein, dann könnt' ich schon im Westen sein."

Bild 1: Zementverbundstein, monoton, über die gesamte Straßenbreite zwischen Häusern aus Gründerzeit und Jugendstil

Bild 2: Von einer Hausgemeinschaft bunt lasierte Betonsteine, aus H. Wolff "Das Pflaster" Dt. Kunstverl. (87)

Das Pflaster ist noch nicht tief in unseren Zivilisationsschichten versunken, nur von dünnen Asphaltlagen überzogen (Bild 3), aber wie schwer fällt es doch, einen zeitgemäßen Einsatz in Städten zu finden. Wellen des Protestes und Applauses fand der neu gestaltete Rathausplatz in Köln (holprige Natursteine, breite Fuge mit Granulat verfüllt, teilweise mit Grasbewuchs, Plattenbelag am Rand und in Querstreifen). Einerseits die alte Klage mit den Stökkelabsätzen, andererseits ist es für die engagierte Stadtkonservatorin "geradezu ein sinnliches Vergnügen darüber zu laufen" *)

Auch an anderem Platze in Köln, der mit Großkopfpflaster in traditionellem Basalt, mit dichtem Rasen in den Fugen neue, lebendige Gestalt erhielt,

Bild 3: Pflaster mit Asphaltüberzug

Bild 4: Basalt-Pflaster mit Rasenfugen, An Groß-St. Martin, Köln

*) Kölner Stadtanzeiger, 25. März 1988, Nr. 72 S. 9

ist an den Benutzungsspuren abzulesen, wie er von einem breiten Publikum angenommen wird (St. Martin. Bild 4).

Farben- und Formenreichtum bringt der Klinkerverband in vielen Variationen wieder in das Straßenbild. Er war in Norddeutschland besonders verbreitet, dort paßt er auch hin. (Bild 5) In Köln wirkt er wie ein schöner Importartikel. (Heinrich-Böll-Platz).

Wir lernen auch mit Betonstein ansprechende sinnvermittelnde Räume zu schaffen, ausgewogen in den Funktionen für ihre Nutzer und in den Dekorationsaussagen. (Bild 6) Sogar klassifizierte Ortsdurchfahrten mit Schwerverkehr werden wieder gepflastert, zum Beispiel mit Betonformsteinen im Sonderformat (21 x 14 x 14 cm), wegen der hohen Schubkräfte im Diagonalverbund ohne

Bild 5: Klinker- u. Naturstein-pflaster in Buxtehude

Fugenverfüllung ("knirsch") verlegt. Die Ornamentik erinnert an frühere überladene Fußgängerzonen. (Bild 7)

Soweit zur Überlieferung, Tradition und Renaissance des Pflasterns - - jedoch kein Wort zu Haltbarkeit, Umweltbelangen, Wirtschaftlichkeit. Was ist mit Kehren, Streuen, Lärm, Griffigkeit? Auch kein Wort zur Furcht der Polizei vor fliegenden Pflastersteinen! Wenigstens eine Bemerkung noch zum Ausgangspunkt, zur Verkehrsberuhigung:

Eigentlich will sie doch sichere, langsamer befahrene, ruhige Straßen schaffen. Warum mit Pflaster? Mit Asphalt wäre alles einfacher. Wir verlegen Pflaster kompliziert in Huckel und Rinnen, um schnelle PKW zu bremsen, Radfahrer und Busse weniger zu hindern (Bild 8). Bei der Vielfalt der Fahrzeuge funktionieren solche

Bild 6: Betonsteinpflaster in Köln, Sanierung Stollwerk

Bild 7: Betonsteinpflaster, Bundesstraße 241, Borgentreich

Spurführungen noch nicht perfekt. Hätten wir doch genormte Radabstände wie zur Zeit der Antike, dann könnten gezieltere Straßenhindernisse errichtet werden. In Syrakus wurden 700 v.Chr. Gleise in die Straße eingearbeitet, damit Priesterinnen die schweren, noch nicht lenkbaren, Prozessionswagen führen konnten. (Bild 9) In diesem Fall liefert die Antike ausnahmsweise keine Anregungen, die Entwicklung ist davongelaufen.

Oder sehen Sie mögliche Ansätze?

Bild 8: Plateaupflaster zur Verkehrsberuhigung, Berlin-Moabit

Bild 9: Eingearbeitete Gleise in Gräberstraße von Syrakus, 700 v.Chr. (aus H. Wolff)

Statement 5
OPPONENTS REMARKS

Theo Janssen
SWOV Institute for Road Safety Research

In the past the pavement construction in terms of bricks, clinker etc. was "traffic promoting"; traffic in terms of charts drawn by horses. Nowadays the traffic promoting pavement construction indeed consists of concrete and asphalt because of the changed requirements for the traffic like higher speeds and better skid resistance.
Your lovely pavement story tells us about the rehabilitation, the renaissance of the bricks, the clinkers, the "platkeien", the "Walen" and don't forget the "kinderkopjes" (also made in Belgium).
But I will warn for wrong applications in the future. The aim of that renaissance is no longer traffic promoting, it is more or less restraining the traffic the traffic performance. In applying this restrains for reasons of safety you have to be sure that you don't put the charts before the horses.
My question to mr. Keller: which conditions for the road and traffic will guarantee, in your opinion, that this kind of traffic restraints have positive effects on safety and which conditions will result in negative effects?

Statement 6
THE ROLE OF TRAFFIC RULES

Piet Noordzij
SWOV Institute for Road Safety Research

Legal traffic rules tell road users what to do or not to do. Violating such rules means risking a penalty.
The large number of rules and exceptions to that rules limits the behaviour of any road user in any situation. Following the rules is an important part of learning to drive.
Experienced road users seem to have their own set of rules (including rules about when to violate the official rules). The number of violations is enormous, causing great concern for the authorities.
The situation could be improved by separating a set of rules with the aim of deterring road users from dangerous behaviour and a set of rules instructing correct behaviour. The first set should be small and formulated to satisfy the lawyers. The second set should cover almost any situation for any road user with a presentation aimed at these road users.

1. Introduction

Legal traffic rules seem to be an essential element of road safety policy. Official statistics present the causes of traffic accidents in terms of violations of legal rules. A driver examination starts with a test of the nowledge of traffic rules. But large numbers of violations have always given use the doubts about their effectiveness.
The present aim of the Dutch government is to revise the rules to obtain a small set of simple rules that will be accepted by the majority of road users. This is claimed to improve road safety by a better compliance with the rules and a more responsible attitude of road users in general.

Next to this introduction the history of traffic rules will be reviewed in par. 2, followed by the state of the art with regard to the effectiveness of legal traffic rules (par.3). After that the prospects of an improvement in effectiveness will be discussed in par.4.

2. History of legal traffic rules

The introduction of motor vehicles has been accompanied by the introduction of legal traffic rules. At the beginning of this century road accidents were blamed on the behaviour of car drivers and traffic rules were meant to limit the use of cars for the protection of other road users. The behaviour of car drivers and the lack of police enforcement caused a lot of complaints. At the same time the road network was

developed and adapted to the promotion of motorised traffic. At the end of the first half of this century motorisation of road traffic had really started and the legal traffic rules had become a complex set of rules, clearly reflecting the car as the most important and favored means of road transport. The intention of these rules had also developed from deterring road users from behaviour which is seen as immoral or highly dangerous to a description of how to behave properly in almost any situation for any road user.
Since the middle of this century the use of motor vehicles has shown an explosive growth, parallelled by a similar growth of the road network. The same period also shows a steady flow of small changes and additions to the traffic rules. Only recently reactions to these developments have led to restrictions to the use of motor vehicles for the safety and freedom of pedestrians an cyclists and for the sake of the enviroment. Concern for the safety and freedom of pedestrians and cyclists hase resulted in the introduction of pedestrian crossings, pedestrian areas and woonerven with their special traffic rules. Of course the Netherlands have always had an advantage over other countries with regard to the construction of cycle paths and other special bicycle facilities. But this had the dual meaning of protecting the cyclists as wel as removing restrictions to the flow of motor vehicles.

The most recent political trend is aimed at deregulation. As far as traffic rules are concerned this can be justified by the large number of very specific rules, the relative ignorance and the large scale violation of these rules. It is also justified by the large scale use of traffic signs which dominate and sometimes confuse the traffic scene.

3. Effectiveness of traffic rules

Essentially legal traffic rules are prescriptions for the behaviour of road users given by they government, which also has the power of forcing penalties on road users who violated these rules. As with all legal rules the original intention has been to limit the individual freedom of road users only if necessary. However, the present set of rules is very comprehensive and in fact there is little freedom left with a strict interpretatin of the more general rules: entering the road, the selection of speed, turning and stopping are only permitted without causing trouble to other road users and parking is recommanded in special places.

To comply with all the rules a road user should almost continuously ask himself (or herself): which of the rules apply to me in this situation, what is the behaviour prescribed by these rules, what will happen if I do not follow these? In theory the number of violations is negatively related to the speed, certainly and severity of a penalty. The choice between violating or complying with a rule seems to be a simple comparison between costs and benefits. In practice the level of police enforcement makes it very unlikely to receive a penalty for a violation. Apart from this the theory seems to be too simple. First violations look as if they were the results of rational decisions of normal persons under normal conditions. But the behaviour of road users is partly automatic and partly habitual and will only look rational if the learning of this behaviour in the past was based on rational arguments.
Second, individual appreciation of the positive or negative results of a particular behaviour is important rather than some objective measure. Individual appreciation and objective measure of e.g. chance of detection of a violation or severity of penalty are not directly related. Third, for individual road users a legal penalty may be one of a range of penalties related to the particular violation as well as there may be a number of rewarding factors (including the impression made on others).

Despite the restrictions of this theory there is evidence of a deterring effect of legal traffic rules, based on the threat of a penalty. Also there is some evidance of the effectiveness of rules based on the authority and credibility of the government. The government is expected to prescribe traffic rules with great care and expertise and as long as there is no obvions reason to question this, these rules will be accepted.
For pedestrians and cyclists one such reason could be a feeling of severe limitation of their freedom for the benefit of car drivers. The rules may be meant for their own protection but this is hardly a convincing argument. Another reason may be that several traffic rules prescribe behaviour which is overly cautious (for most road users in most situations). Traffic rules give some speficication of the groups of road users or situations they apply to, but this is regardless of the personal condition or competence and regardless of the prevailing conditions.
Quite a number of traffic rules have an indirect meaning for safety in the sense that they regulate the behaviour of road users to make this more predictable to others. The benefits of these rules are most convincing in dense traffic.

Even though the legal traffic rules can be regarded as prescriptions for behaviour and the set of rules is very comprehensive they are not sufficient by themselves to know how to behave in traffic. The rules prescribe the behaviour in terms of their results rather than the pattern of actions to obtain these results. Priority rules can be taken as example. These rules specify which road users have to be given right of way but do not specify in which order to look in which direction when approaching an intersection.
A complication in translating legal rules into behaviour is that several rules may apply to the same situation. But even finding if a rule applies in a particular situation is not a simple matter because general rules are presented first and specifications or exceptions to these rules have to be found in later articles.

In summary the effectiveness of legal traffic rules is based on a threat of a penalty for a violation, or the authority of the government as well as on the right kind of arguments. Their potential as prescriptions for the behaviour of road users is, however, limited.
The effectiveness of traffic rules is very much dependent on other elements of road safety policy. Police enforcement has already been mentioned. Other elements that are relevant in this respect are (driver) training and examination, road design and the use of traffic signs.

4. Prospect for improvement

The effectiveness of the present set of legal ttraffic rules can be improved in a number of ways, starting with a revision of seperate rules. Each rule should be checked if the situations to which it refers are outdated, if the arguments for the behaviour which is prescribed still hold, if the behaviour can be prescribe in more detail. A decision has to be made if the rules have to be kept simple and small in number or more specific for particular groups of road users and particular situations. The first option has the advantage of being simple but the prescription of the behaviour has to be general and vague or more precise but rigid. The second option results in an more comprehensive set of rules each of which is better suited to the diversity of real traffic situations.
A more fundamental decision has to be made if traffic rules should continue their function as the most comprehensive and authoritative set of prescriptions for the behaviour od road users. If this function is to be

continued several improvements can be made. They could be made more accessable by presenting the rules in seperate sections according to different means of transport and different types of roads. They could be presented more convincingly by starting with a number of articles explaining the intentions of the rules in general terms and by providing arguments for individual rules.
This could be completed with some sort of priority ranking of the rules which is likely to result in a better compliance with the most important rules. It could even be taken into consideration to include rules without the threat of a penalty for violation. Compliance could be further improved by translating the legal rules into patterns of actions that can be trained.
These suggestions are being made in an effort to increase the impact of the rules on actual behaviour. However, if it is decided to restore the original function of legal traffic rules (i.e. to use the authority and power of government to limit the freedom of road users only if really necessary) only the most important rules can be kept. In this case, it is much more urgent to follow the suggestions made earlier to develop a seperate set of prescriptions for the behaviour of road users to be used as a basis for training.

Statement 6
OPPONENTS REMARKS

G.Kroj
Federal Highway Research Institute (BASt)

Who is Protected by Traffic Laws?

From certain perspectives, especially the viewpoint of traffic safety, a traffic offender becomes a victim of his own actions as does the other driver, cyclist, or pedestrian involved in an accident. From the viewpoint of accident research, little is known about the relationship between traffic offences and accident data.

From other perspectives, certainly the moral viewpoint, it is always the "innocent" pedestrian, cyclist or driver who claims to have been made a victim and backs this up by the very correctness of his behavior. There is a sharp contrast between the moral indignation characterizing public and policy statements on traffic offences and the alleged importance of legislation for an automotive society on the one hand and the detached, analytic stand of traffic safety "experts" on the other.

In a recent paper I found the following remarks on this difference in perspectives. In essence, these groups talk at cross-purposes: "They represent different conceptual domains and policy priorities. Although they may agree on legislation, they differ profoundly on the significance they attribute to it and in the emotions that they express."[1]

I would therefore appreciate it if we as "experts" could keep these and other different perspectives in mind while discussing the role of traffic laws in our automotive societies:

- Do mandatory traffic rules really tell road users what to do or not to do?

[1] GUSFIELD, J.R.: The Control of Drinking-Driving in the U.S. In: Social Control of the Drinking Driver, University of Chicago Press, Chicago and London, 1988, 121.

- Are these laws really understood and, what's more, accepted by the driving population?

- Which rules are accepted and which ones rejected by the population?

- Are there any research results available on traffic law comprehension and acceptance?

- Are there any research results available to explain the gap existing between the commonsense interpretation of traffic rules and the lawyer's interpretation?

- Is there any relationship between social control and legal control of road user behavior?

- Social control, even where it functions on the road, may not always work for the benefit of safe behavior. There may be cases, where drivers feeling the pressure from other road users engage in risky actions they would not have done otherwise.[2)]

- What about the influence of the sociocultural context on the role played by traffic rules and the significance attached to them - e.g., the attitudes and mores shaped by the Anglo-Saxon legal traditions as opposed to the Latin legal tradition?

Before we start the debate I would like to state my views as an opponent:

- Empirical data on the relationship between laws and their observance on the traffic scene permit assessing the true role played by these traffic regulations.

[2)] Reports of Young Beginners. In: Heft 58 der Schriftenreihe "Unfall- und Sicherheitsforschung Strassenverkehr": Schlag, B., Ellinghaus, D., Steinbrecher, J.: Risikobereitschaft junger Fahrer.

- The instrumental, methodological and financial resources available permit an analysis of only a limited set of traffic regulations thus far.

- More observation of road traffic and the consideration of the traffic regulations as opposed to the outrageous number of convictions for traffic violations (in some countries more than 70 % of the workload of the courts are attributable to legal cases dealing with traffic violations) highlights the following aspects of violations:

- Traffic regulations are often not or insufficiently observed.

- The vast majority of violations can be attributed to drivers' lack of attention or their overestimating their abilities - which by itself reflects a lack of responsibility.

- If we do not trust regulations, do not regard them as a value in themselves, but expect benefits of them in terms of improved road user behavior, shouldn't we then reconsider and - maybe - differentiate between the rules in the sense Piet Noordzij recommended?

In accordance with him I recommend

- enacting a limited set of rules - the ones which are absolutely necessary and useful for the driver community and the public in general and

Additionally to P. Noordzij I propose

- doing away with all those only satisfying the legal standpoint and the authorities.

As far as I am concerned, there is no need for two different sets of rules, one designed to deter road users from dangerous behavior and the other as instructions for correct behavior.

My proposals are:

- that dangerous and correct behavior should be considered as a continuum
- that lawyers and authorities should feel challenged to express themselves in the same language as the general public does on this matter

I therefore recommend the formulation of a limited set of regulations taking the different sociocultural and political viewpoints on laws into account.

Such a set of regulations shoud have a chance to be not only understood but also accepted as a useful guide to safe and responsible behavior.

There is no need for a long catalogue covering everybody everywhere in order to avoid the long list of imaginable hazards and possiblities of risk-taking.

In conclusion I have to confess that I agree fully with Nietzsche when he said "it is much easier to preach a moralistic sermon than to live by it."

For that reason I also favor some of the recent empirical approaches that emerged from our research programs concerning this matter of the last years:

- development of road safety indicators
- the project of police enforcement evaluation
- models of traffic behavior

I suppose "it's a long way to Tipperary."

...

Statement 7

BEHAVIOUR IN YESTERDAYS' TRAFFIC - MESSAGES FROM THE EARLY DAYS

Wilfried Echterhoff
Federal Highway Research Institute (BASt)

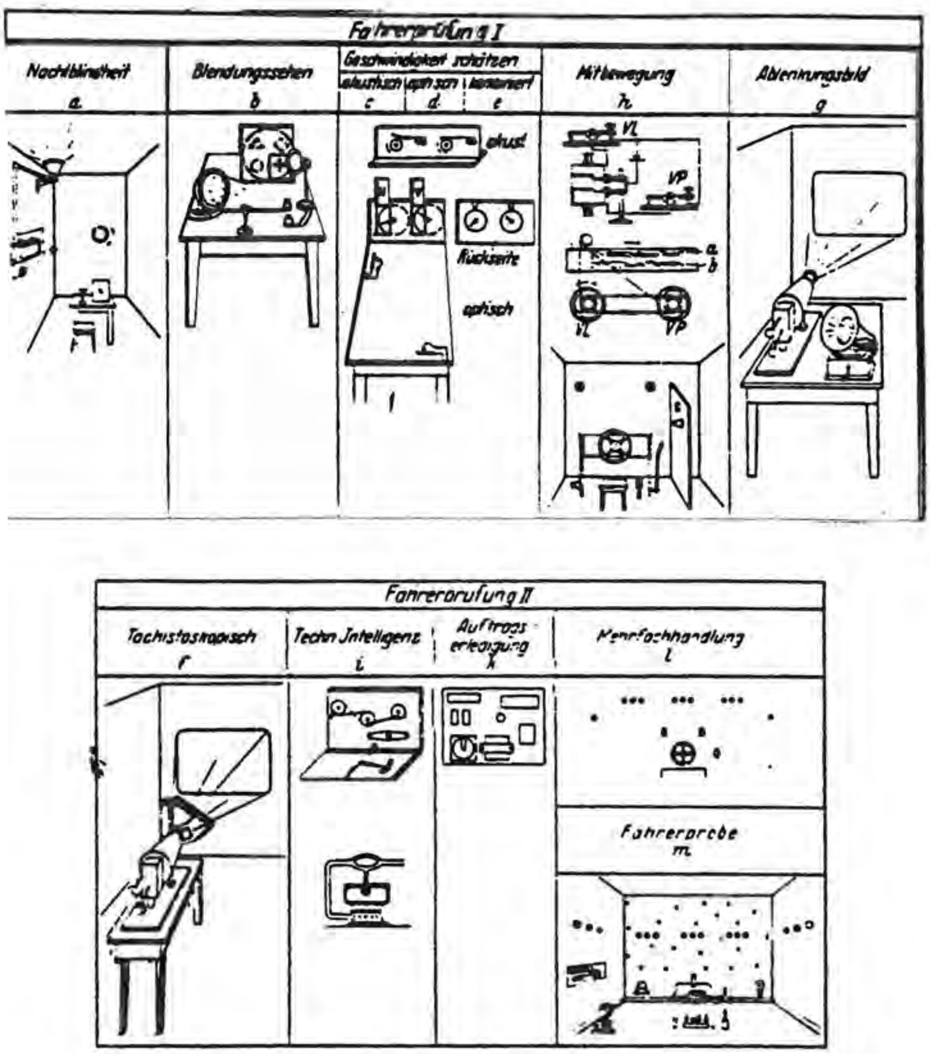
Historically traffic psychology has its roots in work on industrial accident prevention. Drivers of vehicles in the old days were regarded as factory workers operating a machine. First steps in recognizing the rather wide descretion that drivers have in deciding goals and behaviour were taken by psycho-analysts. A term like human engineering would describe quite well most of the early work on traffic psychology. Taking a closer look, we come up against many familiar terms like estimation of speed, road lighting, reaction times, accident proneness and personality characteristics, selection criteria and even driver improvement.

Until now, traffic psychology and psychological accident research are no independent academic subjects in Germany. There are no scientists in German universities in charge of these research areas except on the basis of occasional contracts or individual motivation. In Germany, only "BASt", an institute of the federal government, is charged with scientific work and research in the field of traffic psychology and psychological accident research - carried out by a very small staff. This situation appears to be similar in other countries.

Although a great number of accidents occurred in the times of horse-drawn vehicles, steam locomotives and trams, systematic accident investigations were not undertaken and countermeasures nonexistent until vehicles started to be motorized and their use became widespread.
The first systematic psychological approach to traffic problems probably began in 1915, when drivers in the German army were subjected to psychotechnical aptitude testing. In 193O, Moede (p.389) described the following procedures used in driver testing:

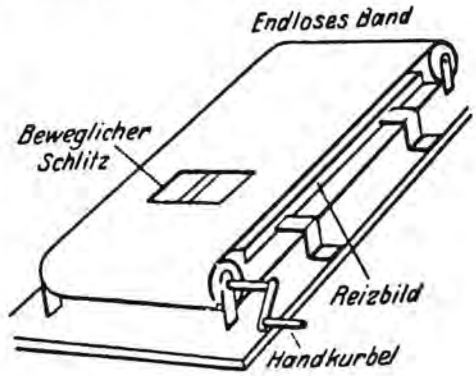
- <u>Driver tests</u> which investigated abstract groups of functions, e.g. multiple actions as a response to moving stimuli, using test apparatus (see Fig. 1).

Fig. 1: Test Configuration for Drivers according to Moede, Fig. 272 (193O, p.389).



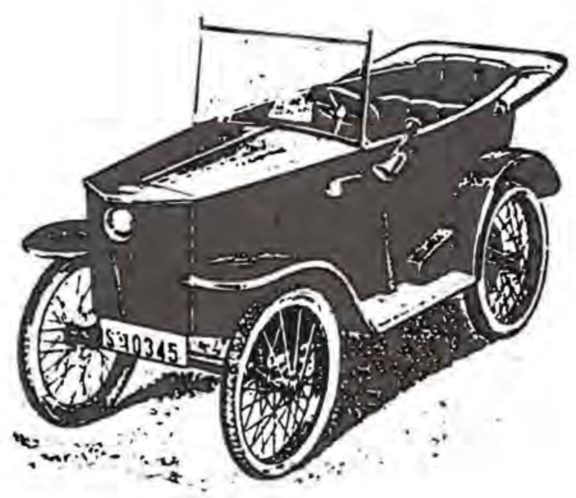
- **Model tests** with driving simulations, e.g. using a hand-operated moving belt based on Münsterberg (see Fig. 2).

Fig. 2: Moving Belt (Line following test) based on Münsterberg according to Moede, Fig. 275 (1930, p.394)



- **Real-life tests**, in which driving tests were carried out with a real vehicle.

Fig. 3: Battery powered vehicle ("Elektromobil") for carrying out real life tests described by Poppelreuter 1929



The dramatic rise in the number of accidents in Berlin in the twenties was blamed by Ach (1929) on the lifting of the speed limit in 1927. With the help of statistics, he showed that accidents among cab drivers (taxi drivers) had increased the most.

Table 1: Accident Distribution among Vehicle Types according to Ach, Table 2 (1929, p.88)

	Personen-Kraftwagen			Last-Kraftwagen			Kraft Droschken		
31 XII.	Zahl	Unfälle		Zahl	Unfälle		Zahl	Unfälle	
1926	15 900	4 900	30.8 %	9 330	1 210	12.9 %	8 550	5 010	58.6 %
1927	21 950	7 000	31.9 %	11 870	4 820	40.6 %	9 220	11 270	122.2 %
1928	29 300	10 440	35.6 %	14 480	6 830	47.2 %	9 130	11 390	123.6 %

Ach suspected that taxi drivers exploited their greater driving experience for commercial reasons and thereby took greater risks. As a possible countermeasure, Ach (1929, p.95) called for a "recording speedometer" to be built into vehicles as an "impartial observer and active conscience". He was thus demanding nothing less than a tachograph or something like a simple "drive-recorder". He hoped this would encourage slower driving, since speed would be constantly and permanently recorded.

Due to the psychotechnical orientation of traffic psychology, less interest has been shown in those investigations focussing on emotional rather than functional criteria, such as the work carried out by Raphael et al. (1929) linking the accidents of traffic offenders in their clinic with higher suggestibility or emotional weakness, or that of the psychoanalyst Fenichel (1928), who suspected that one cause of accidents was the desire for self-punishment among those people involved.

Retraining programmes existed for poor drivers as early as the thirties. Some of the early experiences with selected courses of treatment for such drivers were first described by Johnson & Cobb (1938, p.758):

"About a dozen mobile "driver's clinics" are now operating in the United States... their main purpose is educational ..... one will find that they will very probably show a lower accident rate in the following period of similar length, whether they are subjected to special treatment in the meantime or not, and even though the treatment that they may receive is wholly ineffective." (Johnson & Cobb, 1938, p.760).

In 1962, Mittenecker interpreted the results available from previous practise and training measures thus: "....In certain circumstances (they) can shorten this period of increased danger (at the start of an activity)... Compared to these relatively clear results, the results of treatment and retraining programmes for people who have already suffered a large number of accidents are much harder to interpret. As ...shown, the previous number of accidents is, for various reasons, a very inaccurate indicator of "true accident tendency"." (p.132).

For a long time, the driver was the exclusive object of psychological studies and concepts. Other groups of road users only featured in published reports at a relatively late stage. The subject of "Pedestrians" (Loehrke, 1959) was chronologically only just ahead of "Dog behaviour in city traffic" (Brunner, 1961).

In the USA, the first accident involving a motorized vehicle was reported in 1895 (Marshall, 1988, p.2), two years after the first car had appeared. According to this report, the car of Mr. Charles Dureya went into a ditch after Mr. Dureya had attempted to avoid a farm cart. Marshall further reports that the first car accident in which a person was killed took place in 1899, and that the first road traffic regulations in the world were introduced in New York on 3O October 19O3.

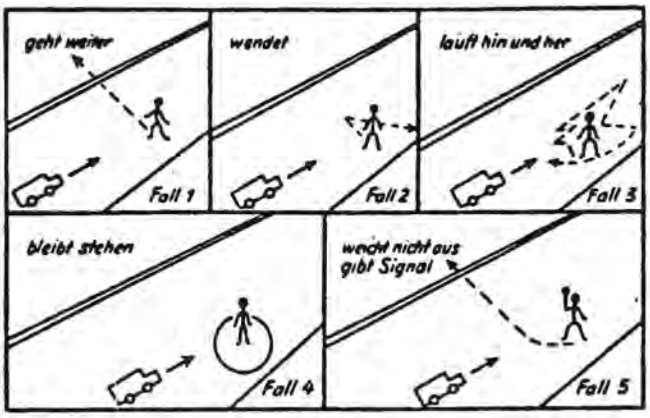
Cars existed in Europe a few years before reaching America, and therefore the first car accident of all time probably happened in Europe, possibly even in Germany.

One of the first known fatal accident occured in France in the year 1898. Marquis de Montaignac touched the wheels of the vehicle of M. Montariol while overtaking with a speed of 3O km/h. When Marqis de Montaignac was turning his head he lost the control of his vehicle. Marquis de Montaignac died in the hospital blaming himself to have caused the accident.

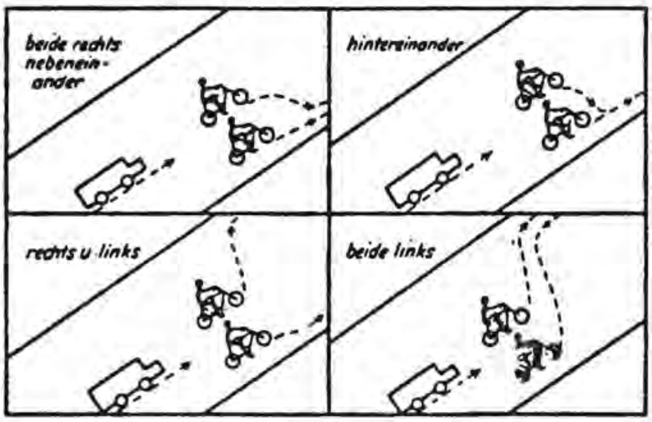
At the end of his conceptual review article, Moede (1944, p.3O3f) referred to more recent safety and traffic behaviour concepts as well as to conflict analysis: "The first warning signals used by cars in traffic were water sprays. Traffic in later years will employ less drastic means and only use warning signals in an emergency, always taking into consideration the probable reaction of other persons involved. The study of behaviour in traffic must be developed from traffic psychology, as illustrated in the examples included in Figs. 9 and 1O."

Fig. 4: Examples of Behavioural Study Themes according to Moede, Figs 9 and 1O (1944, p.3O4)

"Possible Behaviour of a Pedestrian at the Approach of a Car" (Moede, 1944, p.3O4)



"Behaviour of Cylists" (Moede, 1944, p.3O4)



Early road safety initiatives can be seen in a number of illustrations, and in particular in posters promoting road safety (see Figs. 5 to 7).

Fig. 5: "Don't block the pavement! Think of others!" (Fig. 132 from Herwig, 1928, p.807)

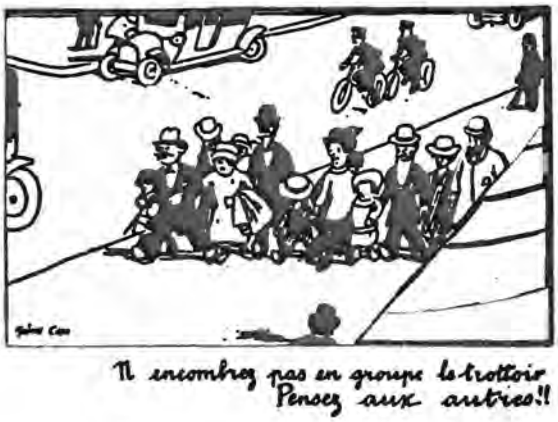


Fig. 6: "Stop and Look" - Warning for Pedestrians at Tram Lines (Fig. 131 from Herwig, 1928, p.806)

Fig. 7: "The Lights That Say: 'Stop!'" "Go Slow" American poster (Fig. 130 from Herwig, 1928, p.805)

In 1944, Moede discussed accident research and its problems:
"Traffic accident analysis is among the most difficult tasks in psychology practise." (p.293)

And the situation today? In addition to the academic problems of accident analysis, which - partly - need not be regarded as quite so important today as in the past, and against a background of new legal developments and regulations (e.g. self-determination of the citizen, in particular the car driver; data protection laws), the main difficulty of our task today lies in getting across an appropriate and sufficiently powerful message to the road user. Aims and ideas, however, appear to be just as plentiful as ever.

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An extended version of this paper in German language is under work to be published in 1989.

Statement 7
OPPONENTS REMARKS

Peter Levelt
SWOV Institute for Road Safety Research

Traffic psychology has as it subject: road users in their traffic environment.
The traffic environment is primarily determined by the means of transportation. So the history of traffic psychology depends on the history of means of transportation.

Accordingly my first curiosity concerned the development of those vehicles, especially of automobiles.
I tried to get a good picture from your paper. I was not helped by the slides you showed us.

I had to conclude that the first car was an animated, humanlike being because you have said that a speedometer could be built into it as an "active conscience". A conscience is a human characteristic. On the other hand you talk about motorized vehicles. So it must have been a motorized animated being.

Later on I could infer the speed and other characteristics from this sentence. I quote: "Cars existed in Europe a few years before reaching America." I must conclude that the vehicle needed at least two years for 6000 kilometers. The speed must have been around 300 meters an hour. I now understand the necessity of a speedometer. Without such a meter you could hardly even observe any movement.

Another conclusion is that the car must have been amphibious, an animal able to live both on land and in water. That explains an other characteristic. I quote: "The first warning signals used by cars were water sprays."

Then I became curious and visited the SWOV library. There I found a lot more about vehicles and accidents (Leerink, 1938). The first locomobile was constructed in England around 1650. Newton improved it 30 years later. Mr. Cugnot, from France, constructed a tricycle with steam traction. He had an accident in 1770: he drove against a wall. Perhaps the first car accident.

I came across two very far reaching accidents in 1832 and 1834, accidents with steam buses. The English authorities have stopped the development of this kind by buses by imposing severe regulations.

And now I will come to my point. This is a very good illustration of how authorities react to developments. They often have to cope with new problems which have to be solved before the end of their term of office. These short-term reactions determine in my opinion the characteristics of traffic psychology too.

Mr. Echterhoff, you have given some illustrations. You mention the influence of the war. A war lasts on average 5 years. Generals need experienced drivers. The emphasis in traffic psychology has been put on selection. That explains probably the psychotechnical orientation. You have also given examples of the consequences of accidents: authorities ask for speed countermeasures like limits and speedometers.

I could imagine a completely different approach and I would like to hear your opinion about this lesson from history. I will give you an example.

The first generation of car drivers were sportsmen. This must have had much influence on the image of traffic people have got.
A sportsman tries to improve his performance and he tries to impress his public. You could expect that the image of traffic has been coloured with concepts as "risk", "speed" and "showing off".
Concepts of "mobility" and "safety" were probably not relevant.
Children learn by observation, observation and behaviour, and observation of intentions, attitudes, opinions etc.
When children later become drivers themselves, those observed conceptions of traffic are the foundation of their own behaviour.

My contention is, and I would like to hear your opinion, that the emphasis of traffic psychology lies on short-term processes because of the short-term intentions of authorities and that the long lasting processes of transferring traffic culture to the next generation have been neglected.

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Statement 8
ESTIMATES OF EFFECTIVENESS OF SAFETY BELTS UNDER DISCUSSION

Fred Wegman
SWOV Institute for Road Safety Research

The use of safety belts reduces the change to be injured or killed in an accident. It has been proven in laboratories by impact tests.
This raises the question as to how much the number of casualties among drivers would be reduced if the number of users increases.
Safety belts are not effective in every (kind of) accident, and they are not always correctly worn or fastened. Some people think drivers adapt their behaviour to their use of the safety belt (risk compensation).
To determine the effectivety of safety belts in real terms before-and-after comparisons are made with adjustments for other influences.
It appears to be hard to execute such research. Recently a number of studies has been carried out in Great Britain, the USA, and FRG, partly as a result of a relatively important increase in the use of belts.
It seems probable that earlier estimates of the effectivity of belts (60%-80%) have to be adjusted downward.

Recently the 4-year Plan for Traffic Safety 1987 - 1991 "More kilometers less accidents" was adopted by the Dutch Parliament.

Worth mentioning of the plan is that the Government has pledged to achieve that there will be 25% less casualties in the year 2000. For the present governmental period this has been translated into 200 fatalities less in 1990 (than in 1985: 1438) and 1500 less in-patients (in 1985: 14520).
The setting of these quantitative goals, seen as a management tool in road safety programmes leads to more interest of politicians and policymakers to evaluate these programmes.

One main stream is the choice for a limited number of favourable points of action. For the following themes a new policy will be executed: alcohol and traffic, speed-behaviour on roads with a 50-km or an 80-km speed limit, safety belts and crash helmets, black-spots, young and inexperienced road users, aged people in traffic.

The improvement of the use of safety belts is considered one of the favourable points of action. After the introduction of the mandatory use of safety belts for front occupants in 1975 the theme safety belts has had some attention, if not very much, in politics. Policy makers directed their attention especially to legislation on the mandatory presence of safety belts (child's seats!) and use on back seats.

The use of safety belts hardly changed in the Netherlands and there have not been reasons to expect a change without far reaching measures.
Renewed attention for the improvement of the use of safety belts has been roused also by developments outside the Netherlands.
Reports from the Federal Republic of Germany and from he United Kingdom informed us that use rates of over 90% has been reached in those countries. The rates did not appear to go down in the course of years. Herewith the Dutch rates of 67% outside built-up areas and 50% inside built-up areas contrast sharply.

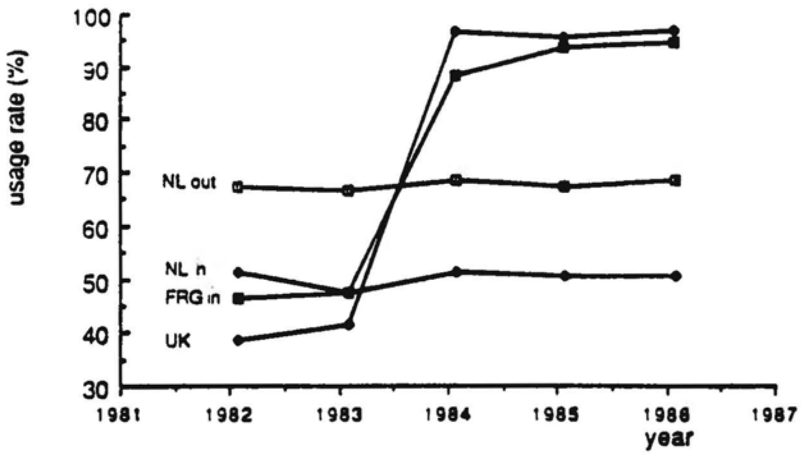


Figure 1. Usage rates in NL, FRG and UK.

Arising questions were:
- which possibilities have been proven succesful in and outside the Netherlands to stimulate the use of safety belts?
- is it realistic to expect to reach usage rates of 90-100% in the Netherlands?

It is of interest for the Dutch to learn from the German experiences in this respect. Are there good explanations why after the introduction of penalties for non compliance for front seat occupants the usage rates went up to more than 90% on all types of roads?

The Dutch policy nowadays could be described as combining police enforcement with information on enforcement like it is executed in the Canadian STEP programme. These programmes are implemented on an local and regional scale.

SWOV research has shown that an intensive campaign can produce a considerable change in safety belt use, even two years after the end of the campaign.

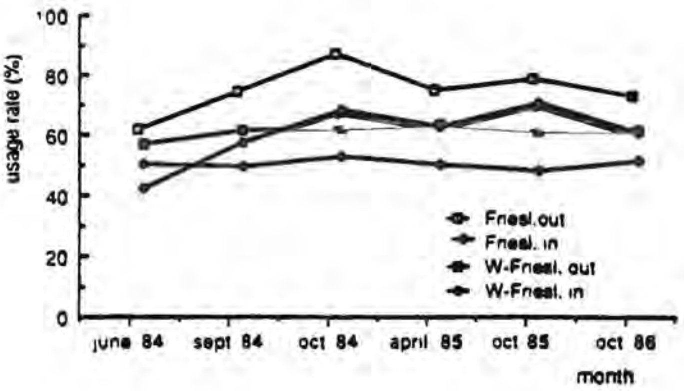


Figure 2. Usage rates in Friesland and control region.

But we have to admit that usage rates of 90% and more are not very realistic with these programmes.

One of our British colleagues told me that one of the reasons perhaps for such high usage rates in the U.K. might be found in the long lasting public discussion, ultimately leading to mandatory safety belt regulations.
It took seven attemps in British Parliament to pass this law. It has been for many years a dispute between defenders of liberty and defenders of life. Long public discussions might lead to high public acceptance?
A prominent opponent in the U.K. for mandatory regulations is John Adams comparing the postulated benefits of safety belts with the Hans Cristian Anderson fable " the emperor's new clothes": are the real effects visible or non-visible, that is the intriguing question.
As a matter of fact Adams has been used the same type of evidence as Peltzmann did in 1975 in his famous and strongly criticized paper "The effect of automobile safety regulation".
In essence Peltzmann and Adams are using the same method: time series of accidents and death rates, with and without intervention.
Both Peltzmann and Adams came to the conclusion that the introduction of safety belts had failed te reduce traffic deaths.
Peltzmann added that also energy absorbing steering columns, improved wind-screens, dual braking systems and padded instrument panels had no real positive effect.

They put forward the hypothesis of risk-homeastasis.
I expect that you are quite familiar with this theory and its prominent defender, the Dutch Canadian Gerald Wilde. This theory wants us to believe that someone using a safety device, e.g safety belt, speed limit, will compensate by increasing his risk, and by doing so producing more accidents. For safety belts this theory leads to the conclusion of no less accidents to car occupants and even more injuries to other road users.

In this presentation I would like to leave the subject of risk-homeostasis and return to the question of how to establish effectiveness of safety belts, accepting the principle of risk compensation.

Evans from General Motors worked out this principle in the following way:

$$\Delta S_{Actual} = (1+f)\Delta S_{Engineering}$$

f = parameter which measures the amount of behavioural respond or feedback in the system.
If f is equal zero there is no feedback. If f is equal minus one risk homeostasis is complete. If f lays in between zero and minus one we have a discount in effect.

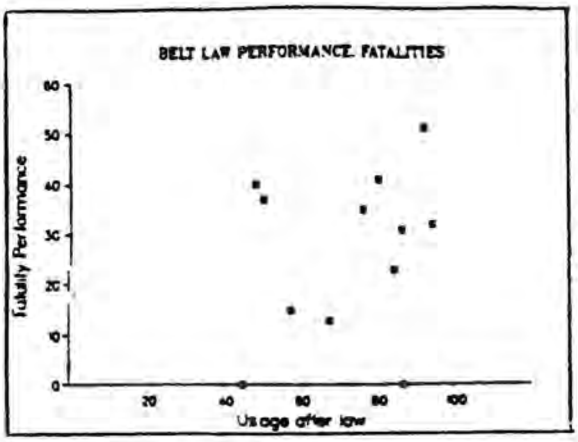
Discussing the effectiveness of safety belt laws it is crucial to distinguish:
- benefits to an individual car occupant (belt effectiveness);
- benefits to the car population due to belt usage change (belt law effectiveness or belt law performance).

Benefits to an individual car occupant deals with the average injury probability difference between belted and unbelted occupants, <u>given a crash</u>.
This measures the potential benefits or in Evans' words the engineering estimate.
Benefits to the car population, or in Evans words the actual estimate, depends on belt effectiveness but there are more influencing factors (belt (mis) use, differences between driving population and accident involved population etc.).

There is no doubt that the engineering safety change of safety belts is positive. Car occupants has better chances of surviving a crash using a belt. Belts prevent car occupants from ejection and from being injured consequently and prevent serious injuries caused by hitting the instrument panel or other parts of the interior of the car. Potential effects of safety belts are considered to be 60 - 70% depending on characteristics of the accident, the car and the driver. But some studies report considerably lower effectiveness.

A very interesting method has been developed by Evans: the so-called double pair comparison method. This type of design uses seat belt usage in accidents instead of in traffic. The Fatal Accident Reporting System in the USA offers this possibility.
The method uses two sets of fatal crashes. The first set consists of crashes involving cars containing a belted driver and an unbelted passenger, at least one of whom is killed. From the numbers of driver and passenger fatalities, a belted driver to unbelted passenger fatality ratio is calculated. From a second set of crashes involving cars containing unbelted drivers and unbelted passengers, an unbelted driver to unbelted passenger fatality ratio is similarly estimated. Dividing the first fatality ratio by the second gives the probability that a belted driver is killed compared to the corresponding probability that an unbelted driver is killed, averaged over the distribution of crashes that occur in actual traffic; this is the measure of safety belt effectiveness sought.
Based on U.S. figures Evans estimates the belt effectivity on 43%. One assumption has been made which limits the conclusion: belt wearing does not change behaviour, a question not yet answered quite well.

Hedlund from NHTSA had prepared a state of the art on actual safety changes due to safety belt laws.
The usage and performance data for fatalities and for injuries are summarized in the following graphs



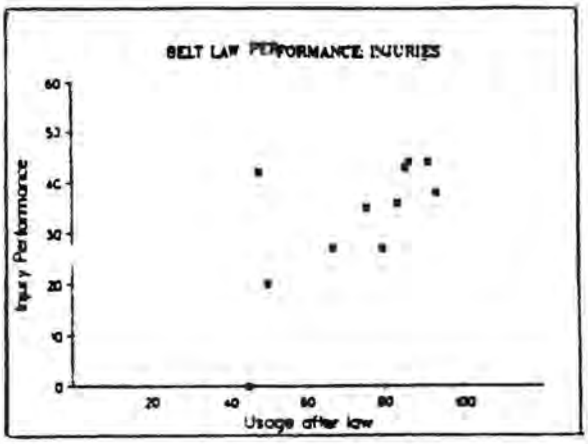


Figure 3. Belt law performance: fatalities and injuries

Seven jurisdictions show for fatalities belt law performances between 31% and 51%, five are below this level (or even negative) and none is above. The injury results are more regular: between 25% and 45%.

But some methodological questions can be put forward reading the underlying research reports. Let me describe some designs and present some observations.

1. Comparing countries/jurisdictions with and without mandatory safety belt use on usage rates and on casualties.
For example Adams compared national accident statistics in thirteen countries with effective laws (incl. Germany and Holland) and four countries without (Britain, Italy, Japan and the United States).
It shows that the index for countries with belt laws fell 17 points between 1972 and 1978, while the index for countries without laws fell by 25 points over the same period.

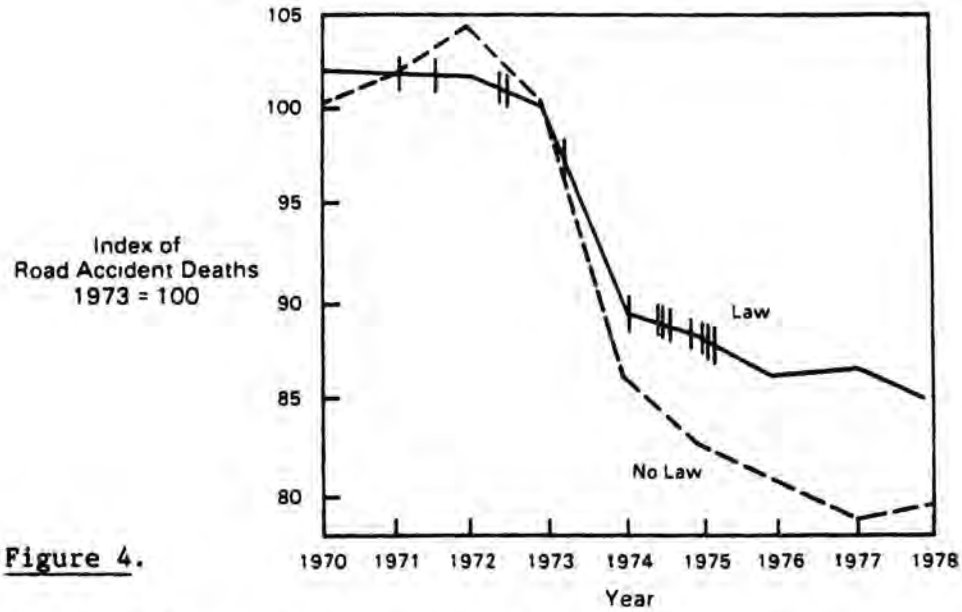


Figure 4.

I don't believe that Adams introduced his control group in a right way. First of all he had used all fatalities instead of just car occupant fatalities. Secondly in this approach belt usage is not considered: it is just 1 (for belt law) or 0 (for non belt law). And at last but not at least: a lot of other circumstances and measures might have influenced accidents in a yet unknown manner.
I have the feeling that this design (international comparison - with and without) cannot be used to establish effectivity rates or performance rates of safety measures, even if it is elaborated more sophisticated than Adams did.

2. Using time series models: in this design a forecast has to be made of the number of casualties if a certain safety measure was not introduced and this expected number must be compared with the observed number. The assumption: no other measures will influence the dependent variable but the independent one. An example of this approach in Figure 5.

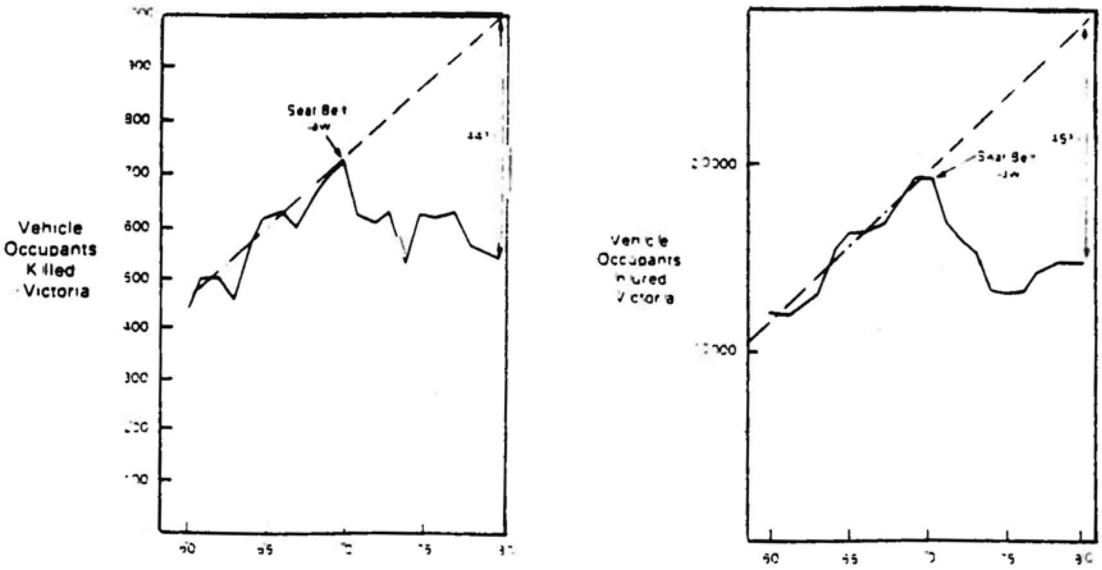


Figure 5. Vehicle occupants killed and injured in Victoria (AUS)

The ARIMA model, based on Box-Jenkins intervention analysis could be used or the structural time series modelling used by Harvey recently to establish the effects of seat belt legislation on British road casualties.

Of interest are the recent activities of a Dutch colleague Wiel Janssen trying to estimate the effect of the rise in safety belt usage on passenger car fatalities, strongly leaning on German figures.
Based on a comparison of fatalities in a period before and after the sharp rise he comes to the conclusion that the effectivity is only one third of the potential effect (engineering estimation). In other terms: a discount factor of 2/3.
The question is: is it really true that in this design other effects are eliminated of influencing factor on fatalities and casualties?
For example in Britain: shortly after the studied period the change in the law on evidential breath testing took place and there may have been an anticipatory effect.
And for example in Germany Janssen compared two different periods in a year trying to control for exposure. Did he really manage this problem?
Methodological questions cannot be answered with hard and good data, there

always remain some doubts, in a creative manner researchers try to deal with inevitable imperfections but these imperfections exist, leaving space for doubts.

3. Comparing in one country the number of fatalities in a certain group influenced by a safety measure compared with other, not influenced groups. In the case of safety belts: compare casualties to car occupants and use other road users as a control group.
If one accept the concept of risk compensation this design is not correct. Adams put forward a "suggestive coincidence" after introduction of legislation in Britain: "By coincidence the number of fatalities under pedestrians and cyclists increased shortly after the legislation and the number of car-occupants fatalities decreased".

In the Harvey study a reduction was found of 25% in killed and 30% killed and seriously injured front seat passengers.
Furthermore, he found an increase for rear seat passengers, for pedestrians and cyclists. Due to the introduction of the law there have been a net reductions in numbers killed and seriously injured. But it is clear that using others as a control group is misleading. These results open the discussion on risk compensation.

In a number of studies use of a belt and driving behaviour have been related. Risky behaviour has been made operational via gap acceptance, drive with shorter headway, responses to yellow/red traffic lights, speed in sharp curves etc.
The different researches indicate that the use of a belt does not influence driving behaviour significantly and that non-users apparently take greater risks in traffic than users. From American research some indication has come that non-users are more often involved in accidents than users and have more violation points. The results do not confirm the risk-compensation theory in so far as the use of belts would lead to taking more risks in traffic, but the opposite seems more apparent: belt users take (took?) less risks. Opponents argue that these tests are not sufficiently sensitive to pick up behavioural changes, but what to think about non observable, changing behaviour?

The results can be seen as a confirmation of the selective-recruitment theory: "that as belt use rises each new group of users is successively more likely to be involved in potentially injury-producing accidents".

If this theory is proven true it means a more than proportional effect on the reduction of the number of casualties with the rising use of belts. An application of the Law of Increasing Return.

There is a broad evidence that high risk groups as young male drivers have lower usage rates than others, or that higher BAC's are related to lower usage of belts. See the figure below, coming form Noordzij.

BAC	Age: 18 to 35 years	35 to 50 years	50 years and older	all ages
<0·20‰	44% (n=606)	57% (n=270)	62% (n=131)	50% (n=1007)
0·20 to 0·50‰	32% (n=63)	45% (n=38)	(n=9)	40% (n=110)
≥0·50‰	21% (n=72)	32% (n=44)	(n=13)	20% (n=129)
Total	41% (n=741)	53% (n=352)	62% (n=153)	46% (n=1246)

Figure 6. Percentage of drivers wearing a safety belt as a combined function of driver age and BAC.

But watching Figure 3 I am not convinced and the conclusion of Wiel Janssen is even stronger: there is no evidence (mainly based on low usage rates (10%) and high effectiveness (>40%) in the US and high usage rates (>90%) and low effectiveness (<20%) in Germany. A subject for further research!

My conclusions and some suggestions.
From a lot of countries mandatory safety belt use has been reported to have stimulated belt use and that this has diminished the number of casualties. The extent of decrease appears to be different. The difference can partly be attributed to the use of different methods of research and problems relating to control for trends in the methods used.
No confirmation of the risk compensation theory has been found in so far as the use of belts is supposed to lead to more risk taking in traffic. But there is a gap between the engineering effect/potential effect and the actual effect: besides human behaviour feedback other explanations (changes in the distribution of characteristics of accidents, quality of belt usage?) must be studied. Some justification has been found for the selective recruitement theory but national accident data do not support this enough. I suggest further research.

Statement 8
OPPONENTS REMARKS

Robert Kühner
Federal Highway Research Institute (BASt)

Estimations and calculations of the effictiveness of safety belt use show figures of reduced mortality rates between 25 and 85 %. For purposes of evaluation, differences of that size are not acceptable.

The reasons for the weakness of these estimations are manifold:

- The kind of figure which is taken to measure the effect of belt use (expected effects such as engineering or biomedical impacts; statistically measured effects as time series or international comparisons, figures of refererence).
- The way in which the rate of belt use is measured (design of measurement in normal traffic flow or in accident cases);
- Political and legislational frame (voluntary vs. mandatory belt use, enforcement policy).

The consideration, that benefits associated with wearing seat belts are reduced as a result of behavioural adaptation (risk homeostasis) cannot be supported conclusively by any study.

The assumption, that the effect of the German safety belt law of 1984 might be a reduction of the mortality rate in the group of car occupants by 60 % seems to be too optimistic, a figure of at most 50 % is confirmed prevailingly by literature.

To agree with Fred Wegman, still further research is needed.

Statement 9
DEVELOPMENT OF SPEED AND FOLLOWING BEHAVIOUR ON MOTORWAYS

R. Hotop
Federal Highway Research Institute (BASt)

For over 10 years, investigations based on empirical random measurements and model calculations have been carried out on motorways into the behaviour of drivers with regard to speed and headway under the speed recommendation of 130 km/h when traffic flow is not impeded. This has allowed the elaboration of trends for specific speed and headway parameters. The investigations can be regarded as the first stage in the development of a driver behaviour index for motorways.

For over 10 years, the Federal Highway Research Institute (BASt) has regularly been conducting standardised random measurements of traffic flow on motorways in conjunction with the ADAC (German automobile association) and the Technical University of Munich. The aim of these investigations is to study the behaviour of drivers with regard to speed and observing the proper following distance under the speed recommendation of 130 km/h when traffic flow is not, or is not significantly, impeded. The results therefore reflect the development of driver behaviour over the last 10 years, indicating changes in vehicle population and in awareness of energy, environmental and safety factors.

First, changing trends for selected speed and headway parameters are calculated from the data gathered at six-monthly intervals (spring and autumn) at 15 motorway measuring points using model calculations. The mathematical model - e.g. for average speed $\overline{v}$ -

$$\overline{v} = f\ (k, SV, P, R, Z, QT) + g\ (MP) + u$$

takes into account both the changing influences of traffic density k and of the proportion of heavy vehicles SV, as well as the base level of the various measuring points P with their directions R and time intervals Z and also the cross-section type QT (2- or 3- lane carriageways). MP is the anticipated trend change for the various measurement periods.

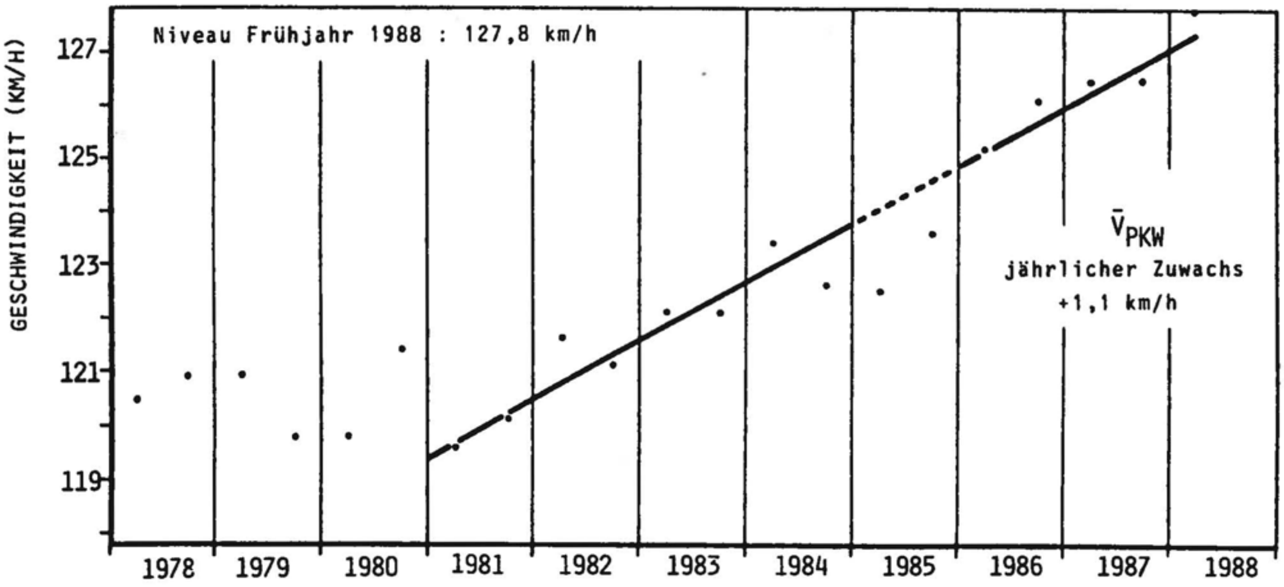
On the whole, the changes from measurement period to measurement period are small. The changes recorded at six-monthly intervals amount at the very most to about 2 km/h in the case of average car speed (Fig. 1). If only the period since 1981 is considered, an average annual increase of + 1.1 km/h can be seen. This trend was only briefly interrupted in 1985 (large-scale exhaust testing). In spring 1988, the level was 1.3 km/h above that of spring 1987.

If the development of the "85% speed" for cars is considered (Fig. 2), i.e. the speed which is only exceeded by the fastest 15% of private cars, this shows an average annual increase of 1.3 km/h since 1981 which is greater than that for the average speed of cars. This can be interpreted as showing that the speeds of faster cars are increasing more rapidly than those of slower vehicles. In spring 1988 the level of the "85% speed" was 1.8 km/h above the level in spring 1987 and 2.3 km/h above that of autumn 1987.

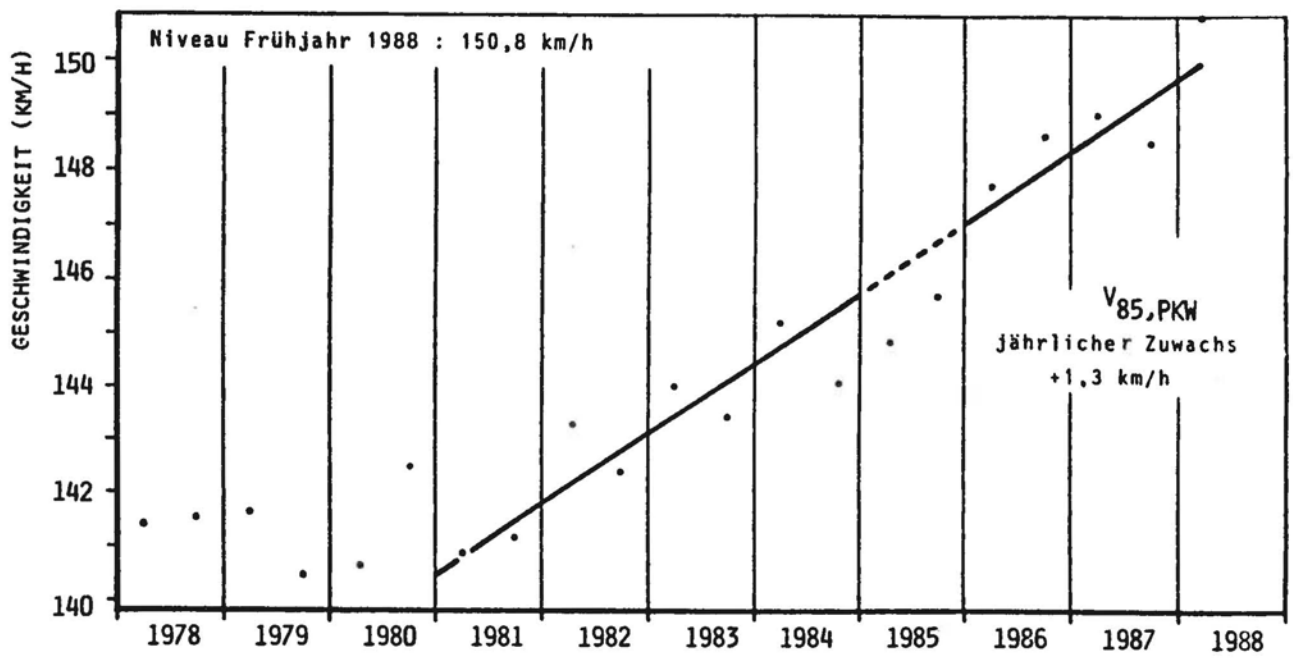
Similar trends can be seen for the proportion of cars with speeds above 130 km/h (Q_{130}, Fig. 3). Since 1981, the number of car drivers who drive faster than the recommended speed has risen at an average annual rate of 1.9 percentage points. From spring 1987 to spring 1988 this increase even amounted to 3.1 percentage points.

For some years, lorry speeds have been subject to increasing criticism. The example of average lorry speed (Fig. 4) shows that there was an annual increase of 0.4 km/h in the period 1978 to 1984. In 1985 (large-scale exhaust testing) lorry speeds also fell but then climbed back to their 1984 level in 1986. This level was largely maintained up to spring 1988 (no significant change from spring 1987 to spring 1988). It is, nevertheless, the case that the maximum speed for lorries (80 km/h) is rarely observed in free-flowing traffic. A recent study by the Federal Highway Research Institute (BASt) showed that, in free-flowing traffic, only 13% of German lorries and only 8% of Dutch lorries were not travelling faster than 80 km/h.

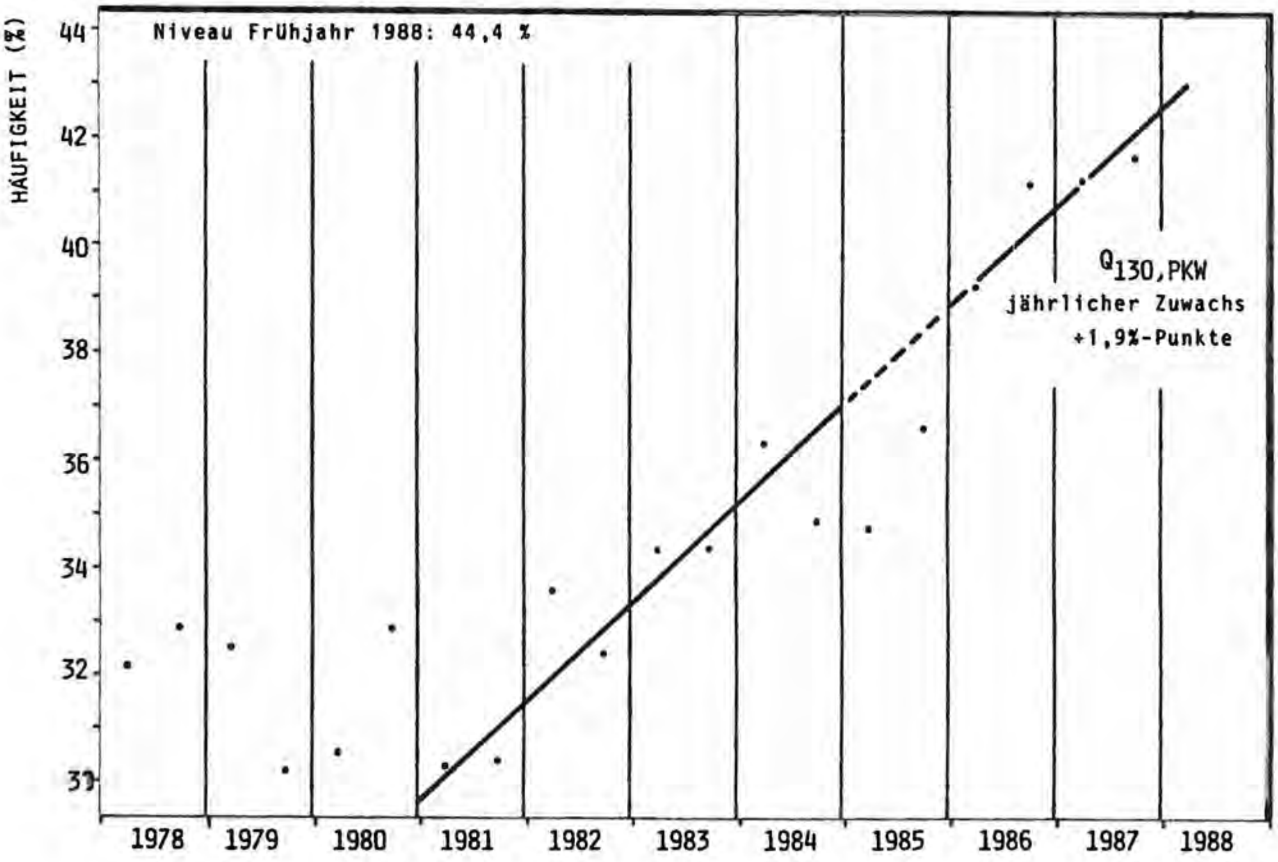
With regard to drivers observing the proper distance on motorways, attention should be drawn here to the change in the number of cars in the overtaking lane with time headways of less than 0.5 s in relation to the vehicle in front. This parameter (RISK, Fig. 5) lies far below the required safe distance and demonstrates the development of dangerously short following distances in overtaking lanes. The annual increase here has been over 0.2 percentage points since 1981, and by spring 1988 the parameter had reached the level of 6 % of all cars in the overtaking lane. This does not represent a further increase over spring 1987, but is higher than autumn 1987 (+ 0.6 % points). The development of the RISK distance parameter in the overtaking lane can be regarded as an increasing tendency to force preceding drivers to drive faster or to leave the overtaking lane.



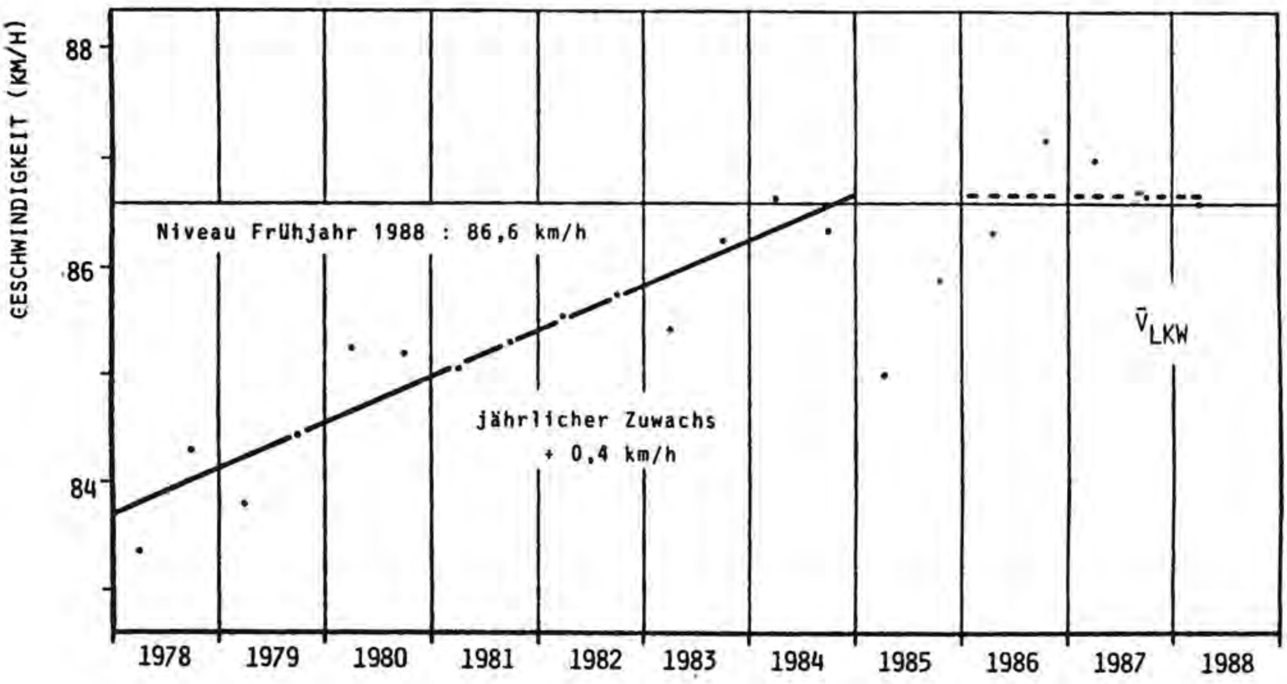
(FIG. 1) TREND OF THE AVERAGE SPEED OF CARS ON FEDERAL MOTORWAYS



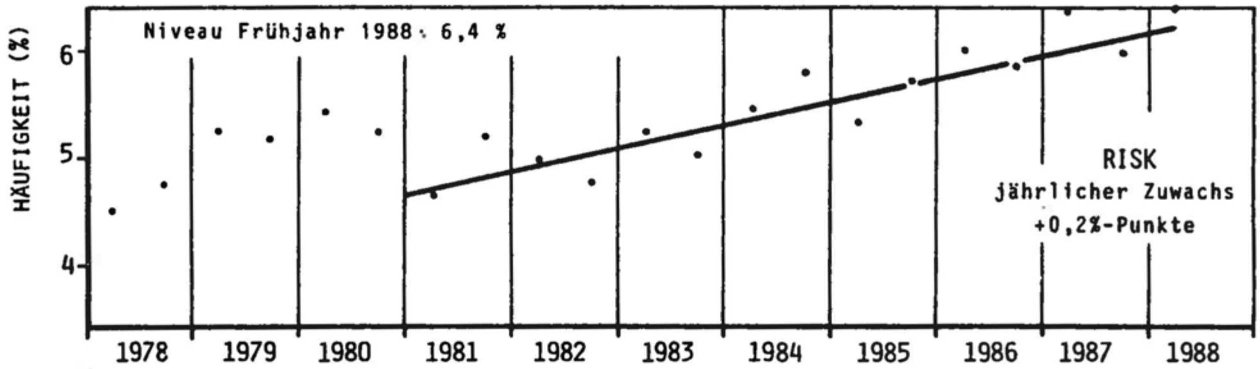
(FIG. 2) TREND OF THE "85 % SPEED" OF CARS ON FEDERAL MOTORWAYS



(FIG. 3) TREND OF THE PROPORTION OF CARS WITH SPEEDS ABOVE 130 KM/H ON FEDERAL MOTORWAYS



(FIG. 4) TREND OF AVERAGE LORRY SPEED ON FEDERAL MOTORWAYS



(FIG. 5) NUMBER OF CARS IN THE OVERTAKING LANE WITH TIME HEADWAYS OF LESS THAN 0,5 S IN RELATION TO THE VEHICLE IN FRONT

Statement 10
POLICE ENFORCEMENT AND TRAFFIC SAFETY

Paul Wesemann
SWOV Institute for Road Safety Research

Research has clearly shown that police enforcement can improve road safety, especially in the field of drinking and driving, speeding and seat belt usage. Therefore it shouldn't be too much a problem to develop a comprehensive and integrated programme of enforcement with relatively high benefits and low costs. However, it can be questioned whether the police organisation is prepared and able to give priority to preventive control in stead of repression. Dutch police officers aim primarily at catching offenders, not deterring them.
Further, many policymakers and citizens prefer other solutions for this type of problems. In the long run, road users should either change habits or the rules should be abolished.
Should enforcement be abandoned ?

My statement deals on the one hand with the application of the results of research by policy makers. On the other it deals with a specific form to present knowledge and data to decision makers, that is by drawing up a cost-benefit analysis.

The field of research I'm talking about is police enforcement of traffic rules, and to be more specific: if and when enforcement is successful to prevent driving while intoxicated, the non-wearing of seat belts (in the front seats of passenger cars) and offending against the 80 km speed limit on rural roads. Each of these offenses has proven to be relevant for road safety: however, as regards to speeding, it must be recognized that the effect on safety depends largely on local and temporal conditions.

We have drawn up a tentative cost-benefit analysis of a comprehensive national programme of police enforcement of these traffic rules. We did this to acquire a commission of the Ministry of Finance to do a more extensive study into the costs and benefits of police enforcement: we wanted this contract because we expected that the form of a cost-benefit analysis was an effective way to communicate the existing knowledge and data on this subject to several decision-making bodies in the field of police enforcement. And further we offered this research proposal to the Ministry of Finance in particular because they initiate each year a programme of studies to improve the effectivity and efficiency of governmental organizations.
I'll present you in a nutshell the results of this tentative cost-benefit analysis. To avoid any possible misunderstanding: this is just a rough

estimation of costs and benefits, to motivate a research proposal. The data I used were derived primarily from evaluation studies in the Netherlands into the effect of experimental police enforcement.
First I'll present you the different types of costs and benefits we included in the analysis (See Figure 1).

I draw you attention to the incomes from fines: I think they can best be dealt with a negative costs: however, some may prefer to put them on the list of benefits.
It was not possible or necessary to estimate all categories of costs and benefits. One of the problems was, of course, in quantifying the safety effects of less speeding. This problem was solved, or should I say avoided, by postulating just a positive effect on road safety without estimating the size of it. Another problem is related to some categories of costs for the criminal justice system, i.e. the handling of offenders and the execution of sanctions like imprisonment. Because it can be argued that these costs are relatively small, the were dealt with as so called "pro memory" items.

The estimated costs and benefits added up to the following amounts: (See Figure 2).

The net costs include a.o.: f 54 million gross costs for the police and f 66 million incomes from fines.

Our main conclusion was that an "investment" of f 54 million in police enforcement gives large "returns". We are talking here about 20% of the police capacity that is used at the moment for purposes of road traffic management. Therefore we proposed to do a more extensive study into these costs and benefits.

However, this proposal was rejected by the Ministry of Finance. Most surprising for me was one of their major reasons: they considered the investment in police capacity too risky because traffic participants might change behaviour and will abide by traffic rules. If that would happen the Ministry of Finance wouldn't receive the estimated income from fines anymore. Apparently this Ministry has a rather limited conception of the "effectiveness and efficiency" of governmental organizations that they want to improve.

Now we are planning to do a cost-benefit analysis as a part of a broader project, which meets more the constraints of the other involved departments. Because these constraints are written down in the abstract you received previously (See Appendix). I won't go into this. Our research proposal has been accepted by the Ministry of Transport. Of course we don't know yet whether the outcomes of the cost-benefit analysis will have any impact on policy making, especially by the Ministries of Justice and of Internal Affairs. The main difference with the former design of the analysis is that we are going to compare the costs and benefits of current programmes with those of a new programme that could replace the existing ones. If I understood well the aims and constraints of these Ministries, this analysis meets their needs to a large extent.

In my abstract I announced also some considerations on the impact that costs-benefit analysis can have on decision makers at the local level, especially by the management of police forces. I'm afraid that time doesn't allow me to work this out now.

costs	benefits
. police (personnel,material)	. less victims
. public information campaigns	-dead:nett loss of production
. public prosecutor	-injured:use medical facilities
. judge	loss of prod.capacity
. income from fines	. less material damage
. execution of sanctions	. less intangibles(suffering)
(suspension licence)	
(imprisonment)	

Figure 1

total costs of enforcement program(fl mill)		total benefits of enforcement program(fl mill)	
nett costs*		benefits	
. dwi	- 11	. dwi	48
. belt wearing	+ 5	. belt wearing	24
. speeding	- 1	. speeding	+
. various	+ PM	. intangibles	PM
	----		---
total	- 7 +PM	total	72+PM

*54 gross costs of police
66 income from fines

Figure 2

APPENDIX

POLICE ENFORCEMENT AND TRAFFIC SAFETY

How to appraise costs and benefits?

Outline for a statement on the BAST-SWOV symposium

An example of a tentative cost-benefit analysis on this subject, drawn up by SWOV, will be presented.
Major elements are:
- personel costs of police and public prosecutor
- incomes from fines
- less killed and injured people
- resulting in a positive b/c ratio

Besides theoretical problems the main question is: what will be the impact of such analysis on police making?
There are several reasons to expect little impact:
A. The costs and benefits accrue to many different decision makers.
B. At least some decision makers disagree on the definition of benefits.
C. The fixed amount of police capacity is a constraint for some decision makers.

The Ministry of Transport is interested in the effects on road safety but doesn't contribute to the costs of enforcement.
The Ministry of Finance receives the incomes from fines, wants to cut the police budget or doesn't allow an increase of the budget; more enforcement is considered to be a risky "investment" because its "return" (fines) are unsure (when people change behaviour or don't pay their fines).
The Ministries of Justice and of Internal Affairs want to diminish claims on police capacity; enforcement should only be a last resort, in principle we shouldn't make rules that are disobeyed by large numbers of people. Social problems should be attacked by the administration in general (so called administrative prevention, e.g. education and information, building the environment), not by making rules. The necessary rules have to be controlled strictly, most offenders should be catched and punished.
And last but not least, within the police itself (the local forces) do

live many different opinions on the (financial and organizational) possibilities for new projects and their benefits; some are interested in catching offenders (of old a main task) others in reducing social problems like traffic accidents.

Conclusion:
On the national level it won't be easy in the Netherlands to decide on new programmes for enforcement, unless at the same time current activities are stopped.
On the local level exist more opportunities for innovating programmes as can be illustrated some examples.

Statement 10
OPPONENTS REMARKS

J. Dilling
Federal Highway Research Institute (BASt)

Traffic regulations are used to bring order and safety into road traffic. If these regulations did not exist, it would scarcely be possible to drive on roads. The alternative of abolishing rules if they are not observed and cannot be monitored sufficiently therefore has to be refuted.

Various approaches show that a number of solutions exist to improve enforcement [1]. In its 1987/88 accident research programme the BASt has therefore formulated and awarded a project on this theme [2]. Drivers, cyclists and pedestrians do not so much view the road traffic regulations as binding, but rather as a framework for orienting their behaviour in road traffic. Compliance with individual rules is therefore based to a greater extent on a subjective appraisal of the significance of these rules to safety and an evaluation of the advantages and disadvantages of violating these rules [3].

The legislator supports this trend in part by laying down a table of fines in which the different violations are listed and from which each road user can estimate the advantages of his subjective interpretation of the rules. The degree of monitoring he has experienced and the level of the sanctions to be expected certainly play a role in this process. In the Federal Republic, for example, exceeding the permissible speed limit by 20 to 25 km/h is accompanied by fine of only DM 60, while driving a vehicle with a BAC level of 80 mg/100 ml or more attracts a fine of DM 500 and a month's ban for a first offense [4]. This is accompanied by entries in the central traffic record of 1 and 4 points respectively.

Attempts to bring about changes and ensure a higher observance of traffic rules can be influenced at first by intensification of the monitoring level. Another possibility is given by an increase in the sanction for violating specific regulations. In individual cases, this sanction should be of such proportions that it serves as a continuous reminder when assessing the advantages and disadvantages of violating a traffic rule.

However, there are also a number of relatively new approaches regarding increases in monitoring intensity. In the administrative district of Cologne, efforts have been increased in monitoring speeds and following distances. This has been coupled with sharper controls of heavy-goods traffic and active publicity work. Initial results gathered by the police indicated a drop in the number of traffic violations [5].

More efficiency can be expected from an improvement in monitoring technology [6] and the privatisation of enforcement tasks. The use of private firms for detecting speed-limit violations and too short following distances may be for an example one possible alternative to the enforcement by the police due to the latter's shortage of personnel and their increasing need in other fields.
In this context the cost-benefit-concept of Weseman may be an important step to improve police-enforcement.

---

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