FUNCTIONAL REQUIREMENTS OF FUTURE TRAFFIC SYSTEMS

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Introduction

The point of departure for this congress is the lack of opportunities for co-operation between policy-making bodies and industry. The administrative authorities are not fully informed of new developments and possibilities in technology. Industry does not know where to aim its development programme, because it does not know the administrative authorities' long term policies. This congress will attempt to provide a first contribution to filling this vacuum. Policy preparing bodies, research institutes, advisory organisations and industry will then have the task of following this up.

Some types of traffic and transportation policy; a description of the policies, consequences and function of scientific research into these policies.

Present day traffic provides great freedom of movement, but at the same time produces: accident victims, environmental damage, and a large energy consumption. We have lang been aware of these negative aspects of the traffic system and in particular of the degree of traffic hazards. For decades the administrative authorities and private bodies have been taking measures to combat these hazards.

There is at the moment a growing demand for radical action. Perhaps it stems from a feeling of powerlessness, that nothing has any effect, that the correct policy is not being pursued.
That is why it is important to see whether any of these feelings are justified.

We can consider the traffic-system as a process changing with time. Keeping such a process under control requires administration. As is mostly the case with process controle, this administration can be performed in a variety of ways which I shall list and illustrate. We shall consider consecutively:
- reactive policies,
- anticipatory policies,
- directing policies.

Reactive policies

The simplest form of administration is immediate reaction to deviations from the desired course. In traffic administration such a course is determined by limits such as the socially accepted degree of traffic hazards, air-pollution, noise and congestion. These limits change with time. When the effects of a sudden event exceed the limit of permissibility, measures are taken. Obvious examples of this are the accidents in fog at Prinsenbeek and Schiphol. "Everyone" immediately demanded that measures be taken. It sometimes even happens that it is only after such a chance incident has occurred that the administrative authorities are enabled to put into action measures which have been ready for some time. If such extreme events do not occur, or if, due to fortuitous circumstances, the normally accepted trend in the number of casualties is slightly reduced, then the result can be that proposed measures have to be introduced at a later date than would normally have been the case.
A policy governed by such chance events is equivalent to "panic football": there is no overall strategy or tactic.
In general, most measures taken are those that can be realised in the short term. They usually concern the operational aspects of the traffic system, such as improvements in traffic control, rules of conduct, traffic signals, provisions to reduce the severity of accidents, such as break-away lighting columns, etc. As they are incidental measures, there is a considerable chance of successive measures being in conflict with each other and not forming a coherent unit of measures having an optimum effect.

An example of this is past policy concerning speed limits. When one or a number of spectacular accidents occurred on a particular section of road, there was an immediate demand for intervention: a speed limit. The result is that our road system is dotted with signs reading "maximum speed", whose cautionary effect and credulity have both been lost. The situation takes on a more serious light when one realises that present accident registration offers no possibility of showing whether part of a road or a junction is really more dangerous than the remaining sections of the road. It is quite possible that many road sections "safeguarded" by speed limits are in fact not at all danger spots, but merely places where, for example, two cars just happened to collide, in which, furthermore, many passengers were involved.

Due to the day to day pressure of such sudden events, there is no time left for taking really far-reaching measures such as fundamental changes in the road system.

The administrative authorities function constantly in spasms and are therefore obliged to choose those measures which can be introduced in the short term. Such a policy is reactive, i.e. it is a result of a sudden serious event or a chance combination of such events. Thus it is limited to combatting the symptoms. This does not mean that combatting symptoms can never have any effect. If measures are based on generalisable and reliable information, e.g. previously carried out scientific research, have no side effects and do not interfere with other measures, then the decision period can be short and the effect sometimes large. An example of this is the decision to make the use of seat-belts obligatory as from this year. It can already be predicted that if all car occupants would really always use their seat-belts, there would be a reduction of at least 50% in car occupant fatalities, which at the moment would mean a saving of around 600 lives per year. Other examples are the obligatory wearing of crash-helmets by all moped-riders by which a reduction of around 200 fatalities or 40% can be achieved, and the installing of crash-barriers, which effects a reduction of 50% in the numbers of fatalities and seriously injured. It is evident that this last reduction in fatalities (and injured) cannot be added to the reduction through use of seat-belts as, to a certain extent, the same road-user population is involved in both cases.
These are examples of measures originating from a reactive policy and which are effective in themselves while hardly or not at all interfering with other measures.

With society organized as it is, we shall continue to see reactive policies in the future. This in itself need not be a disadvantage, but their effectiveness will be largely determined by the extent to which scientific research remains ahead of political decisions.

In order to ensure that the majority of decisions taken under such a policy be based on optimum use of the budget available, cost/benefit analyses will have to be an important instrument in the future.
At the request of the congress committee, mr. Van der Wolf has carried out such an analysis into the effect of introducing traditional traffic regulating systems into built-up areas.

Consequences

What are the consequences for the future of reactive policies. Without any spectacular, far reaching measures, a reactive policy would allow the number of fatalities through traffic accidents to rise to around 3420 in 1975, 3575 in 1985 and 3600 in 2000 (Table 1).

With far reaching measures, however, such as those already announced relating to the wearing of crash-helmets by moped-riders and to seat-belts in cars, i.e. 2730 in 1985 and 2660 in 2000, the picture will be entirely different.
Assuming that reactive policies will not have any influence on the number and length of journeys, nor on the choice of transport mode, the number of traveller-kilometres will increase from 88.4 thousand million in 1972 to 127 thousand million in 1985 and to 140 thousand million in 2000. The total fuel consumption will increase from 4.52 thousand million litres of petrol in 1972 to 6.26 thousand million in 1985 and to 6.82 thousand million in 2000. The required road surface area outside built-up areas will increase from 81,600 hectares in 1972 to 92,000 hectares in 1985 and to 100,000 hectares in 2000, which is 2.72% of the total area of The Netherlands.

Anticipatory policies

Another and better sort of policy is the so called anticipatory policy. Its principle is predicting the course a particular phenomenon will follow, and predicting a number of future limits of permissibility which are laid down as standards and then usually more closely defined in the course of time.
From these two data the period within which certain measures should be realized can be derived if the trend is to be modified at an early stage, that is to say before it exceeds the limit of permissibility, so that it remain below this limit in the future as well.

An example of this are the American requirements limiting the permissible air pollution caused by motor vehicles, which have been laid down for a number of successive years. Such a procedure can be termed an anticipatory policy and leads to short and medium term planning of measures.
Because in this case, the measures do not have to be carried out within a very short period of time, it is possible to take measures of a more fundamental nature as well as the measures concerning the operational side of the traffic system.
A condition for an anticipatory policy is that the effects of every measure in itself but also the effects of combinations of measures should be predictable in advance. This sort of policy will also make use of knowledge gathered through scientific research.
In practice, anticipatory policies seem to be accepted only with difficulty by the bodies which put the policies into effect. These people are not trained in thinking in terms of medium term effects, and especially not in the case of measures whose short term effect, they feel, could well be of a doubtful nature.

Some examples of groups of fundamental measures that could be taken within the framework of an anticipatory policy are: segregating different types of traffic and classifying roads into categories, structuring of residential areas, altering the distribution of the traffic in terms of the various means of transport and improvement of vehicle design.

Road classification

The criterion to be used in classifying roads is that safety is more important than a good traffic flow. In practice, this runs into difficulties with the road administrator. His whole road design is based on traffic through-put aspects and while traffic safety does have a marginal status it does not constitute a basic criterion in the design. This results in the road design characteristics, easily observable by the road user and thus of considerable influence to, for example, his driving behaviour, being so chosen that he is, often unintentionally, invited to drive at high speeds. Such characteristics are: the flatness of the road surface, the width of the carriage-way, the distances of obstacles from the side of the road, the length of straight road sections.

The less easily observable road characteristics such as sharp bends, junctions, etc. then act as unexpected discontinuities. The same is also true for traffic characteristics which are not easily perceptible, such as infrequent, slow traffic on a road having mainly fast moving traffic, or locally occurring higher traffic densities. The aim of classifying roads is the hierarchical grading of the road network, based on the various traffic functions, into categories clearly recognizable by road-users.

Road characteristics which have a bearing on driving behaviour (especially speed) will have to be fitted into these categories in such a way that they influence speeds to a degree which depends on the road category in question. The same is true to an even greater degree for the remaining discontinuities.

A practical consequence of this is, for example, that with roads of a low category, having an unimportant traffic function the road surfaces could be made less flat. The road width should be decreased. Obstacles not involving any danger if collided with should be positioned close to the roadside and bends should be constructed at regular and thus predictable intervals.

This will lead to a hierarchical grading of our road network, both within and outside built up areas, into a limited number of categories.

If the categories are clearly recognizable to the road users and the roads are also matched to the demands made on them with regard to the road characteristics for each category, the final result will be a large degree of uniformity in road user behaviour in each of the categories.
Of course this will require a transition period, both to adapt the roads and to allow road users the opportunity to adapt their driving behaviour.
The Minister of Transport & Waterways has made a first move in road classification by allocating definite speed limits to the categories "motorways","trunk-roads" and the remaining roads.

It will be clear to everyone that to permit incidental exceptions above and below these categories i.e. designating roads or road sections which are allowed to fall outside an already established (or yet to be established) category, is to thwart the policy of classification. This should therefore be avoided as much as possible so that the road user can identify as quickly as possible with the systematic classification. The stimulus to rapidly adapt his roads to the requirements stemming from safety aspects in each of the categories, should be continuously felt by the road administrator. I make a special point of this because considerable pressure is often exerted from the regions to make exceptions of certain roads with the ostensible idea of benefitting road safety. At this point reactive and anticipatory policies are in conflict.
In order to enable road-users to recognize the road categories, maximum use must be made of "structured information", such as that provided by: road markings, perceptible road surface properties, road alignment, all of these being introduced with the intentional purpose of influencing road user behaviour.
In situations requiring information concerning events beyond the range of visibility, signalling systems (electronically controlled) will have to be used. These are already in use along some State Highways. They warn of mist or fog, of expected hold-ups resulting from bottle-necks in our road system, which, at high traffic density and unstable traffic flow, necessitate the upstream transmission of information in order to avoid pile-ups.
In his lecture mr. Beukers will give an account of projects already carried out as well as plans for the future.

Consequences

The overall effect of a well carried through anticipatory policy on the degree of road hazards is shown in Table 2.
We may wonder whether all this trouble is really necessary.

There has been increasing opposition to the use of cars lately. The argument is fora shift from individual private transport towards public transport.
We shall try to see the consequences of such a move.
Table 3 shows an attempt at predicting the consequences of a complete change-over from car traffic to bus traffic. Of course this is only theoretical; everyone realizes that this could not be attained in practice. Even those who reject the car entirely would be prepared to make exceptions for medical and social needs.

Nevertheless, study of such a drastic and theoretical measure can be use due to the indication it can give of the effect of a partial shift from private to public transport. If the effect of a drastic shift is very small, it seems reasonable to assume that relatively small shifts would have only a limited effect.
This calculation is based on the following assumptions:
1. all journeys by private car are replaced by journeys by bus.
2. goods traffic (lorries, delivery vans etc.) remains unaltered, (account being taken of normally expected growth).
Assumptions which may lead to corrections having to be made are:
- a change-over from private transport to transport by bus results in a decrease in the number of journeys;
- lorry/delivery-van transport increases slightly due to the limited possibilities of transporting goods by bus;
- the transport of people by predominantly goods transport vehicles (e.g. travelling representatives with bulky products) remains the same or falls within the category of delivery vans.

It appears from these calculations that the benefit in terms of traffic safety and energy consumption is not spectacular. The degree of traffic hazards is in fact greater than would be the case with a complete restructuring of the road network within, as well as outside, built-up areas, as can be seen from a comparison of Table 2 with Table 3.
What certainly is apparent from these calculations is that this change-over could make a substantial contribution to solving a possible unemployment problem in the service sector, for in 1985 it would entail approximately half a million people being employed in the public transport sector. Whether this is desirable from a macro-economic point of view is another question.

Why is only so little benefit to road safety to be expected from a complete change-over to public transport by bus?
One reason is that at the moment the bus is relatively safe due to its being one of the heaviest vehicles. In a bus-car conflict the car and its occupants will in general come off worst.

If cars are replaced by buses, then the collisions are of the form bus against bus and so the bus is no longer in an adventageous position. Another reason is that a bus,owing to its lesser manoeuvrability, is more dangerous than a car, especially in collisions between buses and slow traffic.

In the absence of a systematic restructuring (e.g. segregation of traffic according to type) and classifying of roads, the way ahead is full of hazards, even for buses.

A shift from private transport to public transport (e.g. bus) only shows a benefit in terms of use of available space which arises from the higher degree of occupancy of these vehicles. In certain situations this efficient space utilisation can play a dominant role. In older towns, often struggling to make the most of every inch of space, a shift from car to public transport may be essential in a medium term policy.

Directive policies

The disadvantage of the anticipatory policies sketched above is that the limits of permissibility are determined as standards and are often based on rather vaguely defined aims. It is very questionable whether this would be acceptable in a future society. The problem is that we need to be able to lay down today what sort of society we want in the future and what role the transport system of the future will play as a part of this society.Furthermore we shall have to make sure that this hoped for society does in fact materialize. This means we must be able to direct and control change in society.
A policy aimed at a guided change of present society in the direction of the hoped for, future society, based on accurately formulated objectives, is called a directive policy. It will of course be based on peoples needs. Such a change can only be effected with the help of long term strategic planning.
It must incorporate a smooth course correction. The optimum course is not simply a straight line between the present situation.and the final, desired situation as this would produce sudden and large corrections. The experience with the oil crisis has shown that too abrupt course corrections can have an almost fatal effect on certain economic sectors of society.
Optimum strategy consists of a large number of small corrections which in their entirety lead to the desired result.
To achieve this we must be able to:
a. accurately define present-day society and its mode of functioning;
b. accurately define the desired objectives, e.g. for the year 2000;

c. have an overall picture of existing as well as yet to be developed solutions and instruments for the course correction, and also a general idea of its predicted effect.

A number of provisional indications can already be given for the desired situation in the year 2000.
With the shortage of irreplaceable resources, energy and space, growth will have to be selective, the emphasis lying more on the quality of life than on its quantitative aspects.
The emphasis for a future traffic and transportation system will be on making the most economic use of available energy and space, and on reducing harm to people and the environment.
Based on the anticipatory policy laid down in America concerning air-pollution, we can already state that road traffic's contribution to air-pollution will be solved in the future, even on the basis of present day means of transport.
The choice of transport means will only have marginal influence on total energy consumption.
We have seen that even by thoroughly restructuring and classifying traffic and roads, the number of traffic victims, although being considerably reduced, would nevertheless remain substantial, i.e. 2340 fatalities in 1985 and 1830 fatalities in 2000, (Table 2).
It is questionable whether in a future society where the accent is on quality of life, we could still accept such a large number of dead (and wounded); from the year 2000, one citizen in 7900 is doomed to be killed on the roads. Assuming that the area occupied in 2000, i.e. 2.72% of the total area (outside built-up areas) is acceptable, the emphasis will then lie on road safety.

If this road safety is to be drastically improved, it will doubtless be at the cost of personal freedom of choice. It is interesting to consider the levels at which this freedom of choice can be interfered with. In an article in the journal "De Ingenieur" 85 (1973)20, p.410-413, I have performed a hierarchical classification into four decision and behavioural levels (Figure 1). Whenever limitation of freedom in traffic is contemplated, there must be careful consideration whether these limitations of freedom do not themselves have direct effects on the quality of life. The greater the extent to which this is the case, the less attractive such a limitation will be when compared to one where this is less so.

One of man's most important needs is the freedom of communication and movement. (See the Universal Declaration of Human Rights, Art. 13, 19 and 20).

During the last few years in particular the view has been gaining ground, especially from the side of the behavioural sciences, that it is not only functional and verbal communication which count, but that emotional and non-verbal communication is also an essential aspect of information transfer which is so necessary between people.
This means that although methods of functional communication such as the telephone, videphone, scribophone etc. can make a contribution to certain aspects of business communication, and as such increase our gross national product, they can only make a marginal contribution to well-being or quality of life.

Although an improved physical planning, up to now still utopia, will diminish average journey lengths, the total number of journeys will keep showing a strong upward tendency.

A limitation of freedom at the highest decision and behavioural level - the choice of destination and time - will, I believe, be the least likely to be considered in the transport system of the future.
A limitation in the choice of means of transport - funneling demand into public transport - would also have a strong influence on freedom of communication and movement. Public transport is insufficiently flexible, even if it were better organized than now. Limiting the choice of route, however, has little or no influence on this freedom except in the case of recreational traffic where the journey is more an end than a means. This is even more valid in the case of the choice of manoeuvres. Thus it seems logical that when limitations in freedom are necessitated, they should be sought primarily in the choice of route and in driving behaviour.
With these rough data it is possible to draw up a provisional profile of a future traffic system. In doing so it is helpful to make use of experiences with transport systems which are already relatively safe, the railways. It should be realized that from the point of view of movement characteristics, the train is essentially a very unsafe means of transport. This is due to its great inertia, its inability to move sideways in emergency situations and its very long braking distance.
This leads to far reaching safety measures being applied to railways, even in an early stage of their development. For example, a consequence of the long braking distance is that the driver can no longer rely on his visual perceptions to establish the relative distance and speed between himself and the train ahead. By the time the leading train has become visible, it is usually too late to brake. The consequence of this was that the tasks of perception and decision were taken over by a centrally controlled signalling system.

This long braking distance and the impossibility of moving sideways caused rail traffic from an early stage to be entirely isolated from other sorts of traffic; the railway is used for one type of vehicle exclusively i.e. the train. When intersecting streams of other traffic, these latter are temporarily kept waiting. In cases where this is not yet the case, the accident probability is high.
Both the rail and vehicles of the rail system are controlled by a single entity which ensures optimum mutual adaption. An ever increasing degree of automation produces an even safer system by practically excluding human errors.
Nevertheless, rail traffic lacks the flexibility necessary for freedom of movement and communication while at the same time making a poor showing in terms of energy utilization even when operating with a high seat occupancy factor.
This is why I believe that even in the future rail traffic will only be suitable for mass transport between a limited number of points of arrival and departure. Where the frequency of the train service needs to be increased smaller units, travelling along a monorail and propelled by a linear induction motor, which can ensure a constant separation between carriages - can provide a distinct increase in capacity compared with traditional trains with their relatively large mutual separations.
Along lesser used routes, e.g. in the country, it is impossible to develop a traditional system of public transport that could compare, in terms of flexibility, with the present day car.

I have already pointed out on earlier occasions, such as the E.T.V. lecture* and the introduction to Intertraffic '72, the advantages of a fully automatic road traffic system. By eliminating the driving skill factor, safety can be substantial improved. Capacity can also be considerably increased by reducing the separation distances and intervals between cars. During the Intertraffic '72 congress I tipped the mini-bus ("call-a-bus"system) for use within built-up areas. It's an interesting fact that the Board for Municipal Mass-Transport of the American Ministry of Transport has in the meantime made a 500,000 dollar contract with General Motors for a design study of an automatic mini-bus system.

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* De integratie van electronische hulpmiddelen in het verkeer. Ir. E. Asmussen. In: Wegverkeer en elektrotechniek; Report of the congress held at the occasion of the 65th anniversary of the Delft Association of Electronics on Tuesday 23rd March 1971. P. 118 to 158. Electrotechnische Vereeniging Delft, 1971.

It is expected that by 1980 many American cities will be putting such a system into practice. In principle, the step from an automatic mini-bus system to an automatic car system is not large. Automatic cars or buses will still need facilities for being driven by hand in the initial and final stages of the journey.
While considering railways as a transportation system, I mentioned the advantages offered by a joint control of vehicles and railway lines by a single entity. Such advantages could lead in the future to automatic private transport also being no longer the property of the individual but nevertheless always being available to him. This leaves us with a sort of "witkar"concept.
Work on a feasible variety of automatic car is also being carried out so far only on paper in The Netherlands and in particular at the technical university in Delft by Prof. De Kroes and Prof. Van der Burgt. Prof. De Kroes will go further into this subject in his lecture. Obviously, switching-over to automatic traffic will have enormous financial consequences. Mr. H.J. Noortman will include this aspect in his lecture on cost/benefit analysis.

A model of society

It is logical that in a democratic country new traffic systems should be attuned to the needs and wishes of the individual, all the more so when the traffic and transportation system has an almost decisive effect on the whole of society. The system finally chosen will have to be integrated into the picture of society desired by the community and into an integral concept of how it is to be carried out. The future traffic and transportation policy must always be prevented from leading a life of its own and thus should be continually examined in the light of the overall policy. The problem is how we can find out what these individual and community wishes in fact are.
A concept such as welfare is too vague and not useful enough in practice. This is why it is essential that these concepts be more clearly defined by means of social indicators. These should be quantified by, for example, a number of units of observation.
In addition society's decision making process needs to be analysed and described by, for example, a schematic representation (Figure 2). Here we see the processes of society described in terms of social indicators.
These social indicators are compared with values that we consider as basic yard-sticks in society.

Whenever they do not correspond with certain aspects of society, they need to be modified. This should lead to the establishment of new objectives which should be realized subject to a number of boundary conditions. Conditions relevant to the traffic system are, for example, the restricted amounts of energy and space. General functional requirements for society and more specific requirements for the traffic system as a part of society can now be laid down. In order that such a system should satisfy these functional requirements, long term strategies and plans can be drawn up. These new strategies and plans also imply the development of new transport systems which are better able to satisfy functional requirements. Subsequently an attempt can be made to predict the effect of all this on society in general and the traffic system in particular. The thus "simulated" future society can be defined in terms of social indicators. These must again be examined in the light of the real values, after which the cycle can begin once again. Using this technique of successive approximations we approach ever more closely, the desired result. If this cyclic process is to proceed in an optimum manner, a number of conditions must first of all be satisfies. In the first place social indicators must be drawn up and the units of observation relating to the social indicators must be developed. This requires a great deal of socio-scientific research. Secondly, society, or at least a representative section of it, must be able to participate in the cyclic process.

It is after all our future society we are talking about and this must not be allowed to be planned by a small group of "experts". This means that for long term strategies and plans, there will have to be a change over from hierarchical decision making to procedures involving consultation.

Complete openness and publicity of all stages of the cyclic process is to be desired and not only of the final strategies and long term plans. This requires an effort on a practically national scale such that all potential creative thinking and facilities will have to be brought into play. These are scattered all over the country, in colleges, universities, and in large national industries. Previously, the number of scientific researchers per 100,000 inhabitants was the best indicator of the degree to which national objectives were realized on the long term.

This has frequently become apparent during research into causes of the growth of material prosperity in terms of the growth of the gross national product per head of the population.

I believe that the manner in which the future of The Netherlands is now being prepared is the root cause of industry and also scientific research organisations such as colleges and universities not being able to participate in the plans for the future. This results in a considerable unused potential that could be helping to tackle these problems.

Summing up

The title aroused the expectation that the functional requirements of the future traffic and transportation system could already be formulated. From the foregoing it is clear that at the present moment this is not yet possible as traffic and transportation policy can and must not be isolated from an overall policy aimed at a vision of our society in the future. Scientific traffic and transportation research must therefore be integrated into more general research into the functional requirements of our future society.

Table 1 Reactive policies

	units	1972	1975	1980	1985	1990	2000
population	10^6	13.38	13.64	13.93	14.14	14.30	14.51
private cars	10^6	2.97?	3.47	4.07	4.49	4.77	5.05
distance p.year p. car kms	10^3	16.9	16.5	16.0	15.5	15.2	15.0
total car kms	10^9	50.2	57.2	65.1	69.6	72.5	75.8
ditto as % of 1972	%	100	114	130	139	144	151
total petrol consump.ltrs.	10^9	4.52	5.15	5.86	6.26	6.52	6.82
average no. of occupants	pers.	1.76	1.79	1.81	1.83	1.84	1.85
passenger kilometers	10^9	88.4	102.4	118	127	133	140
ditto, as % of 1972	%	100	116	133	143	150	158
road surface area outside built-up areas	km2	816			920		1000
ditto, as % of area of The Neth.	%	2.22			2.50		2.72
number of traffic fatalities 1)	1	3264	3420	3530	3575	3590	3600
ditto, with measures taken 2)	1	3264	2860	2760	2730	2700	2660

1) With a reactive policy without spectacular, far-reaching measures.

2) With far-reaching measures such as obligatory use of seat-belts and wearing of crash-helmets by moped-riders.

For justification of calculations, see Appendix I.

Table 2 Anticipatory policies

		1972	1985	2000
Number of fatalities:	1*	3264	2500	2090
	2*	3264	2340	1830
Probability of being killed per year:	1	1:4100 inh.	1:5600 inh.	1:6900 inh.
	2	1:4100 inh.	1:6000 inh.	1:7900 inh.

1* = "weak" policy

2* = "good" policy

For justification of calculations, see Appendix II.

Table 3 Bus system

prognoses:		A[1)]		B[2)]	
	units	1985	2000	1985	2000
bus passenger kms	10^9	127	140	127	140
bus kms	10^9	8.53	9.41	10.24	11.30
number of buses	1000	129	143	186	206
petrol consumption (litres)	10^9	3.1	3.4	3.7	4.1
total bus personnel	1000	361	400	465	515
number of traffic fatilities	1	1975	2090	2140	2270
ditto, with measures taken 3)	1	1795	1910	1960	2090

1) A : - buses travel an average of 66,000 km per year, of which 60,000 with passengers.
- average no. of passengers per bus: 18
- personnel: 2.8 men per bus.

2) B : - buses travel an average of 55,000 km per year, of which 50,000 with passengers.
- average no. of passengers per bus: 15
- personnel: 2.5 men per bus.

3) in particular, obligatory wearing of crash helmets by moped riders.

For justification of calculation, see Appendix III.

LEVEL	Traveller behaviour		Limitation of freedom
	Individual behaviour	"Sum" behaviour	
1	Choice of destination and arrival time and realization.	a . Trip productivity Trip attraction b . Trip distribution.	Unacceptable; always affects freedom of communication and movement.
2	Choice of transport mode and realization.	Modal split, i.e. distribution of travellers over several modes of transport.	Acceptable; in as far as freedom of communication and movement are not affected.
3	Choice of route, timetable and realization.	Applying batch traffic to road networks.	Acceptable; in general does not affect freedom of communication and movement.
4	Choice of manoeuvre and realization.	Traffic flow.	Acceptable; on the whole does not affect freedom communication and movement.

Figure 1. Possible limitations of freedom at decision making and behavioural levels.

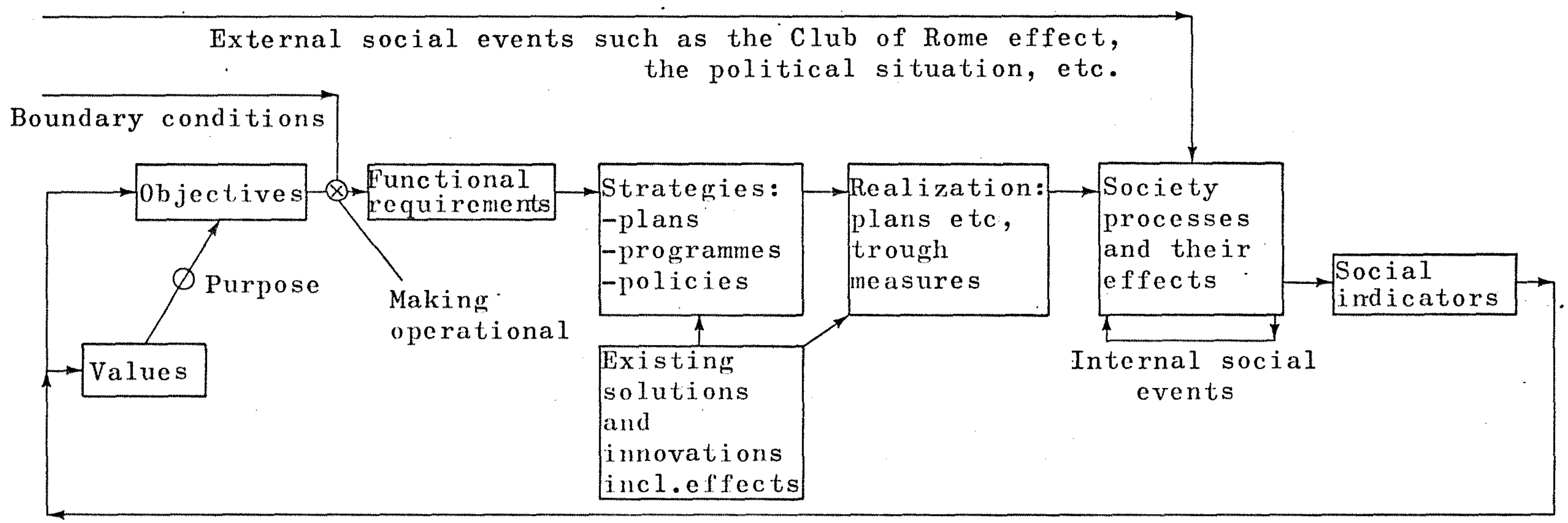

Figure 2. Schematic representation of a society model.

Definition of some concepts:

-values	:	basic yardsticks by which behaviour of oneself and others can be judged.
-Objectives	:	general views of the desired changes in society processes.
-functional requirements	:	purposes made operational within the framework of the boundary conditions.
-social indicator	:	statistic which provides the yardstick for the quality of human life and changes in this quality.

Example : social indicator : probability of survival.
This is expressed in the traffic system as the harm to people caused by traffic hazards, air pollution, noise etc.

APPENDIX I: JUSTIFICATION OF CALCULATIONS FOR A REACTIVE POLICY

J. van Minnen, scientific staff-member of Institute for Road Safety Research SWOV

1. Population

Figure 3, based on the Annual Report of the Rijksplanologische Dienst (2) shows the birth- and death-rates for the period 1960 - 1972 with some indications of future possibilities. The prognosis of the RPD (line I) declines asymptotically to 13,6 births per 1000 inhabitants, thereby indicating a stationary population. In view of the sharp decline of population growth in the last years, SWOV based calculations on a more considerable decline (line II). Table 4 contains in addition to the SWOV-prognosis also that of the RPD, furthermore two prognoses of the Central Bureau of Statistics (1).
Figure 4 is a graphic representation of the aforementioned prognoses, also showing the prognosis of TP 2000 (3) for comparison.

2. Number of passenger cars

Table 5 comprises several prognoses of various institutions: TP 2000 (3), CBS (4), Shell Nederland (5), Hupkes (2), DAF (van Dongen, Haagsche Courant, 19-2-1974), SWOV (based on data of Shell Germany (6).
The SWOV-prognosis (Table 6) seems to be justified, since it takes into account inconsiderable population growth (table 4) and furthermore expects a decrease in carownership, due to an increase of traffic intensity and congestions, the environmental restrictions which become steadily more and more severe and a sharp rise of car costs.
Based on the total population in 2000 these figures correspond to 2.86 inhabitants per car. A survey of the various prognoses is given in figure 5.

3. Average annual mileage

It is to be expected that an important share of the car park's growth will consist of private cars. A CBS - inquiry (8) furthermore revealed that the annual mileage of private cars, i.e. of the "second" cars is much lower than that of business cars: in 1970 about 14,000 km per year as compared to the annual mileage of 21,300 km of business cars. In connection with the increasing number of second cars it is justified to expect that the annual average mileage of 17,200 km of 1970 will gradually decrease to about 15,000 km per year in 2000 as mentioned below:

year	1970	1972	1975	1980	1985	1990	2000
km per car per year	17.200	16.900	16.500	16.000	15.500	15.200	15.000

4. Fuel consumption

In 1970 about 4100 x 10^6 litres petrol were sold in The Netherlands (12), corresponding to about 8.5 litres per 100 km.
In relation to the useful effect of petrol consumption in the future the following observations can be made:
- there is a tendency to obtain a higher engine capacity
- more small cars will be bought
- speed limits will be established
- constructors will endeavour to design car bodies of a more stream-lined shape, etc.

On the other hand, requirements with regard to environment and safety become more and more stringent, lowering capacity. However, a slight improvement, for example to 9 l per 100 km seems to be justified in 2000, in case petrol will still be the main fuel.

5. Degree of occupancy

The average degree of occupancy of passenger cars increased from 1.49 (1960) to 1.75 (1971) (9), corresponding to a rise of 0.0236 per year. Through linear extrapolation an occupancy degree of 2.44 can be predicted for 2000, a value which seems improbably high.
In order to get an estimation for that year, the use of cars was sub-divided according to various purposes, also for the period 1960 - 1972 (9). This sub-division was extrapolated for 2000 and combined with the average of occupancy degree for the various aspects of car use. The latter values were kept invariable.
Table 7 represents the sub-division for 2000. The rise of occupancy degree will be gradually reduced, thereby obtaining the following situation for the years ahead:

	1970	1972	1975	1980	1985	1990	2000
degree of occupancy	1.73	1.76	1.79	1.81	1.83	1.84	1.85

The product of these figures and the number of car kilometers yield the number of passenger kilometers, processed both as absolute values and relative values with regard to 1972 and given in table 1.

6. Road surface area

There are several terms in use for defining the road surface area, for example lanes, lanes and shoulders, lanes, shoulder and the so-called "disturbed" areas, which due to the excessive noise or air pollution are unsuitable for being used as residential, industrial, recreation and agricultural areas.
Therefore we shall limit our discussions to the area of hard-surfaced roads outside built-up areas, including the entire shoulder zone and enclosed areas at junctions.
In case of shoulder ditches, the width of the road is based on the distance between the ditches' center-lines. In this manner we obtained a value of 796 ± 32 km^2 (in round figure: 800 km^2), for the road surface (13).
The road surfaces inside the built-up areas will not be considered, since the city roads, as a rule, have more complex functions and can be regarded as an essential part of the interior city space.

6a. Increase of road surface area

In order to get estimated values, calculations were carried out based on the traffice intensity data of the present road system.
The following factors were applied:
- In order to ensure a reasonable traffic situation, the average daily traffic intensity should not be in excess of the following values:

6-lane motorways	:	54.000 cars per day
4-lane motorways	:	36.000 cars per day
single lane roads	:	8.500 cars per day
secondary roads	:	6.000 cars per day
tertiary roads	:	4.250 cars per day

- In 1970 $0.53 \times 42 \cdot 10^9 = 22 \cdot 3 \cdot 10^9$ km were covered outside the built-up areas by passenger cars. The estimation for 2000 is: $0.50 \times 75 \cdot 8 \cdot 10^9 = 37 \cdot 9 \cdot 10^9$ km, i.e. an increase of 70%;
-other types of car-traffic forms a rather moderate share, but will increase as well, consequently the total increase of car traffic is also estimated at 70%;
- without extending the road system the traffic intensity would increase by 70% on an average.

By reducing the maximum permissible traffic intensities for 1970 by a factor of 1.7, it is possible to deduce from the 1970-intensity data which roads will not meet the requirements in 2000;
- it is assumed that motorways, not complying with the standards for 4-lane roads in 2000, but corresponding to those of 6-lane roads, will be widened;

- it is assumed that motorways, not complying in 2000 with the standards of 6-lane roads anymore, will be replaced by new motorways;
- it is assumed that single lane roads with a daily traffic intensity of 15.000 cars in 2000 (in 1970: 9000), will be replaced by motorways;
- with regard to other single-lane roads it is assumed that new roads will be constructed if the limit values are surpassed in 2000.

Table 8 comprises the most important data, which are necessary for the calculations. The sub-division of roads according to traffic intensity was based on counts effected on national and provincial roads in 1970, (10, 11).

Based on the initial factors, the following deductions can be made from the figures of table 8:

Motorways which have to be widened	:	205 km
New motorways	:	1320 km
New single-lane national roads	:	765 km
New secondary roads	:	1305 km
New tertiary roads	:	1080 km

In order to get a more realistic estimation the calculated road lengths are increased by 25% and rounded off, since new roads will have to be constructed for by-passing routes from city-centers to non built-up areas, furthermore for obtaining more direct connections and extra roads in view of the division of roads into categories. These considerations give the following results:

Moterways which have to be widened	:	260 km
New motorways	:	1650 km
New single-lane national roads	:	950 km
New secondary roads	:	1600 km
New tertiary roads	:	1350 km
Other type of hard-surface roads	:	2000 km

The last value is based purely on estimation, since no intensity data are at disposal.

For each road type an average width (incl. shoulder) is estimated. The increase of ground that has to be used is represented below:

	length (km)	width (m)	road surface area (km^2)
widening motorways	260	10	2.60
new motorways	1650	50	82.50
new single-lane national roads	950	25	23.75
new secondary roads	1600	25	40.00
new tertiary roads	1350	18	24.30
new other roads	2000	14	28.00
In round figure: 200 km2.	Total		201.15

Thus, with regard to 1970 (800 km^2) an increase of 25% can be observed. Upon assuming that in the period 1970-1985 15% will be realised, while the remaining 10% in the next 15 years, the following values are obtained:

	1970	1972	1985	2000
road surface area (km^2)	800	816	920	1000
in % of the surface area of the Netherlands (= 36,700 km^2)	2.16	2.22	2.50	2.72

For the period 1970-1985 a 15% increase of road surface area is assumed, thus 1% per year. Data referring to the actual increase in 1971 and 1972 (12, p. 3) show the increase to have been 6 and 7 km^2, resp. for a total of about 700 km^2 (using evidently a different definition for the road surface area).
The assumed increase is in a satisfactory accordance with the actual one of the recent past.

7. Unsafeness

Accidents, involving exclusively material damage are not recorded anymore in statistics, while the registration level of accidents with injuries has been modified several times in the last years, so that no prognosis can be made for the development of accidents involving injuries. For this reason our prognosis will refer only to deaths occuring in traffic.
Figure 6 represents the number of deaths since 1959, sub-divided according to the occupants of the car and other persons including pedestrians, persons riding bicycles, mopeds, motorcycles, passengers of trucks, buses, etc.
Since 1967 the increase of the total number of deaths refers nearly exclusively to car occupants.

The category "other persons" remains approximately at a constant level, both with regard to the entire category and the separate sub-categories (pedestrians, cyclists, etc.). Evidently these figures are not affected by the increase of car-owners anymore. It is therefore justified to assume that, with a non-modified policy, this figure will not change till 2000 and will be somewhere in the proximity of 1900 deaths per year.
The number of deaths concerning car occupants displays a sharp increase which is however under the increase of the number of cars. When considering the number of deaths per 1000 passenger cars, a distinct decrease can be observed, which has a linear character in comparison with the total number of passenger cars (see figure 7).
In this connection extrapolation has been applied in order to estimate the future number of deaths giving the following results:

year	number of passenger cars	number of deaths per 1000 cars	number of deaths in passenger cars	number of other deaths	total number of of deaths
1975	3.47	0.438	1520	1900	3420
1980	4.07	0.400	1630	1900	3530
1985	4.49	0.373	1675	1900	3575
1990	4.77	0.355	1690	1900	3590
2000	5.05	0.337	1700	1900	3600

This prognosis is based on the assumption that the policy concerning traffic and more particularly traffic safety, will remain unchanged. However, this assumption is not quite realistic, since it is well known that in addition to the speed limit implemented not long ago, other regulations are being prepared as well, which will have a considerable influence on unsafeness, for example:
- a legally established maximum blood alcohol content
- the compulsory wearing of crash helmets by moped riders
- the compulsory wearing of seat-belts, at least by the persons on the front seats.

Investigations have been carried out into the possibilities of improving safety by the compulsory wearing of seat-belts and helmets.
This choice is not based on the assumption that other measures would have no effect at all, but on the consideration that the possible effect of these two measures can be calculated in a rather simple manner.

Assuming that wearing a seat-belt and a crash helmet will not affect the risk of accident, only the course thereof, the advantages of these measures can be summarized as follows:

a. seat-belts

Investigations proved that the risk of fatal casualties is reduced by 60% when using a seat-belt. In 1972 about 10% of the front-seat car occupants used seat-belts. After implementing the legal obligation of using seat-belts this figure will increase to 80% (based on Australian data). In this way the number of deaths for front-seat car occupants was reduced by (0.80 - 0.10) x 0.60 = 0.42 or 42%.
Due to 10% of car occupants using a seat-belt in 1972 the number of deaths decreased by 6%, so that the aforementioned reduction of 42% can be accepted as

$$\frac{42}{1.00-0.06}$$ = about 44% of the corresponding number of deaths in 1972.

The use of seat-belts by back-seat passengers was still very low in 1972, so that a legal obligation to wear seat-belts, amounting to 80% as well, could result in a reduction of 0.80 x 0.60 = 0.48 or 48% of the mentioned number of deaths.

When taking into account that about 82% of number of deaths for car occupants refer to front-seat persons, the aforementioned reductions can be converted into percentages of total number of deaths:

front-seat car occupants	44 x 0.82 =	36%
back-seat passengers	48 x 0.18 =	9%
	Total	45%

We assume that the obligation will relate only to seat-belts already present; thus the use thereof by front-seat car occupants could be in the proximity of 100% about the year 1980 and consequently the reduction would amount to 36%.
Should the use of seat-belts be made obligatory for back-seat passengers as well, the maximum reduction can be calculated in a later stage. Under such assumptions the following reduction rates were obtained, which in combination with earlier estimated number of car deaths determine the reduction in number of deaths:

year	1975	1980	1985	1990	2000
number of deaths in passenger cars:	1520	1630	1675	1690	1700
reduction in %:	25	36	40	42	45
reduction number of deaths:	380	587	670	710	765

b. Crash-helmets

According to estimation the death risk of moped riders wearing a crash-helmet is reduced by 40%. In 1972 about 20% of this group have worn crash-helmets, thus the number of deaths can be already reduced by 8%. When assuming that under obligation about 95% of moped riders will wear a helmet (this can be more easily controlled than seat-belts !), the reduction of death-number for 1972 can be estimated at:

$$\frac{0.40 \times 0.75}{1.00 - 0.08} = 0.33 \text{ or } 33\%$$

Without extending the wearing of helmets about 550 deaths may occur per year (542 in 1972) and in this way the reduction of 33% corresponds to a decrease of 0.33 x 550 = 180 deaths per year. Again assuming that the obligatory use of helmets will be implemented before 1975, the above figure will remain constant for the 1975 - 2000 period.

The following table gives a survey of calculated reductions, completed with the remaining number of deaths:

year:	1975	1980	1985	1990	2000
number of deaths (first estimation) :	3420	3530	3575	3590	3600
reduction through seat-belts:	380	587	670	710	765
reduction through helmets :	180	180	180	180	180
total reduction :	560	767	850	890	945
number of deaths after implementing the regulations:	2860	2763	2725	2700	2655
Idem, in round figures :	2860	2760	2730	2700	2660

8. Summary

The given prognoses show that in the year 2000, with a population of about 14,5 million, the car-ownership will increase to about 5 million cars. A slight reduction of average annual mileage to 15.000 km in 2000 and a moderate rise of the average degree of occupancy to 1.85, will increase the number of passenger mileage to 140 milliard km, which surpasses the corresponding value of 1972 by 58%.
In order to ensure an unimpeded traffic of the increased number of cars the road surface area has to be increased by about 25% (as compared to 1970), as a consequence of which the road surface areas will cover about 2.72% of the total area of The Netherlands in 2000.

With an unchanged traffic policy about 3600 deaths may occur in traffic in 2000, although by suitable measures this number can be considerably reduced. Thus for example through obligatory wearing of seat-belts by car occupants and of crash-helmets by moped riders the number of deaths in traffic could be reduced to about 2660 in 2000. Other measures, the effect of which cannot be calculated so easily, can bring about further reductions.
Figure 8 gives a survey of prognoses, wherein some factors are expressed in relative form, taking the corresponding figures of 1972 as 100%.

Table 4 Birth-rates prognoses

	1975	1980	1985	1990	2000
	Population (x 10^6)				
SWOV - RPD	13,64	13,93	14,14	14,30	14,51
RPD	13,65	14,02	14,34	14,64	15,19
CBS - A	13,55	14,18	14,73	15,22	16,05
CBS - B	13,55	14,02	14,45	14,82	15,39

Table 5 Several prognoses of number of passenger cars

	'75	'80	'85	'90	2000
	number of passenger cars (x 10^6)				
a. TP 2000		4,6		6,2	7,5
b. TP 2000 corrected		4,45	5,06	5,52	6,10
c. CBS (Bonger)		4,62	5,03	(5,15)	(5,31)
d. Shell Nederland (Mulder)				6,0	6,5
e. Hupkes					≦4,7
f. v. Dongen (DAF)				5,5	≈5,6
g. SWOV (deduced from Shell - Duitsland)	3,47	4.07	4,49	4,77	5,05

Table 6. SWOV-Prognosis, number of passenger cars and population (20 - 65 year)

	1972	1975	1980	1985	1990	2000
Population between 20-65 year (x 10^6)	7,20	7,47	7,90	8,37	8,77	9,19
cars per 1000 inh. (20-65 year)	412	465	515	536	544	550
Cars (x 10^6)	2,97	3,47	4,07	4,49	4,77	5,05

Table 7. Sub-division of car use for 2000

Car use	Portion	occupancy degree	Portion occupancy degree
home - office	20 %	1,20	0,240
business	24 %	1,15	0,276
holiday	8 %	3,50	0,280
other private use	48 %	2,20	1,056
Total	100 %		1,852

Table 8. Sub-division of roads; road length for each type

	motorways	other national roads	secondary roads	tertiary roads	other hard-surfaced roads
road length in 1970 (km)	935	2033	3177	4325	37300
acceptable daily traffic intensity	36000 (54000)[1]	8500	6000	4250	?
limit traffic intensity 1970	21000 (32000)[1]	5000	3500	2500	?
road length with intensity:					
> 32000	210				
2100 - 32000	205				
> 9000		700	275	135	
5000 - 9000		765			
7000 - 9000			175		
3500 - 7000			955		
5000 - 9000					
2500 - 500				220	
2500 - 5000				640	

1) 6-lane motorways

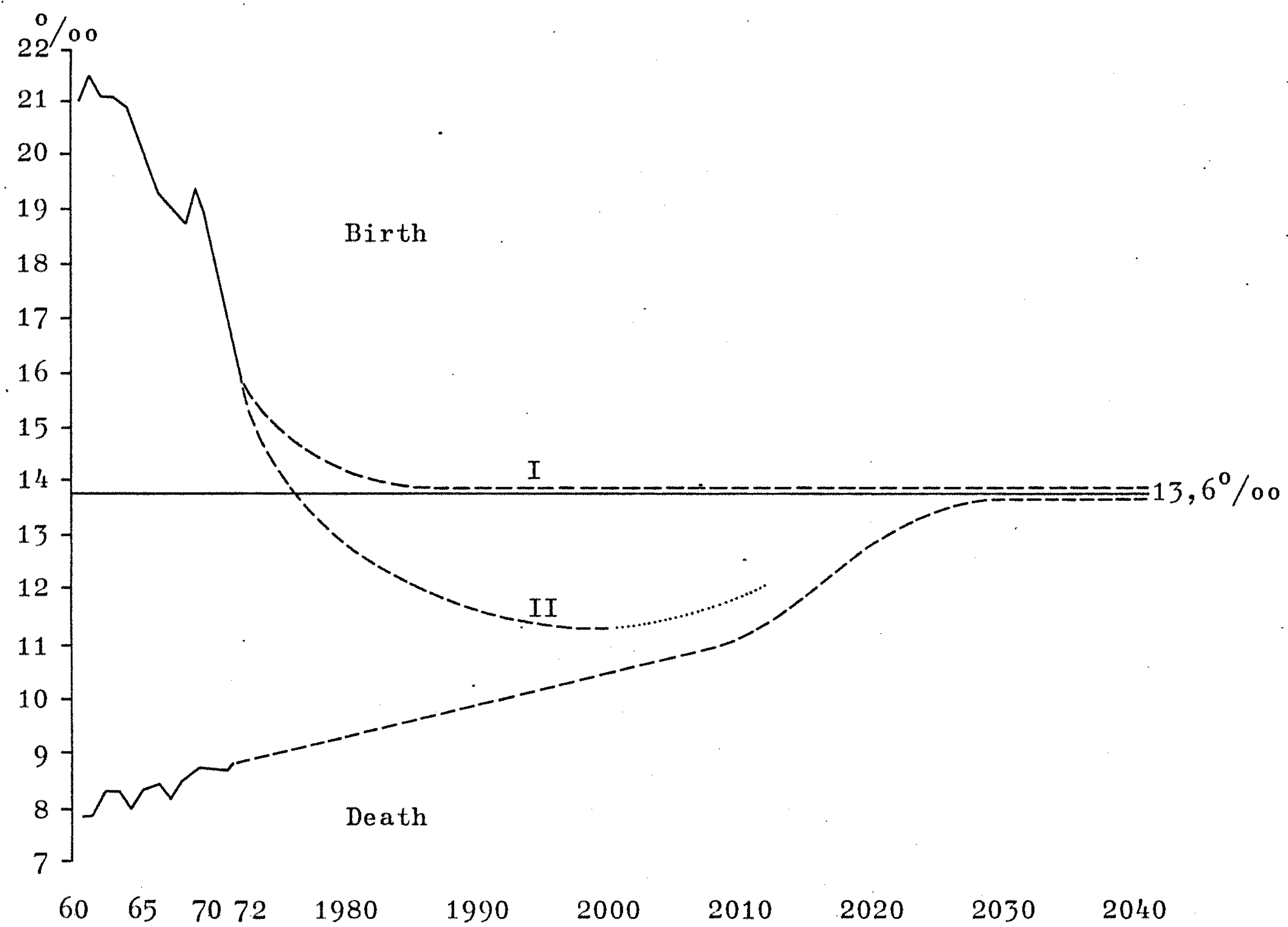

Figure 3. Movement of birth- and death-rates toward the level pertaining to a stationary population.

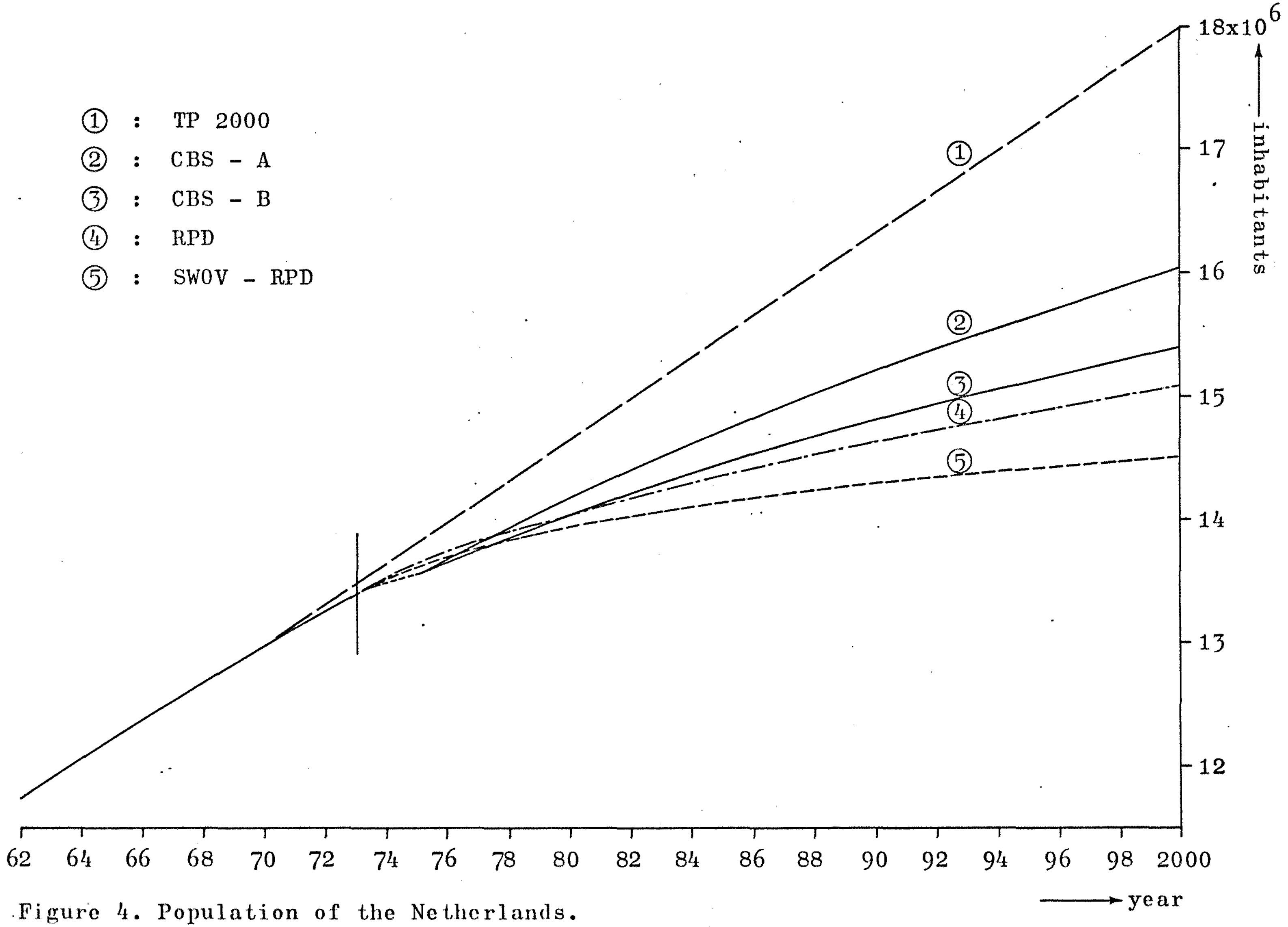

Figure 4. Population of the Netherlands.

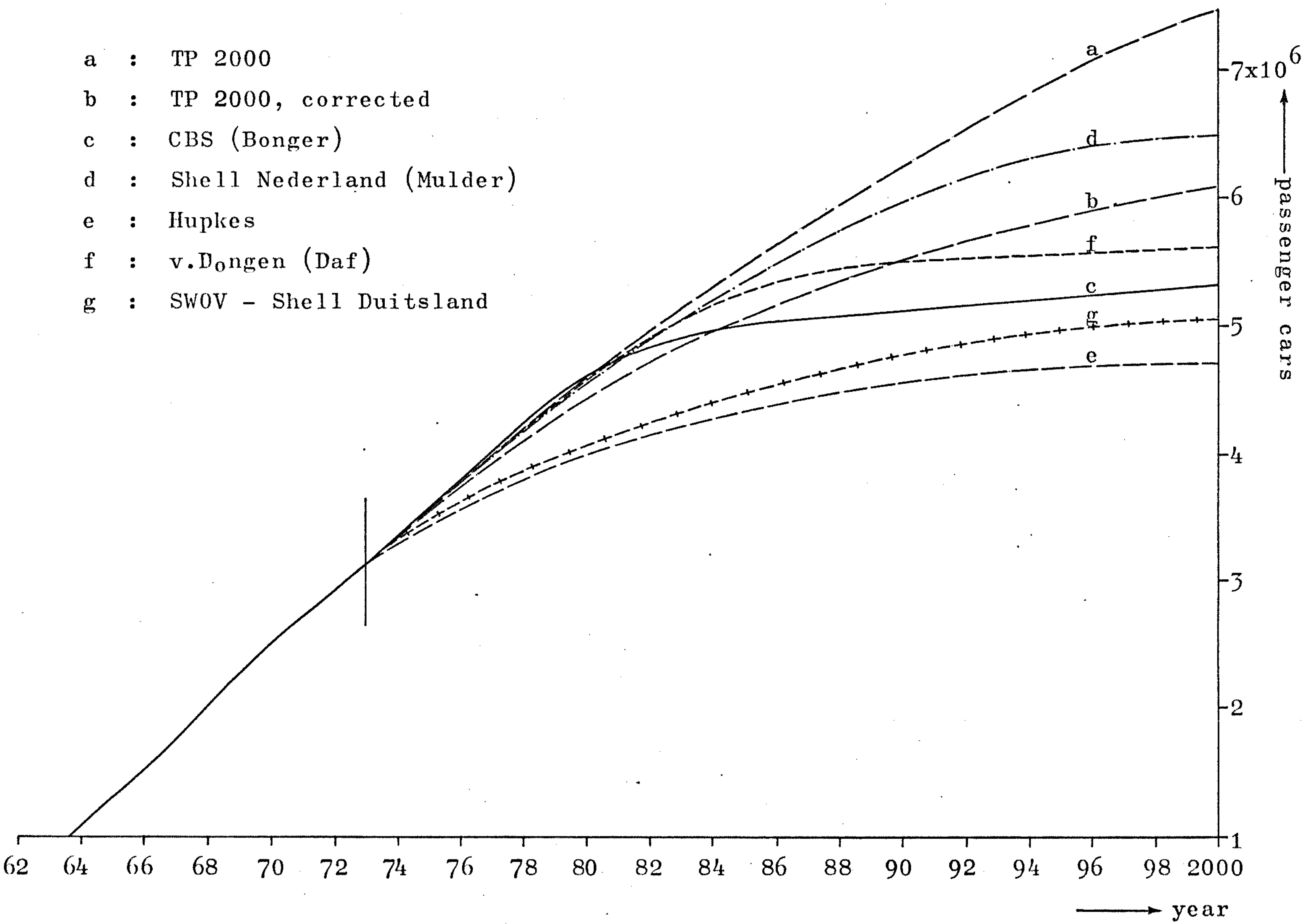

Figure 5. Car- ownership.

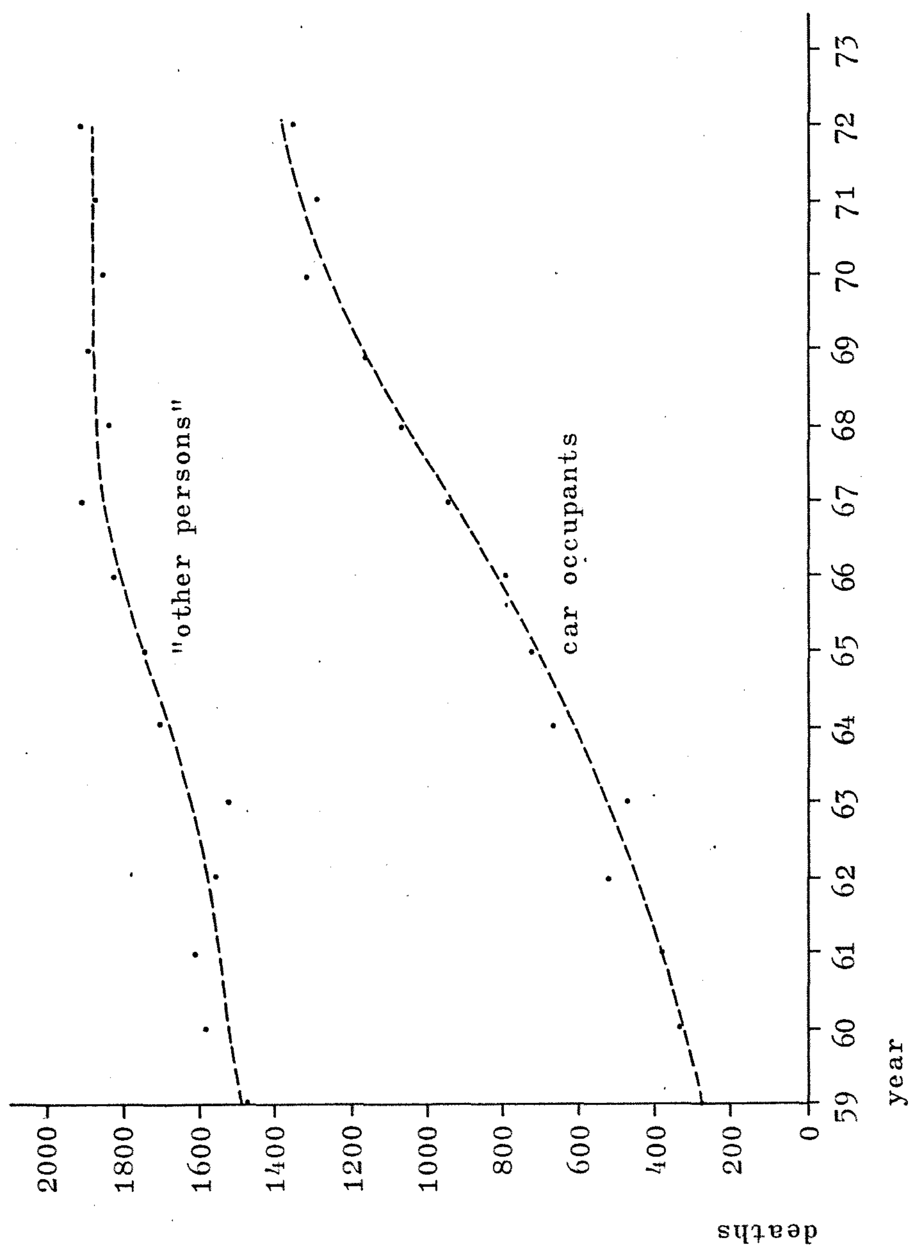

Figure 6. Number of deaths occuring in traffic.

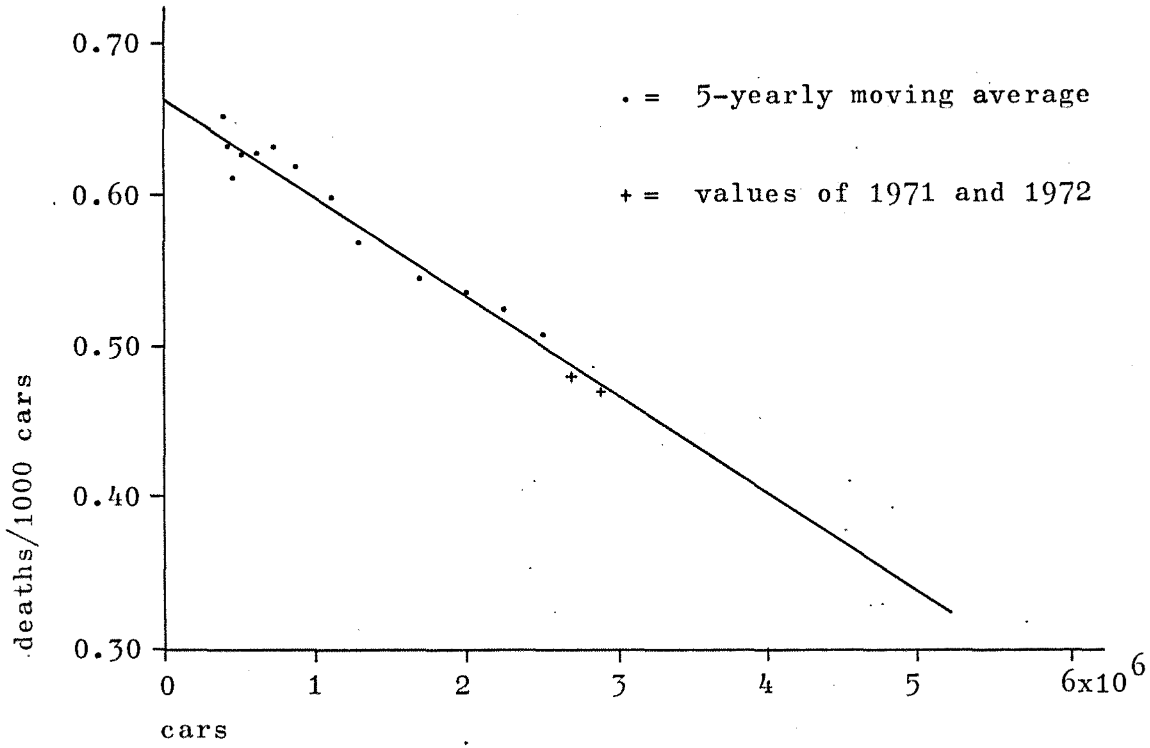

Figure 7. Relative risk of car occupants as a function of the number of cars.

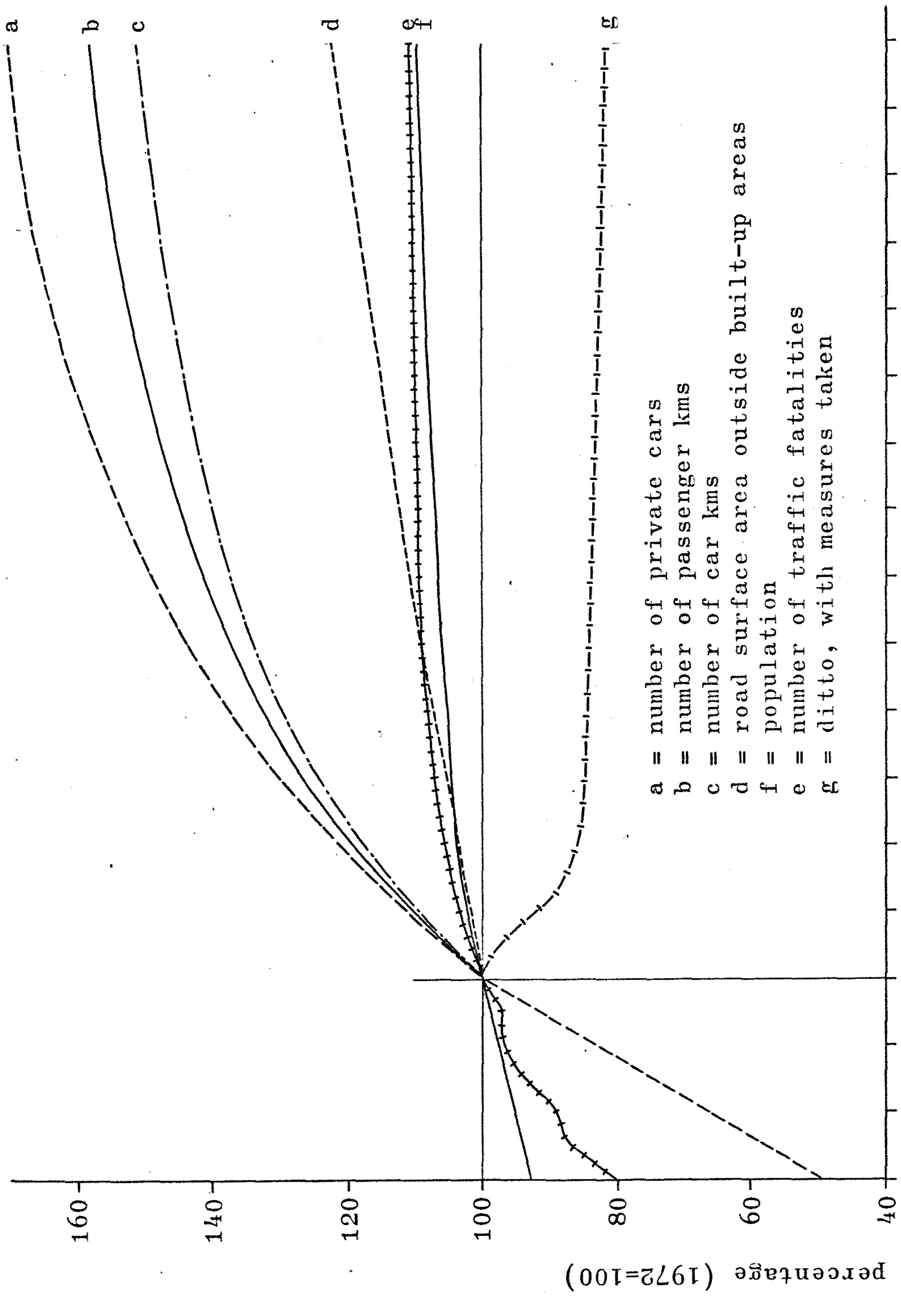

Figure 8. Prognoses, percentage of 1972

APPENDIX II: JUSTIFICATION OF CALCULATIONS FOR AN ANTICIPATING POLICY

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It is assumed that various measures will have a short term or long term effect on traffic safety. When estimating the unsafeness for the near future, the following factors have to be considered:

1. an increase of the number of accidents and casualties, as a result of an increase of traffic, mainly the traffic of passenger cars;
2. a reduction of the number of accidents and casualties, due to various, mostly structural measures reducing the risk of accidents;
3. a reduction of the number of casualties, due to measures mitigating the effect of accidents, for example obligatory wearing of seat-belts by car occupants and helmets by moped riders.

The estimation of unsafeness is limited to the number of deaths to be expected in traffic (see Appendix I., § 7). In this case the estimation can be expressed in a formula, wherein the effects 1 - 3 are introduced as factors. The expected number of deaths for the year j can be calculated with:

$$A_j = A_{1972} \cdot c_i \cdot \eta_\omega \cdot \eta_v$$

where: c_i = the coefficient of traffic increase. Since this increase can mainly be expected for the passenger car traffic and this also goes for the increase of unsafeness, c_i can be calculated from

$$c_i = 1 + a.r.c_a.$$

where: a = share of the number of deaths in passenger cars in 1972, amounting in that year to

$$\frac{1350}{3264} = 0.414$$

c_a = relative increase of passenger mileage for passenger cars.

c_a = 0.43 for 1985
c_a = 0.58 for 2000 see table 1.

r = coefficient, indicating that the number of deaths in cars increases less than proportionally with regard to the number of passenger kilometers. Based on the data of table 1 and Appendix I it can be concluded that in 1985 an increase of 43% of passenger kilometers will result in a 24% increase of traffic deaths in cars. For 2000 these percentages are 58 and 26%. This means that:

$r_{1985} = \frac{24}{43} = 0.558$, i.e. a benefit of 44.2% and

$r_{2000} = \frac{26}{58} = 0.448$, i.e. a benefit of 55.2%.

However, it is not justified to apply these values of r unchanged to the calculations since the benefit indicated in Appendix I refers partly to the consequences of the traffic increase proper, causing higher traffic intensities, modified behaviour on junctions, etc., and partly to the effect of measures, for example construction of new roads, safety measures for junctions, etc. This last effect is introduced in factor η_ω and perhaps also in factor η_v and therefore coefficient r may refer exclusively to the effect of the increase of traffic. Upon estimating this share at 60% of the total benefit, the values of r can be calculated in the following way:

1985: benefit 0.60 x 44.2% = 26% $\rightarrow r_{1985} = 0.74$
2000: benefit 0.60 x 55.2% = 33% $\rightarrow r_{2000} = 0.67$

while the c_i values are as follows:

1985: $c_i = 1 + 0.414 \cdot 0.74 \cdot 0.43 = 1.132$
2000: $c_i = 1 + 0.414 \cdot 0.67 \cdot 0.58 = 1.161$

——— 0 ———

η_ω - refers to the composition of roads and districts by
- reconstruction and classification of existing roads;
- construction of new districts with segregated traffic types;
- improvement of existing districts.

The improvement mainly relates to the risk of accidents (pre-crash). The value of η_ω can be calculated from

$$\eta_\omega = \{\rho_s \pi_s + \rho_t \pi_t + (1 - \pi_s - \pi_t)\} d_s + \{\rho_w \pi_w + \rho_u \pi_u + (1 - \pi_w - \pi_u)\}(1-d)$$

The first term refers to built-up areas, the second to traffic outside built-up areas.

π_s = share of number of deaths within built-up areas, which can be expected in new districts, if built according to traditional methods

ρ_s = relative risk in such districts if built in the optimal manner, i.e. with complete segregation of different types of traffic

π_t = share of number of deaths within built-up areas in rebuilt districts

ρ_t = relative risk in rebuilt districts

π_w = share of number of deaths outside the built-up area on new roads, if these will not be safer than the existing roads outside the built-up areas (average value)

π_u = share of deaths on roads which have to be reconstructed and classified

ρ_u = relative risk on reconstructed roads

d_s = share of deaths caused by traffic within built-up areas

ρ_w = relative risk on "safe" new roads

In order to carry out calculations, the following values have been estimated:

π_s: it is assumed that in 1985 20% and in 2000 40% of the population are living in newly built districts; it is further assumed that these are mostly residential districts, thus with less dense traffic; these figures are then expected to correspond with 15 and 30%, resp., of the number of deaths inside the built-up area. Depending on certain aspects of policy, part of these districts can be built "safely", for example:
a "weak" policy: $1/3 \rightarrow \pi_s$ = 0.05 and 0.1, resp.
"good" policy : $2/3 \rightarrow \pi_s$ = 0.1 and 0.2, resp.

ρ_s: in districts with a far reaching segregation of different types of traffic the number of deaths can be reduced to 1/4 (Gothenburg, Stevenage), and in this case ρ_s = 0.25.

π_t: when assuming that, in dependence on the policy to be effected, 15 - 25% of existing city centers and districts can be rebuilt before 1985, while before the year 2000: 40 - 60%. π_t will be 0.15 - 0.25 and 0.40 - 0.60, resp.

ρ_t: through a reasonable reconstruction, including also traffic-free areas, an improvement of 50% is possible;

however, on the one hand, in the adjoining areas unsafeness can be increased, for example through increasing traffic intensity on certain roads. Again assuming that adequate measures will be implemented in this respect, the estimated net value for ρ_t is: 0.60.

d_s: there is hardly any change in the death rate inside built-up areas since 1968, this rate ranging between 40.3 and 41.2%. On the one hand it can be expected that built-up areas will expand, while on the other hand it seems possible that traffic intensities outside the built-up areas will increase quite considerably. As a consequence, the expected net result will not deviate much from 41% in the future, thus $d_s = 0.41$.

π_w: the road surface area is expected to increase by 12.5% in 1985 and by 22.5% in 2000; since traffic intensity is more than proportional to the road width and since relatively more wide roads will be constructed in the future, traffic performance will increase on new roads, according to estimation by 15% in 1985 and 25% in 2000. In case all these roads are constructed in the optimal manner, we obtain for $\pi_w = 0.15$ in 1985 and $\pi_w = 0.25$ in 2000.

ρ_w: the accident rate for motorways is lower by a factor of 2 - 3 as compared to that of single-lane national roads; in view of single-lane roads of a simpler character (more narrow roads, more bends, more mixed traffic), the difference can be greater. Since a major part of the traffic on new roads will take place on motorways, an average improvement by a factor of 2.5 is estimated, thus $\rho_w = 0.4$.

π_u: in the first place the important roads will be reconstructed and classified; depending on the policy applied the estimations for π_u are:

$\pi_u = 0.20 - 0.40$ in 1985

$\pi_u = 0.40 - 0.60$ in 2000.

ρ_u: the expected benefit with regard to safety on these roads will be considerably lower than in the case of new motorways; a 20% reduction of the number of death seems realisable in 1985; due to experience this percentage can be increased to 25% in 2000 and therefore:
$\rho_u = 0.80$ in 1985 and 0.75 in 2000.

Summary of estimated values:

	"weak" policy 1985	"weak" policy 2000	"good" policy 1985	"good" policy 2000
π_s	0.05	0.10	0.10	0.20
ρ_s	0.25	0.25	0.25	0.25
π_t	0.15	0.40	0.25	0.60
ρ_t	0.60	0.60	0.60	0.60
d_s	0.41	0.41	0.41	0.41
π_w	0.15	0.25	0.15	0.25
ρ_w	0.40	0.40	0.40	0.40
π_u	0.20	0.40	0.40	0.60
ρ_u	0.80	0.75	0.80	0.75

——— 0 ———

η_v: relates to improvement of crash-safety, due to the obligation of wearing seat-belts by car occupants and crash-helmets by moped riders.

$$\eta_v = \{\rho_a g_a + (1-g_a)\}\pi_a + \{\rho_b g_b + (1-g_b)\}\pi_b + (1-\pi_a-\pi_b)$$

ρ_a = relative risk of car occupants wearing seat-belts

g_a = increase of the rate of car occupants wearing seat-belts

ρ_b = relative risk of moped riders wearing crash helmets

g_b = increase of the rate of moped riders wearing crash helmets

π_a = relative number of deaths for car occupants

π_b = relative number of deaths for moped riders

} both π_a and π_b in comparison with the total number of deaths

The values π_a and π_b have to refer to the year for which the estimation is made.

In the calculations the following factors are used:

ρ_a = 0.40; the 60% reduction of the death risk when wearing seat-belt is an estimated value, based on investigations.

ρ_b = 0.60; in case of wearing crash-helmets, a reduction of 40% is estimated for moped riders.

g_a = 0.65; for 1985 and 0.75 for 2000.

In 1972 about 10% of all front-seat car occupants used a seat-belt, corresponding to 8% of the total number of car occupants. When seat-belts become obligatory, an increase of this percentage to about 80% (based on Australian data) can be expected. In this case the increase will amount to 72%. Since the effect of the 8% wearing seat-belts has already been introduced into the death figure for 1972 (reducing the number of death car occupants by about 5%), a correction has to be applied and therefore the increase of 72% has been raised further, up to 75%, $(\frac{0.72}{0.95})$.

This percentage has been established for 2000, while for 1985 65% has been chosen, since it can be assumed that the back-seat passengers will be obliged to wear the seat-belt in a later stage only.

g_b = 0.82 for 1985 and 2000.

In 1972 the rate of moped riders wearing crash-helmets was estimated at about 20%, (based on investigations). When crash-helmets will be obligatory, this rate will increase to circa 95%. This increase of 75% will be corrected, similarly to g_a, in this way obtaining for g_b = 0.82.

π_a: it is assumed in the first place that the number of death increases in a way such as was calculated for c_i, than $\pi_a = 0.48$ for 1985 en $\pi_a = 0.50$ for 2000.

π_b: it is assumed that the number of moped death will not change much in future (542 in 1972); consequently $\pi_b = 0.147$ for 1985 and $\pi_b = 0.143$ for 2000.

Summarising:

	1985	2000
ρ_a	0.40	0.40
g_a	0.65	0.75
π_a	0.48	0.50
ρ_b	0.60	0.60
g_b	0.82	0.82
π_b	0.147	0.143

Results

The calculations were effected for 1985 and 2000, both based on a "weak" policy and a "good" one. The results are given in the following table:

	"Weak" policy		"Good" policy	
	1985	2000	1985	2000
c_i	1.132	1.161	1.132	1.161
η_ω	0.883	0.756	0.828	0.663
η_v	0.765	0.728	0.765	0.728
$c_i \cdot \eta_\omega \cdot \eta_v$	0.765	0.639	0.717	0.560
A_j	2496	2086	2340	1829
A_j in round figures	2500	2090	2340	1830

APPENDIX III: JUSTIFICATION OF CALCULATIONS FOR THE BUS SYSTEM

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1. Introduction

Assuming that passenger car transport is completely replaced by bus transportation, the question arises: which consequences can be expected with regard to the number of buses, fuel consumption, road surface area and traffic safety?
A satisfacory estimation could be made by establishing a complete bus-network, incl. service instructions, travel frequencies, etc. Since there is not enough time and knowledge for such a simulation, a drastically simplified approximation has been decided upon, based on the average degree of occupancy and the annual mileage of the buses. Moreover, since the estimations for both factors of such a bus-system cannot be sufficiently exact, two combinations of basic data have been applied. The estimations were made for 1985 and 2000.

2. Basic data

In 1971 the average occupancy degree of buses on local routes amounted to 16.6 passengers and on interlocal ones to 14.5 passengers ((9), p.25). Each bus covered 57,000 km. per year on an average ((14), p.61); this value is an average for all buses. Based on a plurality of data referring to numbers and mileage for various bus categories, such as common bus, group-transportation, touring cars, etc., ((9), p. 24/29), it can be established that the annual mileage of common buses does not deviate considerably from the aforementioned average of 57,000 km. In case of interlocal bus lines this value is slightly higher (mileages of 80,000 - 85,000 km are being mentioned), while for local lines somewhat lower than 57,000 km. The problem we are now confronted with, is in which manner will the degree of occupancy and annual mileage develop for a comprehensive bus-system. On the one hand, bus-transportation of such a mass-character could result in an increase of the degree of occupancy. On the other hand, a dense bus-system has to be established with bus-routes also in areas with only a limited number of passengers. Moreover, the bus system has to be available in quiet, no-rush hours, even during the night, at a satisfactory frequency and therefore an important growth of occupancy is not very probable. The same applies to annual mileage. The rush hours require a large number of buses, major part of which will not have to be in service in the after-rush hours and on account of all this the annual average mileage of the bus will not be much higher than the present value, if at all. Based on these considerations and using two combinations we arrived at the following estimations: Combination A can be regarded as optimistic, while combination B is of a more pessimistic character. The number of personnel (at present 2.5-3 per bus) is selected higher for combination A, since the number of drivers will have to be increased upon increasing the annual bus mileage.

	A	B
average annual mileage	66,000 km	55,000 km
average degree of occupancy	18 passengers	15 passengers
personnel per bus	2.8	2.5

3. Bus mileage

The number of passenger-mileage per private car was estimated at 127 milliard in 1985 and 140 milliard in 2000 (Appendix I). If all these passengers have to be transported by buses, the number of passenger-kilometers will increase, since the bus follows an established route, whereas in private transportation usually the shortest route is selected. However, an increase of 10% passenger-mileage seems to be realistic.
It has also to be considered that the bus rides sometimes with no passengers at all ("empty runs"), which is estimated at 10% as well. The total number of bus kilometers can be calculated from:

$$\text{bus-kilometers} = \frac{\text{passengerskilometers x 1.1 x 1.1}}{\text{degree of occupancy}}$$

This formula yields the following results:
8.53 milliard km in 1985 and 9.41 milliard km in 2000 for combination A and 10.24 milliard and 11.30 milliard km, resp., for combination B.

4. Required number of buses and personnel

The required number of buses can be calculated through dividing the total number of bus-kilometers by the average bus-mileage, while the number of personnel can be calculated by the number of buses and the personnel required for 1 bus. In this way the following values were obtained:

	A		B	
	1985	2000	1985	2000
number of buses	129,000	143,000	186.000	206,000
total number of personnel	361,000	400,000	456,000	515,000

5. Fuel consumption

According to the reports of some bus companies the fuel consumption amounts to about 33 litres per 100 km on interlocal routes and 40 litres per 100 km on local ones. In Appendix I. there is an estimation that about 50% of car-mileage is effected within built-up areas. This rate should be somewhat lower for buses, since the average degree of occupancy is slightly higher inside the built-up areas. In addition, part of the mileage inside the built-up area is effected by interlocal bus lines. Consequently, it has to be accepted that 40% of mileage is covered by local bus lines.
From this follows that the average fuel consumption amounts to
(0.4 x 40) + (0.6 x 33) = 36 litres per 100 km.
In combination with the total number of bus-kilometers the following values are obtained for the total fuel consumption:
A: 3.1 milliard litres in 1985; 3.4 milliard litres in 2000.

B: 3.7 milliard litres in 1985; 4.1 milliard litres in 2000.

In comparison with private cars' fuel consumption these values indicate a reduction of 50% (A) and 40% (B), resp. (Appendix I).
Furthermore, it has to be taken into account that buses consume nearly exclusively dieseloil, the fuel value of which is 10% higher than that of petrol. Converted into Kcal, the savings effected by the bus system amount to 45% and 34%, resp.

6. Unsafeness

For the same reasons as in Appendix I, here also we shall limit our estimations to the number of deaths in traffic. However, a realistic estimation of deaths with regard to bus systems is hardly possible, because the drastic modification of the entire traffic system has to be considered. In addition to single bus accidents, comparisons will have to be

made between buses and trucks, buses and slow traffic, incl. pedestrians and the buses proper, with regard to one another. There will be no accidents anymore involving private cars, while accidents mutually caused by the aforementioned categories will occur in the future too, without however any possibility of predicting an increase or a decrease of the number of accidents.
The prognosis of unsafeness is based on the assumption that the general accident situation of the other categories remains unchanged as regards single accidents and collisions within the slow traffic category.
The calculations were carried out with the following data (obtained from (15)):

fatal casualties:

year	1967	1968	1969	1970	1971
total	2636	2657	2809	2879	2868
with private cars	1736	1790	1909	2044	2059
non-private cars	900	867	900	835	809

This latter type of accidents is not expected to change in case of a total bus-system; it was estimated at 810 for 1985 and 2000.
For fatal casualties, involving buses, the following data were available:

year	1967	1968	1969	1970	1971	gem.
total (with buses):	67	72	85	78	63	73
- with private cars	21	21	21	26	17	21
- non-private cars	46	51	64	52	46	52
-- involving a truck	6	2	3	2	1	2,8
-- involving a bus	0	0	0	0	0	0

For the estimations concerning 1985 and 2000 the following conditions were assumed:
- the number of fatal casualties involving buses increases proportionally to the bus mileage;
- the number of fatal casualties involving two buses increases more than proportionally to the bus mileage, more accurately raised to the 1.5 power.

A problem in connection with the last condition is that no fatal casualties of this type occurred in the period 1967 - 1971, which of course, can be pure chance in view of the rather low number of accidents to be expected. In order to make an estimation of the data concerning accidents with injuries for the categories bus/bus and bus/truck have been considered as well, these accidents being comparable as regards the degree of seriousness of injuries. Based on these data it could be established that in the period of 1967 - 1971 25 accidents (with injuries) occurred in the bus/bus category, whereas 275 in the bus/truck category (thus a ratio of 1 : 11). Upon applying the same ratio to fatal casualties the estimation is: $\frac{2.8^{*}}{11} = 0.25$ fatal casualties in the bus/bus category. This number is used in prognoses. The calculations concerning fatal casualties for 1985 and 2000 are given in the following table.

	A		B	
year	1985	2000	1985	2000
bus-mileage (x milliard)	8,53	9,41	10,24	11,30
the same with regard to 1971 (=f) (in 1971 this was about 0.53 milliard km)	16,1	17,75	19,33	21,30
number of fatal casualties (excl. bus/bus), (in 1971:52)	837	923	1005	1108
ratio of bus/bus accidents ($= f\sqrt{f}$)	64,6	74,8	85,0	98,3
fatal casualties in the bus/bus category (in 1971: 0.25)	16	19	21	25
other fatal casualties	810	810	810	810

In order to convert the number of fatal accidents into deaths, the number of deaths per fatal accident has to be estimated. In the past years this amounted to about 1.1 and this value is invariably applied to non-bus accidents. In case of bus accidents a higher rate can be expected in view of the higher number of bus passengers.
The estimation is as follows:
bus-accidents (excl. bus/bus): 1.25 for A, 1.20 for B
bus/bus accidents : 2.40 for A, 2.00 for B.
In this estimation it has been taken into consideration that the probability for <u>one</u> fatal casualty is approximately in proportion with the <u>number</u> of bus passengers, while the

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*2.8 was the average number of fatal casualties per year in the category bus/truck for 1967-1972.

probability for a fatal accident increases as well in proportion with the number of car passengers, although in a lesser degree.
The calculation of the expected numbers of deaths is summarised in the following table:

combination	A		B	
year	1985	2000	1985	2000
bus accidents (excl.bus/bus)	837	923	1005	1108
deaths per accident	1,25	1,25	1,20	1,20
number of deaths	1045	1154	1206	1330
bus/bus accidents	16	19	21	25
deaths per accident	2,4	2,4	2,0	2,0
number of deaths	38	46	42	50
other accidents	810	810	810	810
deaths per accident	1,1	1,1	1,1	1,1
number of deaths	891	891	891	891
total number of deaths	1974	2091	2139	2271
in round figure	1975	2090	2140	2270

In case assuming again, similarly as in Appendix I, that crash-helmets will be obligatory for moped riders, the estimated numbers of deaths will have to be reduced. However, calculations could only be made when an estimation of the number of fatal moped-casualties would be possible. At present, there are no sufficient data available for such an estimation. A certain indication can be obtained from the following data.
In 1971 265 fatal casualties occurred in the moped/car category and 14 in the moped/bus category, (thus a ratio of 19 : 1). In case of a total bus system the first category is omitted. Upon assuming that bus/moped accidents also increase in linear proportion to the bus-mileage, this increase can be characterised by a factor ranging between 16 and 25 and consequently no considerable changes can be expected with regard to the number of deaths of moped-riders. In view of the total number of deaths of moped-riders (in 1972: 542) the possible change is relatively still more improbable. On basis of this indication it can be expected that crash-helmet obligation will result in a reduction of deaths by 180 per year also with regard to a total bus-system (Appendix I). The expected numbers of deaths for this case is given in the last line of table 3.

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