Safety standards based on road type

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SAFETY STANDARDS BASED ON ROAD TYPE

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ABSTRACT

This contribution is intended to examine whether, in the process of assessing road safety, it is useful and feasible to locate measures which can be used as 'standards' for the various road types and their intersections. We have restricted ourselves here to a comparison between road types and propose to do so using the following measure of comparison: the number of injury accidents (casualties and fatalities respectively) per kilometre of road length, given the average number of motor vehicles which use the road type per day.
In terms of setting tasks for future road networks, we can opt for an absolute drop in the accident or casualty density and/or a drop in risk. It is evident that we cannot simply impose safety standards on roads and intersections; we must actually work on the safety of the infrastructure. The effects on the risk figure associated with the road type should be predictable for new countermeasures. As soon as the effects are known, they can be included in a new risk figure which can have a task setting function for the road category where the measure is to be applied on a large scale. If safety on our roads can be properly quantified, then we are better able to recognise the - currently hidden - risks and remove their underlying cause. Under preconditions the road safety standards imposed on the individual road categories can make a useful contribution.

Introduction

The traditional role of the road traffic system has been to permit mobility. This task is still imposed on the available road network wherever possible, despite the rapid rise in the number of motorised vehicles. Not that long ago, in the 1950s, the first roads were built with the primary intention of rapidly driving motor vehicles. People also found these motorways significantly safer than existing roads, in any case when viewed from the perspective of motorised traffic and the number of vehicle kilometres they cover. The construction of motorways has certainly led to an increase in the number of motor vehicles, also on other roads not specifically built for that purpose. The effect this has had on the overall degree of road hazard is difficult to determine.
During the 1970s, the number of traffic fatalities reached a record high in the Netherlands and in many neighbouring countries. In response, many road safety measures were proposed and implemented. The residential areas were the first point of concern. The 'woonerf', specifically designed to improve safety, made a prominent debut. This favourable development continued in the Netherlands with the large scale introduction of more efficient 30 km/hr zones. The construction of motorways continued, while the other arterials inside and outside the built up area were largely ignored. Promotional activities were introduced to stimulate use of the bicycle and for the design and construction of

facilities to carry slow traffic. This implied a differentiation in the function and use of a road; the road is not only there to allow rapid transport by car, it also serves to carry other forms of transport and even permits other activities. It has also become clear that many of these functions are incompatible and cannot be combined on the same road.
We are now in the process of reducing the risk for road users at both extremes of the road function scale - the motorway on the one hand and the 30 km/hr road in residential areas on the other. However, the traffic risk on roads in the intervening segment has proven far more difficult to combat. Manuals for tackling 'accident concentrations' dating from the 1970s and 1980s have meantime exerted their maximal effect; the principal local 'design faults' which served to endanger traffic situations have now been detected and dealt with. Despite these curative operations, non-motorways outside the built up area and non-residential streets inside the built up area still demonstrate a high accident risk for all modes of transport. It is precisely with reference to these roads that we must consider preventative measures which serve to safeguard the basic safety of the road transport system. We refer to this as a sustainable-safe system approach, in which more stringent safety requirements will be imposed on the road infrastructure.
This contribution is intended to examine whether, in the process of assessing road safety, it is useful and feasible to locate measures which can be used as 'standards' for the various road types and their intersections. We believe that in order to do so, a functional reorganisation of the roads forming the road network should be attempted, since a standardisation of the quality requirements per road type of course also implies standardisation of the inherent road typology. The safety standards considered here per road type are therefore based on a categorization of roads.

Purpose of the Safety Standard for Road Types

The possibilities for the application of safety standards per road type are numerous. They could help to answer practical questions that arise with the planning, design and management of roads, such as:
- which road types are most hazardous and are becoming more so with respect to other road types?
- which types of road or intersection represent a hazard to certain modes of transport?
- how are priorities set for infrastructural road safety measures?
- which safety standards should be selected as reference or goal values for road safety policy?
- how can road safety measures and policy be evaluated?
- which methodology can be used to predict safety effects in the near or distant future and at local, regional and (inter)national level?
- how can road safety knowledge and information be incorporated into those models which calculate scenarios for traffic plans?

Within the framework of this contribution, the questions were aimed at a comparison between road types:
- which measures can be used to compare and evaluate road hazard for the various road types?
- how do these measures develop over time?
- are there guidelines or standards which can be inferred from the development of these measures with which concern for road safety can be stimulated in the practice of road administration?

Functional Categorization of Roads

The design of the current road network has largely been shaped by history. This does not mean, however, that there is question of any logical organisation. It has been shown that not all roads deserve the appellation 'safe'.
For a long time, we have adhered to the notion that a functional distinction can be made within the road infrastructure based on residential areas and traffic areas. The residential area serves housing, working and leisure needs, while traffic areas are intended for the relocation of people and goods, mainly by means of vehicles. The traffic area is filled with road networks which offer a great variety of relocation options for the various modes of transport. The speed levels in particular have a significant impact on the road hazard associated with these road networks and the quality of life in the adjoining residential areas. Roads are of course intended to drive over, but not all roads are constructed to allow rapid transit. For example, roads can be designed to offer access to properties, to open up districts and cities and to interconnect regions, both at national and international level. While residential areas allow the access of vehicles, their speed should not exceed a certain maximum. Another important principle which we wish to adhere to is the separation of motorised (fast) traffic and the remaining (slow) traffic, which is largely represented by vulnerable road users such as cyclists, moped riders and pedestrians.
In principle, we should therefore make a distinction according to road infrastructure for fast or slow traffic. Both road networks require a functional categorization and an assessment based on measures of road safety. However, we commence with the infrastructure for motorised fast traffic and subsequently determine which roads and intersections can also offer access to other traffic. If slow traffic is not permitted, then a separate infrastructure must be provided. In this way, we arrive at the following functional split of road categories for motorised traffic [SWOV, 1994]:
- flow function: rapid processing of through traffic;
- distributor function: linking districts and regions;
- access function: residential access.

Flow roads should facilitate the rapid transit of traffic, i.e. with the least amount of disruption, also across intersections. Continuity and a relatively high flow speed are possible with a constant flow of traffic (no turns, no entering or intersecting traffic) carrying the same type of vehicle (particularly with respect to size and speed potential).
In contrast, distributor roads should allow frequent exchange of traffic to and from other roads at points of intersection. The exchange is facilitated if the flow of vehicles on the road is travelling at a lower speed. The connecting function of a road is indicated by the intersections, the connections and the parking facilities along that road.

The access road should process local traffic (entering or leaving) at all points along the road. The access function of a road can be directly derived from the functions which are represented along that road, be they residential, work, shopping or recreational. An important part of the public road, particularly the pavement, serves to carry people. People may also be found on the roadway itself, e.g. to cross the road or exit from a parked car. The driving speed of motorised vehicles must be such that these activities can take place without risk of road accidents.

It is the intention that a classified road in fact only fulfils a single, allocated function. With the exception of the majority of motorways (suitable for a flow function), the existing roads are generally unsuitable for specifically fulfilling one of the three major functions, unless they have undergone adaptations. At present, the three functions of motorised traffic are often fulfilled simultaneously in various combinations, and there is no consistent separation of other, vulnerable traffic. Such multifunctional traffic situations are characterised by high accident figures. It would be consistent to bar slow traffic from flow roads and from the main carriageways of regional distributor roads.

The Safety of the Road Types

When comparing the road safety of various road types, use is first made of the data taken from the accident registrations. Road authorities that wish to make comparisons will be mainly interested in the number of disruptions to the traffic process. Accidents are inadmissible disruptions, particularly when they result in much damage and severe personal injury. However, accident registration is far from complete. As the severity of the accidents decreases, the level of registration diminishes. This argues in favour of a measure of comparison which only includes the most severe accidents. A counter-argument is the statistical lack of reliability of the measure when applied at local level. In the example, we have chosen to include injury accidents, i.e. all registered accidents involving casualties, ranging from slight injury to fatal injury. Because policy objectives are largely expressed in terms of lowering the number of road accident casualties, particularly fatalities, it is desirable to also express the measure of comparison in terms of the number of casualties and the number of fatalities.
Injury accidents can be split according to whether casualties were injured or killed using data about the number of casualties per injury accident and further subdivided according to the number of fatalities per casualty statistic. When comparing road types as referred to here, a hazard measure will in many cases need to be assessed in association with a measure of road use. The measure for the use of the road types can be expressed as the number of vehicles which pass per time unit, the distance covered by the vehicles in a certain period of time or the total length of time the vehicles are on the road. If one wishes to assess the road hazard associated with various modes of transport within one road type, e.g. motor vehicle versus cyclists, then clearly the difference in driving speeds can also be included in the assessment. In that case, once could choose for the time spent on the road as a measure of use.
Prior to determining the safety standard for a sustainable-safe road infrastructure, we will consider the safety of the current road networks. We will also follow the development of road hazard for the various road types over a period of years, using the Dutch road network as example.

The Netherlands harbours 15 million people on a small surface area: an average of 350 inhabitants per square kilometre. We possess over 5.9 million passenger cars, 12 million cycles, almost half a million mopeds and 180,000 motor cycles.
The total road network measures 105,000 km, about equally distributed over urban and rural areas. The motorways, representing only 2% of the total road length, processes 37% of the total number of motor vehicle kilometres covered (over 100 thousand million in 1992). The same number of kilometres is travelled on the other rural roads, leaving 25% for the roads within the built up area.
The distribution of road accidents according to road type is entirely different. In 1992, 41,000 injury accidents were registered in the Netherlands; 5% on motorways and 25% on other rural roads, leaving 70% inside the built up area.

Using these figures, we can measure road hazard on the Dutch road network in two ways:
- the number of injury accidents per kilometre road length;
- the number of injury accidents per motor vehicle kilometre travelled.

Table 1 shows that the ranking of the two road types according to the two systems of measurement is not equivalent. Per kilometre road length, the motorway demonstrates by far the most accidents, while this road type scores most favourably per vehicle kilometre. This difference makes it difficult to judge the safety of road types. It becomes even more complicated if we make a further distinction based on accident severity. For example, the ranking of road types in Table 2 is different again for the number of fatalities per kilometre of road length and per vehicle kilometre, respectively.

Road type	Number of injury accidents per 100 km road length	100 million vehicle km
Motorway	102	6
Rural road	19	27
Urban road	58	116
Total road network	39	41

Table 1. *Safety measures using injury accident statistics for the Netherlands, 1992.*

Road type	Number of fatalities per 100 km road length	100 million vehicle km
Motorway	7.6	0.4
Rural road	1.3	1.8
Urban road	0.9	1.8
Total road network	1.2	1.3

Table 2. *Safety measures using fatality statistics for the Netherlands, 1992*

Road Safety Indices: Measures of Comparison for Road Types

We have restricted ourselves here to a comparison between road types and propose to do so using the following measure of comparison:
- number of injury accidents (casualties and fatalities respectively) per kilometre of road length, given the average number of motor vehicles which use the road type per day.

In the Dutch example from the control year, 1986, eleven road types are distinguished:

Outside the built up area
MW>4l: motorway; more than 4 lanes
MW 4l: four-lane motorway
MR 2c: dual carriageway motor road
MR 1c: single carriageway motor road
AR 2c: dual carriageway rural arterial, barred to slow traffic
AR 1c: single carriageway rural arterial, barred to slow traffic
LR 2l: two-lane rural local road, accessible to all traffic
LR 1l: one-lane rural local road, accessible to all traffic

Inside the built up area
AU : urban arterial
LU : urban local road
WE : woonerf and street in 30-km/h zone.

Road type	Number of injury accidents per 100 million mv km	Number of fatalities per 100 million mv km
MW>4l	7	0.4
MW 4l	7	0.5
MR 2c	15	1.4
MR 1c	10	1.8
AR 2c	27	2.4
AR 1c	30	2.0
LR 2l	51	3.8
LR 1l	85	6.0
AU	133	2.5
LU	76	1.2
WE	20	0.3
Total road network	53	1.8

Table 3. *Road safety indices for 11 road types, 1986*

The motorway has now become quite easy to recognise internationally, thanks to the uniformity of the design guidelines.
The motor road as it occurs in the Netherlands is only accessible to motorised fast traffic and has no immediate connections to private property. However, the motor road may be a single carriageway and intersect with other roads directly (no grade separated intersections), lack a broad hard shoulder, have narrower lanes and include more bends than the motorway.
The rural arterial can again resemble the motor road, particularly if it bars any form of slow traffic; in other words, while this rule in any event applies to pedestrians, cyclists and moped riders, tractors are not permitted on this road either. This road can connect directly to private property, is generally less generously designed that the motor road and in most cases has parallel facilities intended to serve slow traffic and to enable access to adjoining destinations.

The road outside the built up area which permits all traffic can be broad, with two lanes, or narrow, with only one lane for both directions. In principle, such a road is used by all vehicles and by pedestrians. Inside the built up area, the arterials can be classified in a similar way to roads outside the built up area. This is already being done in the Netherlands, albeit that the road safety indices are still insufficiently reliable to allow differentiation between the various road types. This is mainly due to the marked variation in design associated with these road types. The same applies, to a lesser degree, to the road types found outside the built up area.

The data given in Table 3 offer an indication of road hazard for Dutch road types for the year 1986. This leads us to another point of criticism, the development of road safety indices.

Development of Road Safety Indices

We are familiar with the development of road hazard on the overall road network. For example, while we know the number of injury accidents and the number of fatalities respectively per vehicle kilometre travelled, we do not have information about the development of road hazard per road type. In fact, this information is more pertinent to policy-makers. From the sources available for the years 1980, 1986 and 1992, we have calculated a hazard measure and a user measure; see Table 4.

Road type	Number of injury accidents per 100 km road length			Number of motor vehicles per day in units of 100		
	1980	1986	1992	1980	1986	1992
Motorway	88	91	102	309	357	479
Rural road	23	21	19	16	16	19
Urban road	90	68	58	16	16	14
Total	53	44	39	21	23	26

Table 4. *Road safety and user indices for 1980, 1986 and 1992*

Using these indices, we can depict the three road types and the overall road network by means of a two-dimensional coordinate system; see Diagram 1. The x axis shows the number of motor vehicles per day and the y axis gives the number of injury accidents per kilometre road length - the accident density. In this way, the diagram offers information about the change in the number of injury accidents in the event of a change in the number of motor vehicles over time with reference to a standardised road length. In addition, the development in road safety can be read from the number of injury accidents per motor vehicle kilometre travelled - the risk is dependent on the variation in angle α, since the tangent of this angle shows the risk expressed through the relationship between the value on the y axis and the value on the x axis. For the overall road network (diagram 1), both the accident density and the risk figure drop over time, while the motor vehicle volume rises. The drops are more marked in the period 1980-1986 compared to the period 1986-1992, while the volume has risen more markedly during the second period.

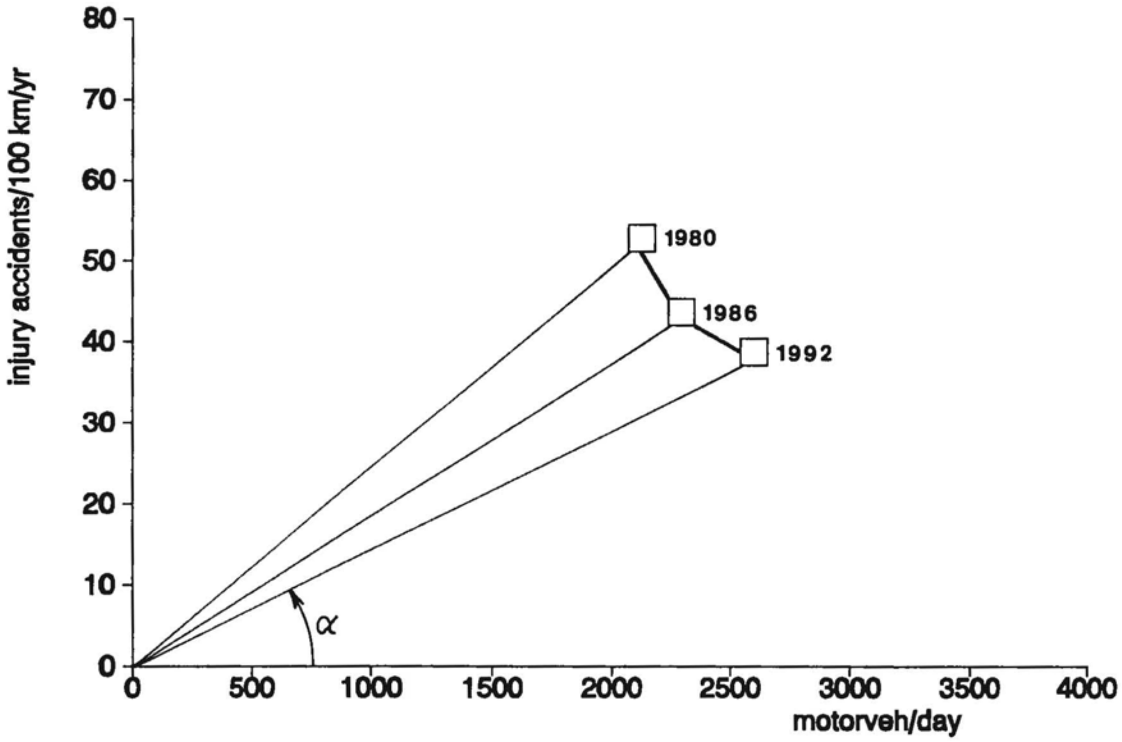

Diagram 1. *Road safety indices total road net for the Netherlands, 1980, 1986, 1992.*

When considering the three road types, it is noted that in the second period, the motor vehicle volumes have risen particularly outside the built up area, even reaching 34% on the motorway. Also, the accident density has risen by 12% on the motorway. Of course, lanes have been added and the actual risk has dropped.
If the data sources do not deceive us, the motor vehicle volume on roads inside the built up area has dropped in the second period. Perhaps this is a result of the efforts made in recent years to reroute through roads around the perimeter of small residential centres. The accident density has also dropped, but the risk has hardly changed. All these data offer many means of interpretation and task setting choices for road authorities.

Setting Tasks for Road Safety

In terms of setting tasks for future road networks, we can opt for an absolute drop in the accident or victim density and/or a drop in risk. Also, the increase in motor vehicle kilometres and/or road length could be restricted. For example, the Dutch ministry of Transport has set itself the task of limiting the growth in motorised traffic to 35% between 1986 and 2010. An unbridled growth would result in a 70% rise. By 1992, growth had already reached 20%. This is the result of over 6% more roads and a 13% increase in motor vehicle volume, on average.
In addition, the ministry is attempting to achieve a 40% reduction in road accident victims and to halve the number of traffic fatalities in the same period. This general task setting can be translated to specific tasks for each road type. Because the development in safety indices differs per road type, the tasks set per road type could also vary. The first task

noted is the functional reorganisation of the road network. In keeping with the objective of a sustainable-safe road traffic system, five road categories are distinguished:

- road type MW: the motorway;
- road type RD: the rural distributor;
- road type RA: the rural access road;
- road type UD: the urban distibutor;
- road type UA: the urban access road.

The definitions given reveal the functional categories into which the road types are classified. At present, the motorway is the most monofunctional in character, with the exception of peak times, when the rapid flow function is temporarily checked. Also, safety is threatened at this point due to stagnation in flow as a result of excessive traffic volume and unanticipated situations, such as sudden mist. The risk figure can be lowered through the use of sophisticated signalling systems.

Inside the built up area, a road with a flow function such as the motorway is not considered desirable.

The other road categories tend to have one dominant function, although these are often strongly mixed with other functions. In a sustainable-safe road traffic system, such a mixture of functions should become obsolete. Connecting roads should separate slow traffic from fast traffic and bar direct access to private properties. The speed of motorised traffic will have to be controlled, particularly at urban access roads and at the intersections of connecting roads.

The effects on the risk figure associated with the road type should be predictable for all these measures. As soon as the effects are known, they can be included in a new risk figure which can have a task setting function for the road category where the measure is to be applied on a large scale.

Even when the effects of measures are not known, safety standards can still be determined. For example, for the year 2010, we can calculate the risk figures for injury accidents by multiplying the 1992 figures with a reduction factor which corresponds with the change in risk over the period 1986-1992. This is equivalent to a task setting which prescribes that the drop in risk in the coming years should at least match the average drop over the preceding period. In the event the road lengths and the motor vehicle kilometres realise the same growth per road category as over the past period, then the number of injury accidents will drop by 28%. When, in addition, we include the recent developments in the number of casualties per injury accident and the number of fatalities per casualty statistic in the task setting, then the number of casualties will drop by 25% and the number of fatalities by 55%.

The task setting which currently applies to the Netherlands indicates that the 81% growth in the number of motor vehicle kilometres far exceeds the permitted growth of 35%. The number of casualties should be 40% lower and is therefore not dropping sufficiently rapidly. The task setting for the number of fatalities would have been achieved with the envisaged development. In order to achieve this result, we must set specific tasks for the accident risk associated with the five road categories. In view of the cited developments, the motorway should carry over 50% less risk and the other rural roads even 70% less. The development on urban roads is striking. Here, the risk would rise by 6%. The latter must be prevented! Based on the given assumptions, the risk for the overall road network in the Netherlands would drop by 60%, an average of 2.5% a year.

It is evident that we cannot simply impose safety standards on roads and intersections; we must actually work on the safety of the infrastructure.

This certainly applies to the urban roads. If safety on our roads can be properly quantified, then we are better able to recognise the - currently hidden - risks and remove their underlying cause. The road safety standards imposed on the individual road categories can in any case make a useful contribution. One precondition, however, is that the figures should be based on reliable sources. Monitoring road safety on roads also requires regular updating and detailing of the data obtained. Finally, we will have to make an extra effort to obtain at least the same reduction in the number of traffic fatalities and injuries as that which has been achieved over the last 12-year period. *So the lessons from the past will shaping the future.*

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