Influence of infrastructure and road's environment on road safety

Paper presented at the Traffic Safety Conference, Rynia, Poland, 26-28 October, 1994

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Fred Wegman
Leidschendam, 1994
SWOV Institute for Road Safety Research, The Netherlands

SWOV Institute for Road Safety Research
P.O. Box 170
2260 AD Leidschendam
The Netherlands
Telephone 31703209323
Telefax 31703201261

INFLUENCE OF INFRASTRUCTURE AND ROAD'S ENVIRONMENT ON ROAD SAFETY

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1. Causes of road accidents

It is seldom easy to assess a simple accident cause. Let me give an example. An 18 year old youth has just passed his driving test. One Saturday night he is driving his friends home from a disco. The teenager has recently bought a second-hand car. The way home takes him over a winding road beside a river. It is raining. The teenager misjudges a bend. The car drives into the river. Because the youths are not wearing seat belts, they are thrown out of the car and drown. The following morning a passer-by discovers the accident.

Cause? A young, inexperienced driver, not wearing a seat belt, driving at night in the rain along a road without a barrier, an unexpected sharp bend, bald tires? All of these factors could have contributed to the accident and to the outcome. Often a critical combination of circumstances is involved (OECD, 1984). Pointing to one single cause, finding one culprit for an accident does not do justice to the complex reality and - unnecessarily - limits the real opportunities to prevent accidents.

Human error is the underlying cause of almost all accidents. The estimates in this regard lead to the conclusion that with over 90% of accidents human errors in observation, decision making and response was involved. Often, and unfairly, the resultant conclusion is that road accidents can only be prevented through education, information and police enforcement. Such a conclusion is erroneous and researchers have warned often enough about drawing such a conclusion. Is it not the case that road improvements, for instance, are intended to prevent human error? Information about the 'single' cause of accidents does not logically lead to a conclusion about the most effective way of preventing accidents. It is also possible to draw erroneous conclusions if one relies on police reports in which the question of guilt is settled. One of the people involved in the accident has always violated the law in some way: traffic regulations are so strict. However, again, this does not say anything about the most effective or efficient way of preventing accidents.

It is advisable to use a so-called phase-model of the accident process when analysing road accidents and formulating countermeasures. Figure 1 shows an example of a simplified model.

There are many opportunities to intervene in this process. The earlier the intervention, the more structural, preventive and effective it will be. In the end the road users themselves will have to prevent accidents and behaviour always plays a part in this. Others, though, (road authorities, road safety organisations etc.) can influence circumstances such that the risk of human errors is reduced. Preventing accidents or lessening the seriousness of the outcome is not only the responsibility of the individual road user but also of collective decision makers (authorities, private organisations, industry etc.).

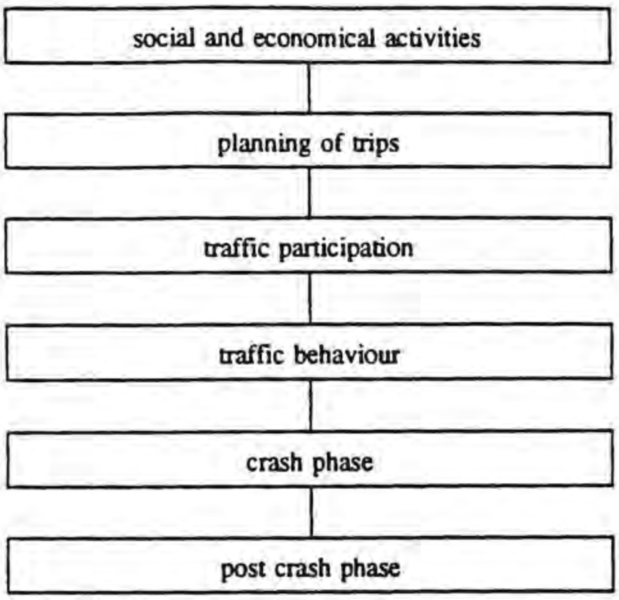


Figure 1. Phase model of the accident process.

Furthermore, people should realise that when it comes to decisions about road infrastructure and about the vehicles that use it, there are more arguments involved than road safety considerations alone: these include physical planning and land use policy, transport and traffic policy, environmental considerations, public health policy, etc (OECD, 1984). This means that road safety is just one of the criteria used in decisions of this kind. It very often happens that road safety is not considered to be the main objective, though decisions are made that may have consequences for road safety. Road safety is one facet of these other areas of policy. This may mean that, unfortunately, insufficient or no importance is attached to road safety, something that can happen consciously or unconsciously. One of the recent attempts to make road safety arguments as explicit as possible in the decision-making process is to undertake a Road Safety Impact Assessment: RIA (SWOV, 1994).

2. Road design to prevent human errors

Proper road design is crucial to prevent human errors in traffic and less human errors will result in less accidents. To prevent human errors *three safety principles* have to be applied in a *systematic and consistent manner* as much as possible:

- preventing unintended use of roads, i.e. use that is inappropriate to the function of that road;
- preventing large discrepancies in speed, direction and mass, thus reducing in advance the possibility of encounters with implicit risk;
- preventing uncertainty amongst road users, by enhancing the predictability of the road's course and of the behaviour of other road users.

The first safety principle: preventing unintended use of roads, calls for first establishing the intention of every road. Roads are built with one major function in mind: to enable people and goods to travel from one place to another. We call this traffic function. Within this traffic function a distinction can be made between the following aspects:

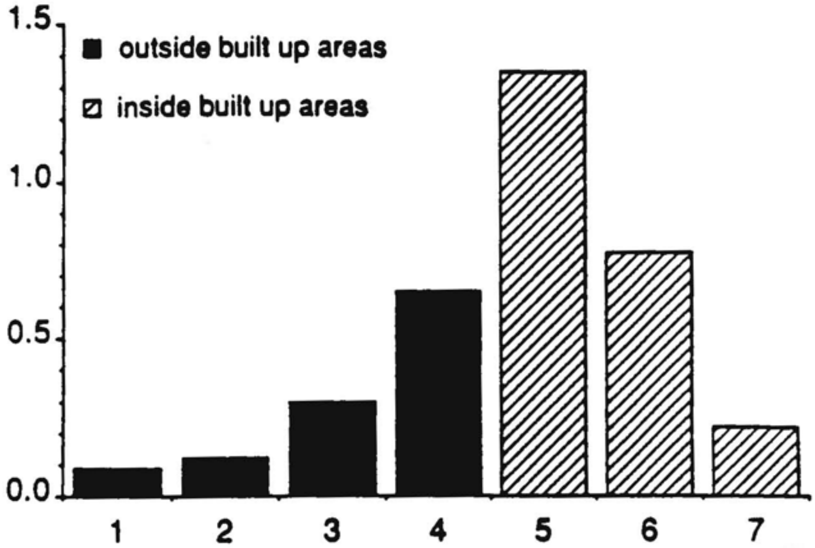
- the *flow function* enabling high speeds of long distance traffic and, many times, high volumes;
- the *distributor function*: serving districts and regions containing scattered destinations;

- the *access function* enabling direct access to properties along a road or street.

Beside a traffic function, streets and roads in built-up areas should allow people to stay in the vicinity of their house safely and comfortably for their social contacts or outdoor activities, should encourage children to play there etc. We call this function the *residential function.*

In the present situation, most roads are multifunctional, i.e. they perform a mixture of the different traffic functions and the residential function as well. But residential and traffic functions do not tolerate each other. And the different traffic functions can not be combined because different functions lead to contradictory design requirements.

The application of this philosophy is most successful on motorways and in special 'woonerven' or 30 km/h-zones. This is demonstrated by the fact that these types of roads and streets show a relatively low accident risk, while arterial roads inside the built up area and rural roads demonstrate a high risk (Figure 2). In general terms: high driving speeds, many inconsistencies, many differences in direction and speed, different types of road users occupying the same space explain the greater risk figures for these roads.



1. Motorway: 100-120 km/h
2. Motorroad: 100 km/h
3. Arterial rural road: 80 km/h
4. Local rural road: 80 km/h

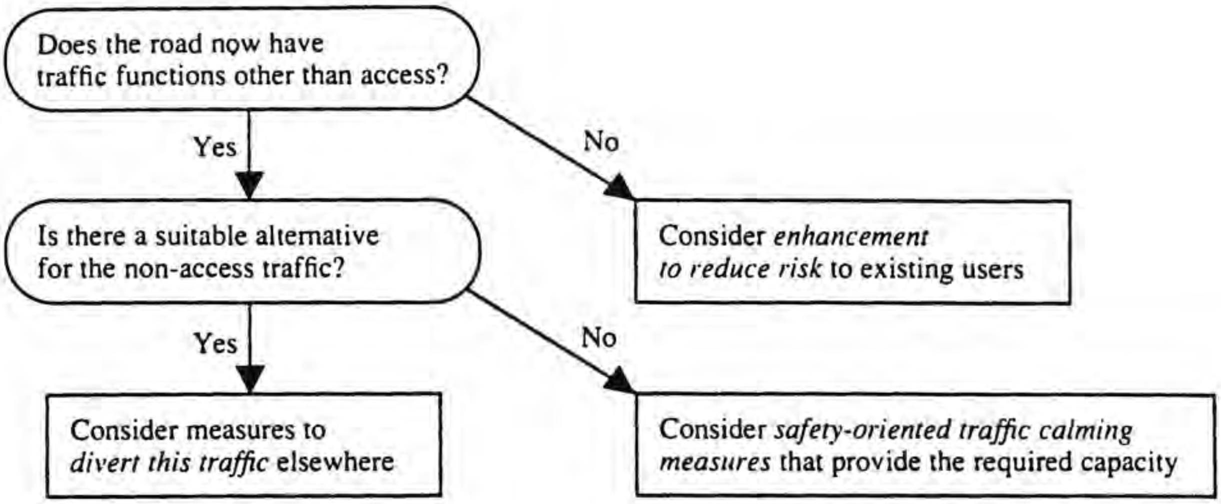
The most elementary classification for the built up area is subdivided into:

5. Arterial roads with a speed limit of 50 km/h (sometimes 70 km/h)
6. Residential streets with a speed limit of 50 km/h
7. "Woonerf" and residential street (approx. 8 km/h to 30 km/h)

Figure 2. Injury accidents in the Netherlands (1986) per million vehicle kilometres.

The function of a road should explicitly be defined in a traffic policy plan or in a plan dealing with land use planning or town planning (Brindle, 1984). Then, it is the task of the road designer to design according to the functional requirements. This design deals with road construction, with traffic engineering measures, road safety devices and, lastly, with traffic rules and regulations. To design new road lay-outs according to these principles is relatively simple. To translate these principles to existing situations is far more complicated. A scheme (Figure 3) from the Guidelines for Urban Safety Management (IHT, 1990) could be helpful in this.

Intended access roads



Intended main roads and local distributors

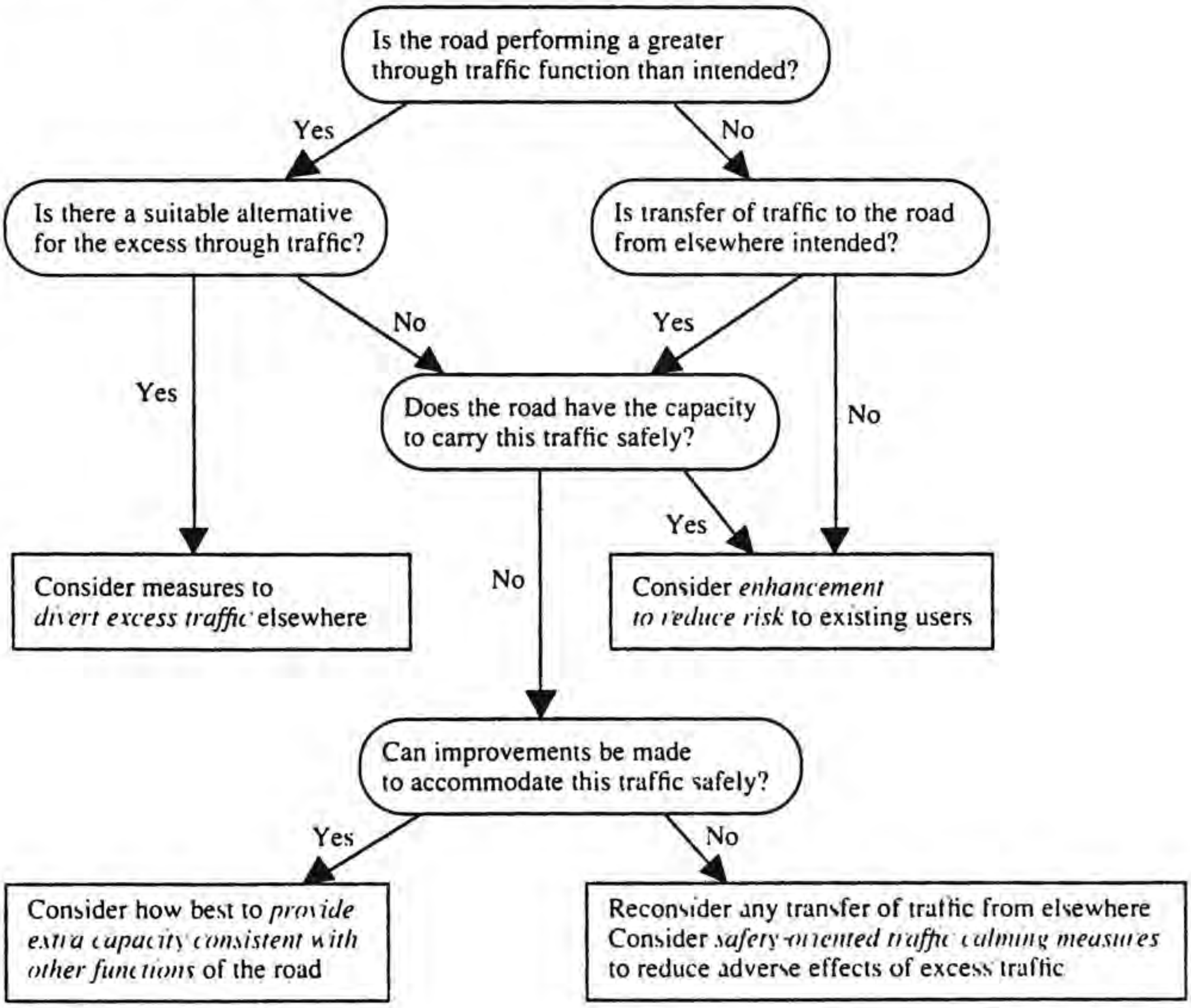
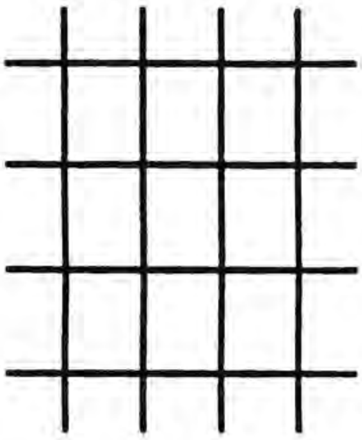


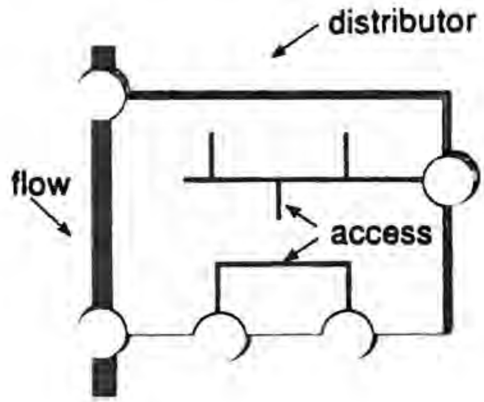
Figure 3. Assessment of possible changes in traffic function (source: IHT, 1990)

It turns out that *road classification* enables the roads to fulfil their various functions satisfactorily and solves the problems of contradictory design requirements of different functions. In Figure 4a and 4b two examples are given of road classification. A so-called *grid-system* (Figure 4a) could be considered as an unsafe system: all roads perform the same function, the same speeds are possible on all roads, safety devices are needed on all junctions, etc.. In Figure 4b a hierarchy of roads is depicted. By using this hierarchy many aspects of traffic can be directed, thus improving the quality of traffic flows, of safety, of the environment, of the amenity, etc.



- all roads: access/distributor/ flow function
- dangerous junctions

Figure 4a. Grid system



- development control
- no through traffic
- access control
- speed control
- junction design

Figure 4b. Road hierarchy

It is impossible to discuss all road categories in this paper. We limit ourselves to two interesting types of roads: rural/interurban roads and residential streets.

4. Rural roads

Using Dutch accident statistics four crash types produced 95% of all casualties on interurban/rural roads (Oei, 1993):

	%
- single vehicle/getting off the road/hit fixed object	32
- collisions with intersecting vehicles	24
- two vehicles/rear end collisions	20
- two vehicles/head on collisions/overtaking	19

There is no reason to believe that these figures should be substantially different in other European countries, but that could be verified of course. Characteristics of these accidents are rather well known, sometimes interacting, seldom one single cause and they could easily be derived from accident statistics: at night, on curves, involve alcohol, speeding, failure to yield, failure to obey traffic devices, age of involved drivers, etc.? Road safety professionals are trained to analyse accidents and to propose coutermeasures to combat these causes.

Different procedures could be used to carry out these road safety analyses (Catshoek & Slop, 1994): road safety inspection, black spot treatment and road safety impact assessment incl. road safety audits. Textbooks and handbooks are available how to come from problem analysis to countermeasures.

The rather traditional starting point of road design is design speed and correlated characteristics (stopping distances, friction coefficients, and sharpness of horizontal and vertical curvature, steepness of grades, width of lanes etc.). Based on these assumptions road alignment design and cross section design could be made.

But we have to admit that we still have to face two main problems talking about safety on rural roads. The first one relates to the fact that function of a road and road design are not attuned leading to human errors and higher accident risks (par. 2). The second problem deals with lack of knowledge: as traffic engineers we do not know exactly how and why the road user behaves like he does, and how we could change behaviour by proper design. From a road safety point of view it is useless, and even misleading, just to deal with 'a mean road user: male, white, job, 30 years of age'. Psychologists and engineers have to cooperate more to understand road user behaviour and to change it properly.

To illustrate this view an example is given of horizontal curves on two lane roads (Brenac, 1994). Statistical studies show high accident rates on horizontal curves (1.5 to 4 times higher). Furthermore, sharper horizontal curves tend to have higher rates than curves with high radii. But, the accident rates are only relatively high when the average curvature of the whole alignment is low. High accident rates are observed at a bend when it follws a long straight line. Moreover, some studies show that internal factors (depending on the design of the curve itself) also have important effects, especially at bends having a small or medium average radius of curvature: the main defect is irregularity of the curvature inside the bend. Results of behavioural studies indicate the scanning-pattern of the drivers, when they detect a bend and after that when they negotiate a bend. When for some reason an unsafe bend on an existing road could not be reconstructed (now) several measures are possible to reduce risks by signing and marking. More homogeneous rules through the different European countries are needed in this field.

So, safe design of curve geometry is more than deriving a right curvature from a design speed. This conventional concept is not sufficient. Introducing, in diverse forms, the expected actual speeds is positive but not sufficient. The introduction of *consistency rules* concerning the succession of the different elements of the horizontal alignment (radius of a curve following a straight line, compatibility of radii of two near curves) seems necessary from the safety point of view. We could expand this example to other design elements as well. *Consistency seems to be a key word in modern road design to create predictability and so to prevent human errors and accidents.*

5. Residential areas

A majority of road accident casualties inside built-up areas take place on traffic arteries, those streets or roads where traffic or flow function dominates. About 20 - 40% of the accidents has occurred in streets with a residential function. It is an exception rather than a rule to find black-spots in residential areas. Accidents are scattered over the entire area. This leads to the conclusion that an area-wide approach to solve road safety problems in residential areas is most appropriate.

Many children and older people, pedestrians and cyclists are casualties of road accidents in residential areas. These road user groups belong to the most intensive users of these areas. Older areas seem to be less save than new ones. No simple explanation can be found for this, but a combination of various factors play a part (more mixed functions of streets in older areas, more through traffic and parking problems, less space to play for children etc.

A literature study of Kraay & Wegman (1980) gives a survey of criteria, which have a positive or negative effect on road safety:
- Residential areas with closely built houses, old residential areas which are not very far from the town centre, display a relatively low road safety level. Areas with many shops and schools, with little playing space for children are relatively unsafe;
- In densely populated residential areas, with many young pedestrians in the streets, the road safety is relatively low.
- Undifferentiated road systems, a poor segregation of traffic categories, many cross-roads, long and narrow streets, involving complex traffic situations, have an unfavourable effect on road safety.
- Busy streets with relatively heavy traffic and many parked cars affect road safety negatively.

Studies from other European countries support these conclusions (Kjemtrup & Herrstedt, 1992).

In Dutch cities and villages, about 4000 residential areas were newly built or reconstructed and reclassified on the basis of this concept. Results of accident investigations indicate that the woonerf-concept lead to a reduction of approximately 50% in the number of accidents. The reduction in the number of injury accidents turned out to be even 70-90%. The woonerf was successful in improving amenity in residential areas and reducing accidents. Although some drawbacks could be notified as well: relatively high construction costs because of the additional engineering measures, the space needed for realisation and under high parking pressure conditions legal obligations could not be fully met. More simple and less costly options showed to perform at least as effective as the woonerf.

It was generally acknowledged that with regard to safety in residential areas two features are essential: reducing speed of traffic and reducing (through) traffic. From accident studies it turned out that the collision speed should remain below 30 km/h, because then the probability of serious injury will be minimal. From this finding it was deduced to set in residential areas the legal limit at 30 km/h. To guide Dutch municipalities to select effective speed-restricting measures a Handbook for 30 km/h measures was developed (Ministry of Transport, 1984). Over the years many municipalities have decided to implement 30 km/h-zones. Based on a recent survey we expect that in 300 out of almost 700 municipalities have realised 30 km/h-zones. From accident studies we concluded a reduction in injury-accidents of 22%. This relatively low reduction percentage (compared with maximum results achieved) can be explained by the low magnitude of existing problem in many redesigned areas and the lack of quality of implemented countermeasures. A careful design is most important.

Conclusions and recommendations

Road accidents usually occur as a result of a critical combination of circumstances and seldom have just one cause. There appears to be many opportunities for preventing human error that brings about road accidents (cf. the so-called phase model of the accident process). It is advisable to use this model when analysing road accidents and formulating countermeasures.

Proper road design is crucial to prevent human errors in traffic and less human errors will result in less accidents. To prevent human errors three safety principles have to be applied in a systematic and consistent manner as much as possible: preventing unintended use of roads, preventing large discrepancies in speed, direction and mass, preventing uncertainty amongst road users. Where these principles have been applied best (motorways and residential streets) low accident risks occur. In general terms: high driving speeds, many inconsistencies, many differences in direction and speed, different types of road users occupying the same space explain the greater risks for arterial roads in urban areas and for rural roads.

The function of a road should explicitly be defined in a traffic policy plan or in a plan dealing with land use planning or town planning. It turns out that road classification enables the roads to fulfil their various functions satisfactorily and solves the problem of contradictory design requirements of different functions.

To illustrate this design approach two examples are given: for rural roads and for residential areas. Consistency seems to be a key word in modern road design to create predictability and so to prevent human errors and accidents. Road design manuals and guidelines are recommended to be prepare and delivered to the designer. This offers the best possibility for safe designed roads and streets.

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