Urban traffic safety strategies in the Netherlands

A contribution to the international conference 'Living and walking in cities - Town planning and infrastructure project for safety in city life', 3-4 June 1994, University of Brescia, Italy

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1. Introduction

The increasingly dominant role of motorised traffic in urban areas poses a growing threat to vulnerable road users like pedestrians, particularly the elderly, children and handicapped among them. Moreover, it affects the quality of life also by restricting social and residential activities, as well as due to environmental pollution. On the other hand, transport and traffic are requirements, inherent to the urban society.
Hence, in urban areas a conflict of interests arises between the desired accessibility for motorised traffic and upholding the quality of life. In this conflict between the 'traffic' functions and the 'living' functions of the urban area, a well-balanced solution has to be found.

Since the 1970s, the Netherlands have tried to tackle this problem by adopting the principle that the urban area should functionally be divided into traffic areas and residential areas.
In the first, the flow and circulation of traffic remain the elementary function and safety is mainly sought for by segregation the incompatible traffic modes: the motorised traffic and the other - highly vulnerable - road users.
In the second, the intention is to focus on residential activities such as walking, shopping and playing, while access is only allowed to destination traffic. Here, the leading principle for ensuring safety is integrating the different traffic modes.

Starting from this principle, various types of solutions have been developed, and applied in practice. The effects of most of them on traffic safety have been evaluated by now. The experience contributes in evolving the new concept of a 'sustainable, safe traffic system' in urban areas.

After first having described the traffic safety problems inside residential areas, this paper presents the principles underlying a functional, safety oriented road categorization of the urban infrastructure. Then, various applications in practice will be discussed, as well as some results of evaluation studies on their safety impact. Finally, the concept of 'sustainable urban traffic safety' will be addressed.

2. Traffic safety problems inside residential areas, an outline

The Netherlands is a small country, which is densely populated: 15 million inhabitants, 350 inhabitants/km^2.

Dutch citizens own more than 5.7 million passenger cars, 12 million bicycles, almost 500,000 mopeds and 180,000 motorcycles. The total network is 103,000 kilometres of road, of which 47,500 km streets and roads inside built-up areas.

Since an all time peak in 1972 - almost 3,300 road deaths - the yearly number of fatalities reduced till less than 1,300 in 1992, despite the fact that, over the same period, the degree of mobility almost doubled. The number of traffic accident casualties per 100,000 inhabitants in the Netherlands is 8.5, which makes the Netherlands, together with countries such as the United Kingdom, Sweden and Norway, relatively safe. However, in recent years the annual number of road fatalities has ceased to drop sharply, and now seems to hover around some 1,300 fatalities a year.

Of the total number of fatalities plus hospitalised injuries in 1992, 54% (or 7003) occurred inside built-up areas.
Among these most serious casualties inside built-up areas, 32% (or 2233) concerned cyclists and 15% (or 1046) pedestrians.
A majority of traffic accident casualties inside built-up areas takes place on traffic arteries: those streets or roads where traffic or flow function dominates.
About 20-40% of the accidents occurs 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. Therefore, an area-wide approach to solve traffic safety problems in residential areas is most appropriate.

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

An early literature study of SWOV (Kraay & Mathijsen, 1980) gave already a survey of criteria, which have a positive or negative effect on traffic safety:
- Residential areas with closely built houses, old residential areas and areas which are not very far from the town centre, display a relatively low traffic 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 traffic safety is relatively low. Undifferentiated road systems, a poor segregation of traffic categories, long straight streets, involving complex traffic situations, much (through) traffic, have an unfavourable effect on traffic safety. Busy streets with relatively heavy traffic and many parked cars affect traffic safety negatively.
- On the other hand, the segregation of traffic categories, culs-de-sac with sufficient space at their end to turn a car around, and loop streets have an undoubtedly positive effect on traffic safety.

3. Functions of the road infrastructure

One of the main problems of the road transport system today is that roads and streets are expected to fulfil incompatible functions at the same time, where the road user generally has to guess what to expect from the road traffic situation, and is presumed to guess what others expect from him: a thousand times it goes smoothly, until the one time he makes an error.

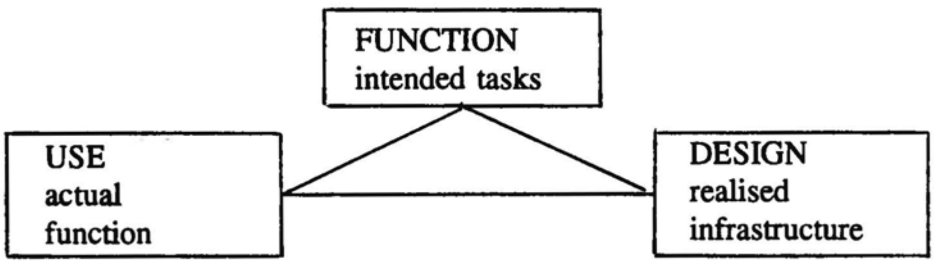
The principle for a safe infrastructure is that every road is appointed a specific function and is designed in such a way that the road or street in question meets the specific functional requirements as optimal as possible; most of all that it guarantees optimal safety.

The urban area is covered with a road network. On the one hand the network is intended for the transportation of people and goods, generally by means of vehicles. On the other hand, people live, work and spend their leisure time in its adjacent residential (and working) areas.
It is largely the speed options which imply hazards on this network and for the quality of life in the adjoining residential areas. Roads are indeed intended for driving on, but not all roads are constructed to allow fast driving. For example, some roads enable access to properties, other roads open up districts and towns, link up regions, and so on. Although vehicles are allowed to enter residential areas, their speed should not be excessive.

In the following, the function of the road network and its elements: the roads and streets, will be discussed, as well as the relation of that function to its design and actual use. Three functions of the road network will be distinguished.

3.1. *Function, design and use*

The function, or the purpose, of the road refers to the tasks to be fulfilled by that section of the road infrastructure. The function should explicitly be defined in the traffic policy plan of local (and higher) authority, usually as a result of the local policy and decision-making process (e.g. OECD, 1990).
Once the function has been stated, it is the task of the road designer to give 'shape' to the functional requirements. Hence, the design has to translate the requirements for traffic facilities into road constructions and traffic measures.
Lastly, traffic rules and regulations are necessary to enhance a proper use of those traffic facilities by the road users.
This relation between 'function', 'design' and 'use' is depicted in the triangle below:



The use or the actual functioning of the traffic facilities can be compared with the envisaged function. The difference between objective and reality might be measured through the signals received about undesirable traffic obstructions, accidents, noise pollution and other forms of traffic inadequacies.
Using a hierarchical classification of the road network, many aspects of traffic can be directed, thus improving the quality of the traffic in terms of flow, safety, comfort, the environment and cost.

Road users should have an understanding, conscious or otherwise, of the functional relationship between parts of the road network. Consequently, the function of the road and its surroundings will have to be communicated to them, as well as to the persons residing along that road.

3.2. *Residential functions*

In urban areas, roads and streets currently tend to have a more or less dominant residential function, in addition to a traffic function. Here activities take place like shopping, walking and playing, mostly as a consequence of buildings and other constructions close to the site. Accordingly, the residential or 'habitat' function can be associated with a prevailing presence of pedestrians.
Residential and traffic functions do not tolerate each other well. Only when the traffic function is very much subsidiary, it can be combined with a residential function. This notion is underlying the 'woonerf' and the 'pedestrian shopping zone' concepts. In other cases, each function needs its separate domain: driving lanes, cycle paths etc. for the traffic and pavements for the residents.

3.3. *Traffic functions*

Certain parts of the road infrastructure can be appointed to distinct traffic functions:
- the flow function: rapid processing of through traffic;
- the distributor function: rapid accessibility of residential areas, districts and other areas;
- the access function: accessibility of destinations along a street, while making a street as safe as a meeting place.

On flow roads, traffic should be able to circulate as efficiently as possible, with minimal disruption in particular at junctions. On distributor roads, emphasis is to be placed on the possibility of multiple exchange of traffic to and from other roads at intersections. On residential access roads, traffic to or from its final destination must be taken into account along the full length of that road.

When we divide roads into one of these categories, we must ensure that each classified road actually fulfils only that one function, thus avoiding that roads and streets accomplish several - incompatible - functions at the same time.
With the exception of motorways (suitable as flow roads), existing roads and streets tend to be unsuitable for fulfilling one of the three cited functions without any adaptation of their design. Design is seen here also in its broader sense, including traffic rules and regulations.

The three traffic functions will be elaborated below.

Flow function
The quality of traffic flow and circulation increases with greater continuity of the traffic stream and higher vehicle speeds (within stipulated limits, of course). At larger traffic volumes, the same quality can be reached by widening the road. Thus, appointing the flow function to a road is in principle independent on the traffic volume. Flow continuity and speed are benefitted by a steady flow: without traffic turning off, crossing or entering. Usually, the desired quality requirements for flow will be set at a higher level as the volume of 'through' traffic increases. A distinction between 'through' traffic and 'destination'

traffic on a stretch of road can easily be made in theory: through traffic does not have its origin nor its destination along that stretch of road.
The physical road characteristics which accentuate a flow function are recognized by the cross section (for example broad, dual carriageways), conflict-free crossings, by the design and by the longitudinal profile (for example, due to the lack of tight horizontal and vertical curves). The more dynamic characteristics of the flow function are determined by the traffic itself: for example, high and homogeneous speeds by motor vehicles only, driving in one direction without being hindered by intersecting traffic.

Distributor function
The distributor function is determined by the available means for access and for leaving the road. The quantity of 'distribution' increases as the number of discontinuities rises (intersections, connections and parking possibilities). Additionally, the distributor function increases when more use of the intersections etc. is envisaged. The distributor function will perform better if the vehicles on the road move at a lower speed.
Road characteristics indicating the distributor function, can be found at all intersections, connections and parking facilities along the road. The frequency and density of such connections determine in part the flexibility of distribution. Dynamic characteristics determine the distributor function as well. Speeds for instance vary markedly over the length of the road as a result of a relatively large number of vehicles intersecting, turning off, parking or moving on.
The design of the connections and the permitted volume of through and local traffic - the use - should be derived from the function, the envisaged task of the road.

Access function
The access function can indirectly be derived from the envisaged function of the area in the vicinity of that road. An important section of the public road, i.c. the pavement, serves to harbour people. People can also be found on the road itself, for example to reach the other side, get off a bus or alight from a parked vehicle.
The static characteristics of the access function are of course determined by the constructions and surroundings alongside the road. This environment is enormously diversified, due to the many different human activities. Recognizing the nature of these activities, despite the many variables, should not be a problem for the road user. However, the intensity of the activities is often wrongly assessed. In traffic, it is mainly the pedestrians - who are seen on the pavement and on the road - who, sometimes too late, make the access or residential function of the road recognizable.

4. Current practice in town planning and its effects

In the Netherlands, the principle of functionally dividing the urban area into traffic and residential areas has induced several 'real world' experiments, leading to numerous applications in practice.

With regard to residential areas, especially the 'woonerf' and the '30 km/h zone' has been adopted as measures to ensure traffic safety. Here, integration of incompatible traffic modes is the objective. These types of measures have been thoroughly evaluated in the meantime.
Segregation of such incompatible modes is also applied in residential areas. It mainly concerns the creation of a 'traffic free city/town centre' or a 'pedestrian shopping zone'

(often in combination with a 'traffic circulation plan'). In few cases the 'new town' type of solution is in use, for either a newly built town or urban district.

With respect to traffic areas, the attention was initially focused on the management of the motorised traffic inside the built-up area. It mostly gave rise to 'traffic circulation plans', at least regarding the major arterial roads of the municipality. Much attention was paid to separate bicycle paths alongside these roads, 'conflict-free' crossings and also to special bicycle routes, for bicycling is an important transport mode in the Netherlands and bicyclists belong to the most vulnerable road users.
In a more recent period, measures with regard to (the infrastructure of) residential, working and shopping areas were often incorporated in such plans. In that way, they evolved into 'area-wide plans' or 'city/town plans'. In this approach, safety and other objectives of local policies were finally integrated (OECD, 1990).
A contemporary development concerning a specific measure is the much wider use of a 'new style' roundabout, which turned out to have a favourable effect on traffic safety.

In the following, backgrounds and experiences on the subjects just mentioned will be discussed.

4.1. *Experiences with the 'woonerf'*

On a 'woonerf' the 'living' aspect, and as a consequence the interests of the vulnerable residents, is the governing principle. This concept received legal status in the Netherlands in 1976.
Motorised through traffic is discouraged. Only destination traffic is admitted, but this then has a second rate role with respect to the other road users. The permitted speed is described as walking pace (or approximately 5-8 km/h). No sidewalks for pedestrians are necessary and allowed. At junctions all traffic from the right has priority.
In other words, on a 'woonerf' the motorised traffic lost his predominant role and has to play now 'second fiddle' to the safety and well-being of cyclists, pedestrians, playing children, and so on.

In Dutch cities and villages, about 4,000 residential areas were newly built or reconstructed and reclassified on the basis of this concept.

The 'woonerf' led indeed to a substantial reduction in the number of injury accidents. It has been shown in the case of the so called 'demonstration projects' in Rijswijk and Eindhoven.
In 1977, two urban districts were selected in these municipalities, each covering an area of about 100 hectares. The measures used in reconstructing both districts were divided into three options. They vary from relatively cheap and simple to expensive and complex:
- Option 1: to reduce the volumes of motorised traffic (cars, motorcycles and mopeds) by directing traffic away from areas where it does not 'belong' (mainly through the introduction of one-way systems);
- Option 2: to reduce traffic and to restrict driving speeds of motorised traffic by redirecting of through traffic, together with speed controls for motorised traffic travelling to these areas (mainly by installing ramps);
- Option 3: to reduce traffic, to restrict driving speeds and create a pleasant 'habitat' by redirecting of through traffic, speed controls for motorised traffic and measures which make the environment more attractive (by redesigning it as a residential zone).

To assess the effects of the distinct options, two periods were compared: a six-year period prior to introduction and a five-year period in which the measures were fully effective. Control areas were selected to establish the impact of trends.

Some of the main outcomes of the study were, that in the distinct options the number of injury accidents had reduced at least 70% per year. An overall effect of 25% fewer casualties and of about 50% fewer accidents per year has been stated, when taken together the data of both the residential zones and the traffic zones of the two districts. The traffic safety problem has not been 'exported' to the surrounding area, in the contrary. The 'safety radiation' to the surroundings turned out to be positive. Interestingly, more simple options showed to perform at least as effective as the other ones. (Janssen, 1991).

However, there are also disadvantages associated with the approach. It concerns the legal design requirements, the additional engineering measures, the space needed for realisation and, last but not least, the high construction cost, especially in case a 'woonerf' has to be realised by adapting an existing residential area. Consequently, the application of the 'woonerf' often remained restricted to relatively small areas.

4.2. *Experiences with '30 km/h zones'*

It was generally acknowledged that with regard to traffic safety in residential areas two features were essential: reducing speed of motorised 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 a serious injury will be minimal. From this finding it was deduced to set in residential areas the legal limit at 30 km/h.
Since 1983, Dutch municipal authorities can institute a maximum speed of 30 km/h on roads or in zones within built-up areas.

So, in fact, the concept of the '30 km/h zone' has been deduced from the 'woonerf'-concept. It attempts to improve traffic safety and living quality in areas which predominantly serve as a residential function. However, it seeks to offer safety to a wider residential area at far less cost, thus avoiding the major drawbacks of the 'woonerf'-approach.

Over the years many municipalities have decided to implement '30 km/h zones'. Based on a recent survey we expect that 300 out of almost 700 municipalities have realised one or more '30 km/h zone'.

The concept has been developed over these years. Design elements have been conceptualised, undergone further refinement and have been applied to various locations. Speed-restricting engineering measures represent an essential element in the reorganisation of residential areas, where a speed limit of approx '30 km/h' is intended. The following objectives were aimed for:
- to lower the speed of motorised traffic;
- to discourage through traffic;
- to improve traffic safety, both in terms of accident reduction and diminishing the threat posed by traffic;
- to reduce traffic nuisance, such as parking congestion, noise and other pollution;
- to promote the mobility of cyclists and pedestrians.

To guide Dutch municipalities to select effective speed restricting measures a 'Handbook for 30 km/h measures' was developed. Nowadays these measures can be found in a publication called the ASVV-Recommendations for urban traffic engineering.

In an evaluation of the effects of '30 km/h zones', changes in traffic flows, opinions of residents, conflicts, and accidents were extensively studied in 15 cases (Vis & Dijkstra, 1992).
Recently, the effect on the number of injury accidents was studied in 151 of such '30 km/h zones' (Vis & Kaal, 1994). In order to enable correction of effects which were not associated with the realised measure, all injury accidents inside the built-up area were collected for the same municipalities over similar periods (control areas).
Following correction based on the trend shown in the control areas, it was determined that the number of injury accidents had dropped by 22% (± 13%).
It has been shown as well, that these areas tend to carry a lower volume of motorised (through) traffic, while the number of cars taking shortcuts through these zones has also diminished to a significant degree.

It is obvious that the safety effect demonstrates a large variation. Probably this has to do with the magnitude of the traffic safety problems in the before period and the quality of the measures taken. Taking into consideration the (average) results, however, the measure can certainly be considered as very successful. Comparisons of the effect on accidents of 'woonerfs' and '30 km/h zones' learned that their effectiveness is about the same. Intensive stimulation to foster implementation of '30 km/h zones' on a broader scale, particularly for existing residential areas, is therefore recommended. At the same time, it is advisable to check if the quality of the different applied countermeasures are functioning as planned and if this is not the case to find out why, in order to avoid this in the future.

4.3. *Experiences with 'area-wide' or 'city/town' plans*

A road accident can be considered being the product of a process: the transport and traffic (safety) process, as specified in the so called Phase-Model (OECD, 1984). The model clarifies that transport and traffic is generated by social activities and its resulting economical needs. In order to accomplish the forthcoming travel necessities, one has to determine the purpose of travel, the travel mode, the route and time-table. At the time of the trip to some destination, the lateral position on the road, the speed, etc. have to be chosen and, during encounters with other road users, one has to adapt those variables, thus avoiding traffic incidents and accidents.

In short, the model explains the distinct phases which - even prior to traffic participation - predispose circumstances finally causing accidents on the road. Hence, circumstances which have to be prevented for the sake of traffic safety.
In order to do so, traffic safety policies have to address other fields of local policies like town planning, transport and traffic management, enforcement, education and information, rescue services, etc. In that way, traffic safety might constitute an integrated part of local policies, whether being embedded in those policies or being a priority issue to these (OECD 1990).

The approach of integrated traffic safety management for the whole territory of a town or city has been adopted and developed by several municipalities from the mid 1970s. Maastricht, a town with a population of about 120,000 inhabitants, provides an example of

such a municipality preparing a traffic safety plan on its own initiative. In 1976 already, its traffic department made the first long term plan for a 'livable' town, in which residential and traffic areas were defined and considered separately for traffic safety treatment. It resulted in a set of extensive measures for the reconstruction of residential areas, for the design and structure of arteries, secondary roads, cycle tracks and school trip routes and for education and enforcement.
Another example is Groningen, a town with a population of about 170,000 inhabitants. It closed, for instance, its entire town centre for all motorised traffic, except some forms of public transport, thus coping with the burden of international heavy traffic.

Area-wide traffic safety plans were promoted among the municipalities by the Dutch Government, making it a requirement for participating in an incentive program, the so called 'minus 25% action'. An action with the objective to accomplish 25% fewer accidents in the year 2000 compared to the number in 1985 (see also Ch. 5). In such plans, traffic safety goals and policy tasks, the financial and other investments, etc. have to be clearly stated.
As a result, virtually all municipalities have at the moment a traffic safety plan at their disposal.

4.4. *Experiences with the 'new style' roundabout*

A 'new style' roundabout is understood to mean a more ore less circular plaza with a central area which cannot be traversed, and at least three connecting roads, where all traffic on the roundabout may only drive in a prescribed direction (in the Netherlands anticlockwise). They tend to be small plazas with a single lane both circling the centre and on the access and exit roads. This ensures speed is limited, without excessively restricting manoeuvring potential. The most important characteristic of the 'modern' roundabout is that - in contrast to the traditional roundabout - approaching traffic must give way to traffic on the roundabout.

The first accident study into these 'new style' roundabouts (van Minnen, 1990) related to 46 roundabouts. Then it was already found that they were considerably safer than intersections. Compared to traditional intersections, whether or not subject to priority rule, a reduction of about 50% in the number of accidents was demonstrated. The number of road accident victims was reduced by more than 75%.
Although emphasis was placed on traffic safety, the study also considered the effects on traffic flow. Despite their limited dimensions, the capacity of roundabouts, with no more than a single lane on the connecting roads and on the plaza itself, proved to be relatively high.

Since about 300 roundabouts have been built in the meantime, a second study into the safety aspects has been carried out (Schoon & van Minnen, 1994). This study selected 201 roundabouts which were put into service prior to January 1, 1991. Two main subjects were investigated:
- The safety level after conversion of an intersection to a roundabout.
- The differences in safety between various roundabout designs.

The latter point devoted particular attention to the three possible engineering facilities catering to cyclists and moped riders: separate cycle paths, bicycle tracks on the roundabout or no specific bicycle facility.

It was established that substitution of an intersection by a roundabout has a particularly favourable effect on traffic safety: a reduction of 47% in the number of accidents and 71% in the number of victims (after trend correction).
The various categories of road users did not all profit to the same degree. The largest reduction in road accident victims was noted amongst occupants of passenger cars and pedestrians: 95% and 89% respectively. The reduction among cyclists scored 30%.
The improvement in safety proved to be partly attributable to the change in the traffic situation, which made certain conflicts impossible (such as head-on collisions), while pedestrian crossings were also simplified. But to a significant extent, the gain in safety was also due to the drop in speed by motorised traffic.

With regard to the distinguished engineering facilities provided for cycles, no major difference in accident statistics could be demonstrated. Based on the registered number of casualties, however, it was determined that a daily traffic intensity of over 8,000 motor vehicles, a separate cycle path clearly scores more favourably than both other types of engineering facilities for cycles. At lower car and cycle intensities, it was not possible to indicate which of the three types was preferable for cyclists. Therefore, it is recommended to base selection on the design of the connecting roads.

5. Towards sustainable urban traffic safety

In 1987 the Dutch Government launched a 'Long Term Plan for Traffic Safety'. The plan formulated a concrete task for policy: 25% fewer road accidents in the year 2000 with respect to the number in 1985 (1385). A plan drafted by the Dutch Government, in which the desired mobility developments in the future and the investment in the infrastructure are outlined (SVV-II, 1990), also includes the targets for the year 2010: 50% fewer fatalities and 40% fewer hospital admissions resulting from traffic accidents.
However, in recent years the annual number of road fatalities has ceased to drop as sharply as during the period 1972-1992, as mentioned already. Then a reduction of more than 60% was achieved. In the SVV-II plan a controlled growth in mobility of 35% was considered acceptable. Therefore, meeting these safety objectives implies a greater challenge to policy.

The SWOV Institute for Road Safety Research, in close cooperation with a number of other research institutes, was asked by the Dutch Government to develop a scientifically supported, long term concept of a considerably safer road system.

Inspired by the concept of 'sustainable development' as recommended by the UN Brundtland Commission in 'Our common future', a new vision on traffic safety measures is being developed: the concept of 'sustainable safety'.

Starting point of the concept is, that we should try to drastically reduce the probability of accidents in advance, by means of the infrastructural design. And where accidents still occur, the process which determines the severity of these accidents should be influenced such that serious injury is virtually excluded.
Another essential element of the concept is the principle that man is the reference standard. Hence, a sustainable, safe traffic system has an infrastructure that is adapted to the limitations of human capacity through proper design, vehicles fitted with ways to simplify the tasks of man and constructed to protect the vulnerable human being as effectively

as possible, and a road user who is adequately educated, informed and, where necessary, controlled.
Moreover, the concept adopts the approach of neatly appointing a specific function to every road or street in the way discussed in Chapter 3, thus avoiding improper use of the road infrastructure.

The key to arrive at a sustainable, safe lies in the systematic and consistent application of three safety principles:

- prevent unintended use, i.e. use that is inappropriate to the function of that road or street;
- prevent large discrepancies in speed, direction and mass at moderate and high speeds, i.e. reduce the possibility of serious conflicts in advance;
- prevent uncertainty amongst road users, i.e. enhance the predictability of the course of the road or street and people's behaviour on the road or street.

Within this interpretation, the concept of a sustainable, safe traffic system is not something futuristic, not a completely overhauled road transport system, but nevertheless, a system that does differ considerably from the current one.

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