

Sustainable Safety in the Netherlands: the vision, the implementation and the safety effects

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Contribution to the 3rd International Symposium on Highway Geometric Design, 26 June - 2 July 2005, Chicago, Illinois

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Summary

Human errors play a vital role in road crashes. This paper deals with the prevention of human errors by proper road planning, road design and improving existing roads within the framework of the Dutch 'Sustainable Safety' vision. This vision focuses on three design principles for road networks and for roads and streets: functionality, homogeneity, and predictability. A minimum safety level should be defined and agreed upon by all road authorities, national, regional, and local. Implementing this vision has the ambition to result in a considerable reduction of the number of crashes and casualties, and keep the Netherlands as one of the countries in the world with the best road safety records.

This vision was launched at the beginning of the 1990s and accepted as a formal part of Dutch policies in the mid 1990s. This resulted in a so-called Start-up Programme on Sustainable Safety, not only addressing the planning and design of road infrastructure, but also strongly emphasizing this. The contents of the Start-up Programme will be described as the process leading to implementation. An overview will be given of implementation of different (road infrastructure) components of the Start-up Programme and the measured effects on road crashes. Attention will be paid to functional road classification, expansion of 30km/h zones and 60km/h zones, safety of mopeds and cyclists, and large-scale introduction of roundabouts, etc. Evaluation studies suggest a positive effect on the number of crashes and casualties in the Netherlands, leading to about 6% reduction in the number of fatalities and in-patients. The lessons learned will be used in defining the next phase.

The Start-up Programme has been used to draft new guidelines and recommendations for road planning and road design. An introduction of this will be given, including some ideas on new road designs. Finally, some thoughts will be given to the next phase: how to proceed under circumstances where less public funds will become available. Integration with other policy sectors is suggested.

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1. Introduction

Early in the 1990s, SWOV Institute for Road Safety Research was asked how road traffic in the Netherlands could be made considerably safer: not 1000 deaths a year, but no more than 100 a year. Two approaches were explored. The first was to achieve a considerable improvement by intensifying current improvement activities. The second approach was that such a considerable improvement could be achieved by adopting the vision that safety should be a design principle for the road traffic system (as it is for other transport modes). In the end, the conclusion was that the first approach could lead to further improvements, but that additional ideas would be necessary to make the road traffic considerably safer. We called this a paradigm shift. This originally led to the idea of an 'inherently safe road traffic' (derived from energy production and consumption). In order to obtain sufficient political and public support, the vision was renamed 'Sustainable Safety'.

The Sustainable Safety vision is based on two leading ideas: how to prevent human errors as far as possible, and how to ensure that the crash conditions are such that the human tolerance is not exceeded and severe injury is practically excluded. The starting point of 'Sustainable Safety' was to drastically reduce the probability of crashes in advance through safety conscious planning and design. Where traffic crashes still occur, the process that determines the severity of these crashes should be influenced, so that serious injury is virtually excluded. Within Sustainable Safety, man is the reference standard (human error and human tolerance). A sustainably safe traffic system has an infrastructure that is adapted to the capabilities and limitations of humans through proper planning and road design, has vehicles that are equipped to simplify the driving task and offer protection to the vulnerable human being (crash protection), and finally, has road users that are properly educated and informed, and whose driving behaviour is regularly controlled. The key-issue of 'Sustainable Safety' is that it has a preventative rather than a curative (reactive) nature.

The term 'Sustainable Safety' has been a vision in the Netherlands since 1992 (Koornstra et al., 1992). During the 1990s, a lot of research was carried out on how the vision should and could be translated into the design of all components of the Dutch road traffic system. The main requirements for a sustainably safe road infrastructure are described. A subsequent step was to include these requirements in existing design standards and guidelines. Major steps have been taken to do so.

Right from the beginning it was clear that adapting the existing road infrastructure to these requirements were very ambitious. This resulted in defining two implementation phases. The first phase was called the 'Start-up Programme'. This Programme comprised 24 actions that were agreed upon (mandated) by all tiers of government. A short description of the Start-up Programme is given, specifically the infrastructure related activities. This Programme was implemented in the period 1997-2002. The first evaluation results are presented.

The next phase/steps are not fully developed and established yet, but have to fit in prevailing policy circumstances in the Netherlands. The report closes with conclusions and recommendations.

2. Sustainable Safety: the vision

The aim of Sustainable Safety is not to burden future generations with the consequences of road traffic crashes resulting from today's and future mobility demands. The means are available to substantially reduce the costly and largely avoidable road casualty problem. From this perspective, it was chosen to 'borrow' from the well-known Brundtland-report on sustainable development, the adjective sustainable for road safety as well: no longer do we want to hand over a road traffic system to the next generation in which we tolerate that road transport inevitably leads to thousands of deaths and injuries in the Netherlands, every year. Within Sustainable Safety, man is the measure of all things. With this is meant that the traffic, the road environment and rules (the traffic and transport system) must be adapted to the limitations of human capacity. In a sustainably safe road traffic system, everything is aimed at preventing crashes. However, if a crash is unavoidable, the severity of the crash must be minimized. Therefore the infrastructure must be adapted to the capabilities and limitations of humans, vehicles must be equipped to simplify the driving task and offer protection to occupants, and finally, road users must be properly instructed and informed, and their driving behaviour must be regularly controlled.

The key to arriving at a sustainably safe traffic system lies in the systematic and consistent application of three safety principles:

- functionality
- homogeneity
- predictability

The functionality of the road system is important in that actual use matches with intended use, as designed by road authorities. This produces a road network with three categories: through-roads, distributor roads, and access roads (*Figure 2.1*). Each road or street may only have one function (e.g. a distributor road may not give direct access to houses, shops, or offices). The homogeneity of the road system is meant to avoid significant differences in speeds, driving directions, and mass (preferably by segregating incompatible traffic types, and if this is not possible or desirable, by forcing motorized traffic to drive slowly). Finally, for a sustainably safe road system, it is of utmost importance that road users are familiar with the behaviour demanded by different road types, and what they may expect from other road users. To enable this the infrastructure should be recognisable to the road user thereby enhancing the predictability of the system as a whole (see *Figure 2.1*).

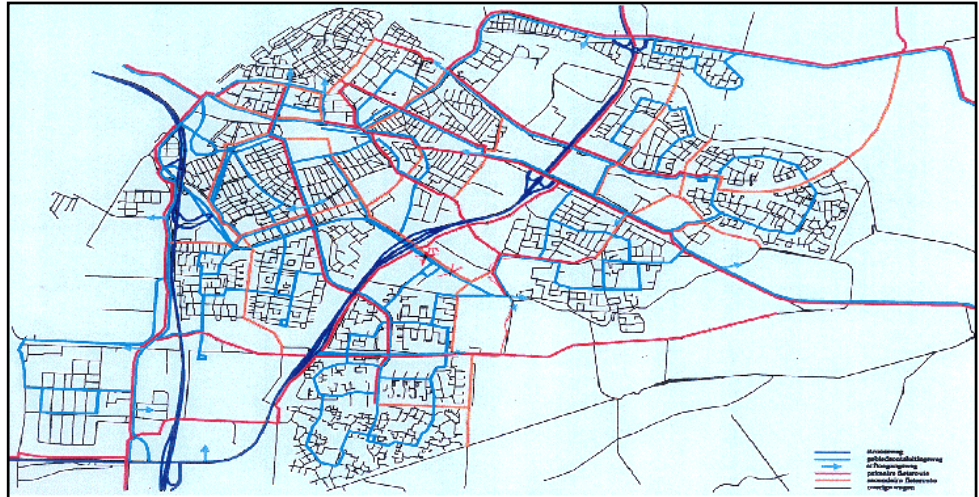


Figure 2.1. *Categorised road network according to Sustainable Safety.*

As stated before, the road user as the reference standard represents the central element in a sustainably safe traffic system. He/she must be prepared to accept an infrastructure (vehicles, rules of behaviour, and information and control systems, which may restrict his/her personal freedom) in return for a higher level of safety. If this willingness is not present, resistance will be the result. Sound arguments motivating why this freedom is restricted are essential and if these do not exist then freedom should be not restricted. Social marketing techniques could be used.

Education could and should play an important role in the transition period from the traffic system of today to a sustainably safe system. Education could concentrate on the reasons and needs for Sustainable Safety. Public awareness, public participation, and education should create support for implementation and find their place alongside implementation of other elements of this vision. Without any doubt we shall need to teach and to motivate people to use the system safely and to deter undesirable and dangerous behaviour by organizing an effective 'deterrent chain' (police enforcement and punishment), especially during the transition period.

With respect to vehicles, their diversity should be kept to a minimum. Furthermore, the various types should be clearly distinguished. When used in the same physical space, vehicles should demonstrate the same behaviour – in all respects – or otherwise be provided with separate road facilities (homogeneity principle). In the sphere of passive Sustainable Safety provisions, lie those that work independently of the driver or passenger: 'built-in' devices like solid passenger compartments of cars with crush areas and airbags (in addition to the compulsory use of seat belts). Improvements to the front-end design of passenger cars can reduce injuries to vulnerable road users like pedestrians and cyclists. In the field of active safety a lot of progress may be expected from devices that provide relevant information to the road users, improve their observation, or simplify their tasks.

An interesting development is the so-called Intelligent Speed Adaptation (ISA). Two real problems have to be solved here: gaining public acceptance and support, and developing an introduction strategy.

3. Main requirements of a sustainably safe road infrastructure

3.1. Functional requirements

A sustainably safe road infrastructure has to be planned and designed following the three principles: functional use, homogeneous use and predictable use. These principles have been translated into twelve functional requirements (CROW, 1997). These requirements, subdivided by type, are summarized in *Table 3.1*.

	Functional requirement	Type
1	largest possible areas with traffic calming (both in rural and in urban area);	General
2	a maximal part of the journey using relatively safe roads and routes;	Functionality
3	journeys must be as short as possible;	
4	the quickest and shortest routes must coincide;	
5	avoid the necessity to search for directions/destination;	Predictability/ recognition
6	easily recognizable road categories;	
7	limit and make uniform the number of possible types of design;	
8	avoid encountering oncoming traffic;	Homogeneity
9	avoid encountering traffic crossing the road being used;	
10	separate types of traffic;	
11	reduce speed at potential points of conflict;	
12	avoid obstacles near the carriageway.	

Table 3.1. *Functional requirements/demands (CROW, 1997).*

Each road network has to fulfil three fundamental functions to allow each road user to:

- be able to go from origin to destination (flow function);
- be able to enter and leave an area with scattered destinations (area distributor function);
- be able to access properties alongside a road or street (access function).

Roads and streets, generally speaking, fulfil more than one function. This combination of functions results in higher risks. That is why, in a sustainably safe road network, each road should only have one function. Together, these three functions form a road network that (greatly simplified) looks like that depicted in Figure 1. The sections of these roads do have a different purpose than the intersections. Intersections are for traffic exchange (allowing changes in direction etc.) whilst road sections facilitate traffic in flowing. Exceptions to this are the road links of access roads where traffic modes are not separated, speeds are low, and all types of road users share the roadway. Main roads with a flow function (motorways or freeways) do not have intersections, but are fully grade separated so that traffic only flows (see *Table 3.2*).

	Road elements	
Road type	Road section	Junction/interchange
Through road	<i>Flow</i>	<i>Flow</i>
Distributor road	<i>Flow</i>	<i>Exchange</i>
Access road	<i>Exchange</i>	<i>Exchange</i>

Table 3.2. *Purpose of road sections and intersections on different road types (CROW, 1997).*

3.1.1. *Recognizable and predictable traffic situations*

For a sustainably safe traffic system, it is of great importance that road users understand the road's course, the behaviour that is required on the various road types, and what they can expect from other road users. Optimizing the physical characteristics of the different road categories to make them distinctly different from each other should support this ambition. In the operational requirements of CROW (1997), four road features are included that are especially meant to realize this third principle. These road features are:

- marking in the longitudinal direction;
- directional separation;
- presence of breakdown facilities;
- specific intersection types within a road category.

These road features were derived from research by SWOV and TNO Human Factors (Gundy, 1994, 1995; Gundy et al., 1997; Kaptein & Theeuwes, 1996). This project is ongoing and definite conclusions cannot as yet be drawn about the precise influence of the various implementation forms of these road features on the perception and behaviour of the road user. Many of the new features have been conceptualized but not yet physically realized. For the design of a sustainably safe road environment, it would be more interesting to know what the influence of new road features is, and if these need to be adapted to achieve an optimal road environment. The influence on the recognizability of the rest of the surroundings (i.e. not road features themselves) is also of importance.

Research using a driving simulator, or implementing these features in experimental, adapted networks, is recommended and needed to gain better insights into these effects before large scale implementation is introduced. Experiments in the real world are carried out with new road features, such as the ongoing experiments (Schermers, 2002) with the dual carriageway 80km/h distributor roads with one lane per direction.

3.2. **Operational requirements: geometry and design requirements**

The general (functional) requirements of a sustainably safe road infrastructure have been supplemented with requirements for road sections and intersections of the different road categories or types. These supplementary requirements (also known as operational requirements) form the link between the exact road form and the functional requirements. For example, an operational requirement on 80km/h rural distributor roads is that

the directional separation must be difficult to drive over. To achieve this one can introduce a low concrete median separation in the form of a longitudinal ridge or, alternatively place flexible bollards at regular intervals along the centre line. The requirements for intersections are less detailed and will be useful only when the geometric requirements become available.

3.2.1. Geometry of sustainably safe road types

The geometry of sustainably safe road categories has not yet been finalized. In the interim the CROW has published three documents that provide guidance. For urban roads (*Table 3.3*) only simple measures are proposed (Infopunt DV, 1998). The CROW working party 'Sustainably safe criteria for urban roads' made recommendations for designing distributor roads and access roads within residential areas (Infopunt DV, 2000). Guidelines for the geometric design of rural roads have also been developed (CROW, 2002 a-c). In addition, a guideline outlining the essential physical characteristics of roads and based on the principles of Sustainable Safety has been proposed (CROW, 2004). Once implemented these should make the difference between the different road categories clearer to road users (see *Table 3.3*).

Requirement	Distributor (road)	Access road
Marking (longitudinal)	fully (but different from through-roads)	no
Physical separation of directions (number of lanes in one direction)	yes (1 or more)	no (only 1)
Pavement, surface irregularity	minor	major
Obstacle-free zone	medium	(very) small
Directional signing	(to be decided)	(to be decided)
Lighting	(to be decided)	(to be decided)
Speed limit (km/h)	50 or 70	30 or less
Type of physical separation	difficult to cross	n.a.
Emergency facility	hard shoulder or lay-by	no
Private or business accesses	no	yes
Crossing (mid-block / between junctions)	grade separated or install a quasi-junction	at grade
Parking	parking lane	carriageway
Public transport: stops	bus bay	carriageway
Cyclists on the carriageway	no	yes
Moped-riders on the carriageway	yes	yes
Slow-moving motorized vehicles (e.g. agricultural vehicles)	yes	yes
Speed-reducing facilities (e.g. humps)	occasionally	yes

Table 3.3. Example of operational requirements for road sections of sustainably safe road types in urban areas (derived from CROW, 1997 and Infopunt, 1998).

The design of (urban) access roads is well described by the Information Centre (Infopunt DV, 1998).

In urban areas there are currently two types of distributor roads, the 70km/h arterial and the 50km/h arterial. The 70km/h road has separate carriageways, broken white edge lines, no pavements or parking facilities directly adjacent to the carriageway and pedestrians, mopeds and cyclists are not allowed except to cross at designated intersections.

An ideal 50km/h road has directional separation with a double continuous centre line marking, broken edge line marking, and pedestrians and cyclists are not allowed to use the roadway except to cross at designated intersections.

In urban areas cycle lanes (i.e. on the main roadway) are not used on urban main roads. Cycle paths (generally separated from the main roadway) are widely used and have a minimal width of 1.5 metres. Parking spaces are never provided next to a cycle path, and are only permitted on the left-hand side of cycle lanes.

Ideally, no direct accesses to properties are allowed from the carriageway of distributor roads. Where this is unavoidable, only turning right is permitted (for traffic to and from the access road). To facilitate safe crossing of pedestrians and cyclists, intersections are provided with measures that reduce speeds to below 30km/h or alternatively provide separation in time (signals). No speed reducing measures are allowed on road sections but are permitted on the approaches of intersections. At locations where a main road crosses a residential access road, motorised traffic should only be allowed to turn right. If left-turning traffic from the distributor road is unavoidable, a left turn lane with a minimum width of 2.5 metres should be provided.

The operational requirements for rural roads are summarized in *Table 3.4*. The surfaced width of (rural) access roads may vary between 2.5 and 7.5 metres. No centre line marking is provided and the lane edges are marked with a broken white line. The effective lane width (between the broken edge line markings) is between 2.5 and 3.5 metres and this is reserved for motorized traffic in both directions. On wider cross-sections, the space between the road edge and the broken lane edge line is used as a cycle lane, whereas on very narrow cross-sections, the shoulders are hardened with some form of grass-penetrable paving blocks. Junctions between access roads and distributor roads can be shaped like a roundabout or as traditional T-junctions or crossroads. Plateaus are often used and these are placed on the access road, 100 metres before and 100 metres after the intersection. The intersection of two access roads has a raised plateau. The obstacle distance (clear roadside area) on rural access roads is 4.0 metres.

Two types of (rural) distributor roads are distinguished. Type I is the regional motorway, a dual carriageway road with 2 lanes in each direction and generally with a speed limit of 100km/h. This type is only permitted in exceptional situations (e.g. where there is no national alternative and capacity is inadequate). Type II distributor roads are the preferred option and these are either dual carriageway with one lane per direction and 100km/h or single carriageway with one lane per direction and 80km/h speed limits.

The edge marking of rural distributor roads consists of a broken white line. On the single carriageway alternative the directional separation can be a double centre-line marking with or without some form of vertical element to enforce the overtaking restriction.

Intersections of distributor roads are preferably roundabouts or alternatively traditional priority or signal controlled T-junctions or crossroads. In some instances plateaus are introduced on the approaches of the intersection. Junctions between distributor roads and main roads have the shape of a diamond interchange or a partial cloverleaf. Crossings of a distributor road and a solitary cycle path are either grade separated or at-grade with a speed limiting measure or some form of time separation on the distributor roads. The minimum obstacle distance (clear roadside area) is 7.0 metres.

Through roads (rural roads with a flow function) consist of national and regional motorways. On the motorways the speed limit is 80/100/120km/h, there are one or more lanes per direction and there is physical directional separation (guard rail, New Jersey barrier etc.). The minimum obstacle distance of a motorway is 10.0 metres whereas it is preferably 15 metres on national motorways (see *Table 3.4*).

Requirement	Through-road	Distributor (road)	Access road
Marking (longitudinal)	fully	fully (but different from through-roads)	no
Physical separation of directions (number of lanes in one direction)	yes (2x1, 2x2 or 2x3)	yes (2x1 or 2x2)	no (only 1x1)
Pavement, surface irregularity	minor	minor	major
Obstacle-free zone	wide	medium	narrow
Directional signing	each exit	each junction	(to be decided)
Lighting	depending on volume	(to be decided)	(to be decided)
Speed limit (km/h)	100/120	80	60 or less
Physical separation	yes	no, but difficult to cross	n.a.
Emergency facility	emergency lane	hard shoulder or lay-by	no
Private or business accesses	no	no	yes
Crossing (mid-block / between junctions)	grade separated	grade separated or install a quasi-junction	at grade
Parking	no	parking lane	carriageway
Public transport: stops	no	bus bay	carriageway
Cyclists on carriageway	no	no	yes
Moped-riders on (main) carriageway	no	no	yes
Slow-moving motorized vehicles (e.g. agricultural vehicles)	no	no	yes
Speed-reducing facilities (e.g. humps)	no	occasionally	yes

Table 3.4. Example of operational requirements for road sections of sustainably safe road types in rural areas (derived from CROW, 1997).

4. Start-up Programme sustainably safe traffic

The Association of Local Authorities, the Association of Water Boards, the Inter-Provincial Consultation, and the Ministry of Transport, representing all tiers of government in the Netherlands, together signed an agreement on the so-called 'Start-up Programme for Sustainable Safety' in December 1997 (Ministerie van Verkeer en Waterstaat, 1997). The agreement contains 24 measures and actions, which were implemented between 1998-2002. The measures were presented (their traffic-engineering, technical, legal, and organizing aspects) in a manual published by the Information Centre for Sustainable Safety (Infopunt DV, 1998). The components included in the Programme dealing with financing of measures, enforcement, education, communication, etc., are not described here.

The Start-up Programme had two parts: a package of 'action plans' that could be implemented in a limited period of time, and secondly an outline of the intentions concerning the decision making processes required for a next phase, a full-scale implementation of Sustainable Safety. The (six) action plans which were aimed at changing the road infrastructure and/or legislation regarding the use of the infrastructure, were:

- functional classification/categorisation of the total road network in the Netherlands;
- extension of urban 30km/h zones;
- extension of rural 60km/h zones;
- assigning priority on intersections of all distributor roads;
- standardizing priority on roundabouts;
- removing mopeds from the bicycle paths.

For the implementation of the Start-up Programme, a subsidy of € 110 million of the central government was made available. To qualify for the subsidy, the road authorities had to supplement the subsidy with a matching amount. To speed up developments, road authorities were allowed to adopt a so-called 'low-cost design'. To facilitate this, existing regulations had to be changed.

The Start-up Programme, as all tiers of government agreed upon, was a compromise that was considered feasible to be implemented in the period 1997-2002. SWOV tested the proposed measures and their implementation using the original safety principles of Sustainable Safety. The implementation of the Start-up Programme differed on a number of points from these original principles. For example, the proposed speed limit of 60km/h in rural areas is not an ideal safe speed if one considers that pedestrians, cyclists and motorised vehicles share the same space. However, a lower limit was not seen as acceptable for motorists and not considered feasible because of the assumed high costs for speed reducing measures etc.

Another point is the desired recognisability of traffic situations that can be achieved by, among other things, uniformity. In the present proposals deviations from the general principles are possible and allowed; this is especially so for priority rules in traffic calming areas and on cycle paths

along the access roads. An especially worrying issue is the areas in transition (potential traffic calming areas), where the urban speed limit remains 50km/h (and the rural speed limit 80km/h) but where the general priority regulations for intersections (yield to traffic from the right) still apply. This does not conform to the Sustainable Safety principles. In general, it has been concluded that the proposed measures do not discourage a mixture of motor vehicles, bicycles, and mopeds; nor do they reduce driving speeds of motorized traffic to required levels.

Due to political developments in the Netherlands the plans for the second phase were drafted, but have not as yet resulted in formal steps being taken.

5. Road safety effects of the Start-up Programme

The six infrastructure related action plans are described and where, relevant, the intended road safety goal outlined. Finally a description of the realized safety effects to date will be described.

5.1. Road categorisation plans

The methodology for categorizing roads entails a sequential process of actions and decisions that lead to a concept road network hierarchy. According to the agreement in the Start-up Programme all road authorities were expected to reclassify their road networks before the end of 2000. The new road classification plans (see *Figure 2.1* for a simplified example) would be based on the guidelines set out by the CROW (CROW, 1997). In addition, road authorities would liaise regionally to ensure that an integrated and sustainably safe road network evolves from local through provincial to national level.

According to the latest evaluation (AVV, 2004b) nearly all 500 local authorities and the 12 provincial authorities have reclassified their road networks and the responsible governing bodies have formally adopted these plans. Most road authorities indicated that they had not fully used the procedure recommended by CROW to develop a reclassified network and that they felt a need for more design alternatives within the primary road classes. Almost all road authorities are using the classification plan as basis for future infrastructure planning and design purposes and this led to the conclusion of a very successful component of the Start-up Programme.

5.2. Expansion of 30km/h zones

Prior to the launching of the Start-up Programme, 30km/h zones and home zones had been implemented in a large number of towns and villages throughout the Netherlands. In total some 8,500 kilometres of the approximately 55,000 kilometres of urban residential streets had been designed as home zone or 30km/h zones (Schermers & Van Vliet, 2001). The Start-up Programme anticipated that 30km/h zones would be expanded by an additional 12,000 kilometres by the end of 2002.

The urban access roads purely provide access to properties alongside these roads. That is to say: through traffic taking a short cut should be prevented. Because these roads are open to all traffic and permit all movements, speeds should be low in order to be safe. All access roads are designated as 30km/h roads.

Following the launch of the Start-up Programme, local authorities submitted applications for the national subsidies and it became apparent that the budgeted funds would be inadequate to cover the demand. Furthermore, many local authorities realised that an amount of less than € 10,000 per kilometer (50% of which is for the account of the road authority) would be totally inadequate for re-engineering certain road types now designated for 30km/h use. Certain roads had generous geometric standards applicable to higher order roads but these now had to be downgraded and their layout

adapted to conform to standards set for 30km/h zones. To achieve this within the design principles set in the standards would require substantial investments. In the short term it was realised that funds for this could not be made available and therefore the concept of 'low-cost' implementation was introduced.

Depending on the budget available to the road authority, he may implement traffic calming measures on the basis of the existing guidelines for 30km/h zones (optimal spacing of measures) or implement on the basis of guidelines for a 'low-cost' approach. The latter implies that traffic calming devices should be implemented:

- at high crash locations;
- at locations that are subjectively unsafe (complaints by residents);
- at locations generating pedestrian and other vulnerable road user traffic (e.g. schools, old age homes, shopping and recreational areas, etc.);
- at locations near and with pedestrian or cycle routes (intersecting or alongside);
- on roads which differ in terms of appearance, volume or speed to other roads in the area;
- at locations on the boundary of the area.

The 'low-cost' approach essentially allows for the phased introduction and realisation of roads in newly designated 30km/h zones. In this way, the area can be gradually transformed to the desired end-state. In the short term, the posted 30km/h speed limit is partially supported by traffic calming devices, whilst the transformation of the area is made clearly evident to the user. Over time, the density of measures can be increased.

At the beginning of 2003 it was estimated (AVV, 2004b) that some 30,000 kilometres of 30km/h roads had been implemented, almost 10,000 kilometers above the agreement made in the Start-up Programme. Without any doubt, this was a very successful result!

In order to learn the road safety effects of this expansion of 30km/h zones an evaluation study was carried out (DHV, 2004). The zones were selected on the basis of size, period of completion, style of the suburb, access to the area, willingness of the local authority to assist with measurements (traffic volumes, speeds, and law enforcement), and road safety. The areas were selected to be nationally representative and geographically distributed over the entire country.

The average size of the 30km/h zones was 43 hectares with an average road length of 0.19km/hectare (8.2 km/area) and an average housing density of 27.5 dwellings per hectare. The housing and population densities in suburbs that were built in the 1950s and 1960s were the highest (36.3 dwellings per hectare and 91.7 persons/hectare). A number of the selected areas had already implemented traffic calming measures prior to designation the area as a 30km/h zone. Some of the older suburbs (50/60s) with grid layouts had an average of 15 speed humps, plateaus, or exit constructions, whereas two-thirds of the suburbs of the 1970s and 1980s that have a ring structure had an average of 21 measures per suburb.

The majority of local authorities opt for vertical speed reduction measures such as speed humps (average of 6.0/area), plateaus (avg. 5.8/area) and

speed cushions (0.4/area). On average the areas have 6.9 gateway treatments of which 3.1 were combined with exit constructions. As far as costs were concerned these averaged € 174,350 per area (€ 4,050/ha). On average this cost is low since the subsidy was based on an average cost of € 5,450 per hectare.

Expressing injury crashes as a rate per 1,000 kilometre road length, the fatality rate decreased from 1.77 deaths/1000km in 1998 to 1.57 deaths/1000km in 2003 (small number of fatalities!) whilst the number of in-patients decreased from 54 to 21.7 in-patients/1000km. This represents a reduction of 10% in the fatality rate and nearly 60% in the in-patients rate.

5.3. Introduction of 60km/h zones

In the Start-up Programme it was agreed upon to implement at least 3000 kilometres of rural roads in 60km/h zones over the period 1998-2002. These are minor rural roads with an access function only.

In principle the same aims apply as to roads in urban areas (no through traffic, reduced speeds especially on intersections). However, certain situations in traffic restrained rural areas require specific attention. One of these is the treatment of property accesses to farms that may or may not be surfaced. These intersections must be reconstructed as exit constructions with a vertical difference between the 60km/h road and the (property) access road. In principle, intersections on 60km/h roads are uncontrolled and the rule 'yield to all traffic (incl. cyclists and mopeds) approaching from the right' applies. In certain situations the road authority may assign priority at intersections (e.g. poor sight distances or potentially unsafe conditions). Also locations where large pedestrian movements occur may be restricted to a 30km/h speed limit and traffic calming devices to support this should be introduced.

Roads designated as potential 60km/h roads will (at least in the short term) operate as 80km/h roads. Because of the higher speed differential between road users, road authorities must pay specific attention to intersections with cycle/moped paths to ensure the safety of the more vulnerable road user. On these provisional 80km/h roads we recommend that mopeds use the cycle paths.

In general, speed limits are posted as a logical result of the road scene as observed/perceived by the road user. For 60km/h roads however, new conditions were introduced in regulations and standards and these are:

1. The road primarily provides access to (private and public) property.
2. To prevent high volumes and proportions of through (non-local) traffic, roads and their environment are adapted (calmed) accordingly.
3. In the light of speed reduction and/or raising the awareness extra attention is paid to (potential) unsafe locations. Examples of these are locations with high volumes of crossing pedestrians, intersections with high volume cycle routes and priority intersections.
4. Roads with transition zones from one speed limit to another are marked to indicate the higher or lower limit.
5. If the transition to a higher speed limit occurs within 20 metres of an intersection, that intersection will be priority controlled or an exit construction will be introduced.

A new design element of these 60km/h-zones was the introduction of a motor vehicle lane in the middle of the carriageway. The marking consists of a broken line on both sides of the motor vehicle lane. The rest of the width, consisting of two (edge) strips - sometimes covered in red asphalt - is reserved for cyclists. The Information Centre for Sustainable Safe Traffic as well as the Association of Water Boards recommends this lane division in their publications. The aim is to give motorized traffic and cyclists their 'own' space, although not physically separated.

SWOV reported a comparison between rural access roads with and without these specific lanes (Van der Kooi & Dijkstra, 2003). The conclusion was that roads with the lanes had a slightly lower average driving speed than roads without. Cyclists also seem to use 'their' lane, and cycle further from the road edge than before there was a lane. Free-driving car drivers often do not keep to their middle lane, and thus drive no further from the road edge than when there was no lane marking (which was the intention). Car drivers, who overtake cyclists, swerved slightly less to the left in the after-study than in the before-study. This means that the mutually chosen space is smaller than was thought possible from the available space in the cross section.

The results of the Start-up Programme (AVV, 2004b) indicated that at the beginning of 2003 some 12,500 kilometres of 60km/h road had been realized. The total length exceeds the original target of 3,000 kilometres by 9,500 kilometres. The majority of these roads were re-designed and re-engineered on the basis of the so-called 'low-cost' approach. Again, this was a very successful intervention.

The Association of Water Boards commissioned an evaluation (before-and-after study) of twenty 60km/h zones comprising some 800km of rural access roads (Beenker et al., 2004). These roads were changed by introducing measures specific to them: raised junctions, road sections with bicycle lanes and speed humps. The crash trend in these twenty zones was compared to the crash trend in control areas (with a total of 2,300km of rural access roads). Prior to the infrastructure changes (also referred to as the before period), the roads in the control and roads in the test areas had similar geometric design characteristics. The injury accident rate (no. of injury crashes/km) in 60km/h zones has decreased by 18% compared to the control areas. The total number of casualties (both fatalities and injured) was 25% less after the 60km/h zones were installed.

The absolute number of crashes with injury on junctions within the 60km/h zones decreased by 50% compared to the control areas. Most of the effect can be contributed to the (raised) junctions; the effect of the measures on road sections is small (and not statistically significant). Examining the casualty rate (number/1000km road length) on 60km/h roads, then the number of fatalities decreased from 8 in 1998 to 2.6 fatalities/1000km road length in 2003. Simultaneously the number of in-patients decreased from 40.8 in 1998 to 27.6/1000km in 2003. Installing a 60km/h zone is cost-effective. The cost to introduce measures on roads in 60km/h zones is approximately € 7,000 per kilometre and this is equal to saving approximately one casualty per € 16,000.

5.4. Priority cyclists from the right and priority on distributor roads

In 2000 legislation was amended to change the general rule 'motorised traffic approaching from the right has priority' (unless indicated otherwise) to 'all traffic (excluding pedestrians) approaching from the right has priority'. This amendment especially covered cyclists, mopeds, vehicles for invalids, and all other slow vehicles. However, before the amendment was carried out, road authorities had to ensure that their road networks were adapted to safely accommodate the new rule. These changes included introducing intersection control on distributor roads, raising intersections to increase visibility, and taking measures at uncontrolled intersections on access roads.

To meet the implementation date (finally set for 1 May 2001) road authorities had to ensure that priority at all intersections on urban distributors was controlled (regulated). By mid 2001, the vast majority of local authorities had defined the urban distributor road network and some 86% had implemented priority control at intersections along these roads. Yield control (signing and marking) was predominantly favored as the control strategy at previously uncontrolled intersections. The 14% that had indicated not to have implemented the required changes, attributed this decision to a lack of funds, the fact that speeding remained a problem, and thirdly, that the public did not fully understand the new changes in the regulations.

One year after implementation of these two measures, a study was initiated on a sample of urban distributors to determine the effect of the measures on the number of road crashes (AVV, 2003). This study did not reveal any (positive or negative) safety effect resulting from assigning priority on urban distributor roads. However it has to be stated that the measure "priority cyclist from the right" was not included in the Start-up Programme from a road safety perspective, but to improve the position of cyclists in traffic and improving uniformity throughout the Netherlands. Initially, it was anticipated that the measure would have a small positive safety effect, but this was found not to be the case. The number of crashes (with injury) of the type 'failing to give priority' and the number of casualties remained the same in the one-year period following introduction.

5.5. Roundabouts

Another action plan was achieving uniformity at roundabouts. In the Netherlands there were two primary issues that concern priority at roundabouts and old 'traffic squares'. The first was that two different priority rules applied to motorized traffic on roundabouts, one where traffic on the circulating carriageway has right of way and the other where traffic on the approach has right of way. To ensure uniformity it was decided to convert the approximately 70 roundabouts operating under the old priority rule (entering traffic has priority) to the 'new' rule. At the same time the geometry of some of the 'old style' roundabouts, designed with flared and tangential approaches was changed to conform to the new design standards, resulting in lowering entry speeds at roundabouts. Proposals were drafted to achieve the required uniformity as was a proposal submitted for subsidising these activities. As in the case of cyclists, this measure was principally aimed at ensuring national uniformity with respect to roundabout design and operation. Improvement of road safety was not a direct goal. Various

evaluations have been conducted by SWOV (Van Minnen, 1990, 1995, 1998; Dijkstra, 2004).

The process of changing four-arm and three-arm junctions into single-lane roundabouts started in the 1980s, long before the Start-up Programme. Constructing roundabouts was no formal part of the financial agreement in the Start-up Programme. But because roundabouts are such a key-component of the Sustainable Safety vision, it is decided to include roundabouts in this evaluation. The evaluation of the safety effects revealed that such conversions yield a reduction of 73% in the number of casualties (controlled for the crash and casualty trend on junctions in urban areas). For cyclists and mopedists the number of casualties decreased by 62% (Van Minnen, 1990).

A remaining issue at roundabouts concerns priority for cyclists on separate cycle paths. Currently there is no mandatory requirement for this. CROW-guidelines have been published (CROW, 1998) and these recommend that cyclists on separate cycle paths at roundabouts in urban areas have right of way (i.e. traffic entering/exiting the roundabout must yield to cyclists) and in rural areas they do not (i.e. they must yield to traffic on the approaches). Since this is only a recommendation, road authorities have freedom to follow or ignore this recommendation. Throughout the country different opinions have formed. This lack of uniformity is currently a topic of discussion amongst local, provincial, and national road authorities. The crash rate at roundabouts with the rule 'priority to cyclists' is higher than at roundabouts with the rule 'priority to drivers' (0.11 versus 0.02 crashes with in-patients per roundabout per year) (Dijkstra, 2004).

5.6. Mopeds on the roadway

In the Netherlands, mopeds are limited to a maximum speed of 30km/h in urban areas, mopedists are compelled to wear a crash helmet and may ride on designated roads and/or cycle paths. Resulting from a significant increase in the incidence of moped/cyclist and moped/car crashes it was decided in 1998 to introduce changes to the legislation and regulations banning mopeds from certain cycle paths and allowing them to use the roadway. During 1999 these changes were achieved by legislation and the new rule was introduced on 15 December 1999.

In the urban environment, and especially on 50km/h roads, it was recommended that mopeds be banned from cycle paths and assigned to the roadway. There are however certain exceptions where this is not to be recommended. One of the exceptions applies where the moped is diverted from the cycle/moped path to a short length of roadway and then back to the cycle path. In these cases it is preferable to provide continuity by means of (other) infrastructure or traffic management measures. A second exception applies where the cycle path offers the logical shortest route and diversion to the roadway would lead to significant increases in the moped journey time.

Where the moped remains on the cycle path the new sign 'Compulsory cycle/moped path' must be erected. Road authorities must pay specific attention to the transition zones where the cycle/moped path switches to the roadway. These must be located such that all road users can anticipate them, use them safely and clearly comprehend the situation.

A survey (AVV, 2004b) was carried out among local authorities to establish to what extent the measure had been implemented. From the response it was evident that mopeds had been diverted to approximately half of all the urban distributor roads (based on a sample of 170 local authorities and representing 1,772 km of road). On average local authorities had 18.5 kilometers of cycle path of which 8.1 kilometers is still shared by cyclists and mopeds (implying that nearly 60% of moped trips are now made on the roadway). One year after the introduction of the new rule the number of injury crashes involving mopeds at locations where mopeds had been diverted to the roadway decreased by 31%. Nationally, this represented a reduction of 15% in injury crashes involving mopeds (AVV, 2001).

5.7. In summary

The exact contribution of the Start-up Programme on Sustainable Safety to the reduction in the number of road crashes is difficult to isolate, especially since there is interaction between the various measures that have been implemented and since other activities such as enforcement, education etc. have continued. In general it can be stated that each of the infrastructural measures outlined in the original agreement has been implemented and that each one has contributed to making the road environment in the Netherlands safer as is the case for the construction of roundabouts. This effect is seen in the overall development of traffic fatalities and in-patients in the Netherlands (*Figure 5.1*). As far as number of fatalities are concerned over the period 1997-2002, a reduction of 9.7% percent was realised. The number of in-patients was reduced by 4.1%. This downward trend can for a part be contributed to the efforts of the first phase of Sustainable Safety. Although a formal evaluation study has not been carried out, a rough estimation is possible.

Before presenting the estimated effects of the different 'action plans' agreed upon in the Start-up Programme, one other major intervention could explain, at least partly, the observed downward trend in fatalities and in-patients: intensified regional traffic enforcement (Mathijssen & De Craen, 2004). These intensified police enforcement plans concentrated on speeding, drink driving, not wearing seatbelts and crash helmets, and red light running. We must conclude that the implementation of regional plans in 2000/01 has not had clearly positive road safety effects. In the regions that had implemented such a plan, the number of crashes with in-patients and/or fatalities did not decline more than in the other regions (the control area). If, however, only the development in the number of deaths is examined, it appears that in the regions that had implemented such a plan, there has been about a 10% stronger reduction than in the control area. Although this difference was not (statistically) significant, we consider it to be a relevant effect. This results in the conclusion that these regional enforcement activities did not explain the downward trend in in-patients and fatalities.

30km/h zones

The common residential streets show a rate of 0.324 fatalities and in-patients per million-vehicle kilometre. For the length of 30km/h zones, which was installed during the Start-up Programme, this results in an expected number of fatalities and in-patients of 948 in 2002. However, only 294

victims were registered. So the estimated effect of the zone 30 in 2002 amounts to $948 - 294 = 654$ casualties.

Roundabouts

During the Start-up Programme about a 1,000 roundabouts were built. The mean number of fatalities and in-patients is 0.44 per year on a common junction and 0.08 per year on a roundabout. The difference between these accident rates was the effect of the roundabout: 0,36 per roundabout per year. The effect of 1,000 roundabouts in 2002 was 360 fatalities and in-patients.

Mopeds on the Roadway (MoR)

AVV (2001) estimated the yearly effect of MoR as at least 928 victims (all severities of injuries included) and 1,540 at most. If we assume that the percentage of fatalities and in-patients is around 18%, then the number of fatalities and in-patients that is saved annually by MoR is in between 167 and 275.

60km/h zones

This type of measure was installed on a part of the rural access roads with a Water Board as road authority. The mean number of fatalities and in-patients on this type of rural access roads (before implementing the measure) is 0.16 per million-vehicle kilometre. This would imply that for the 725km of roads in 60km/h-zones the number of fatalities and in-patients would have been 38, however the actual number is 25. The effect of this measure is a reduction of 13 fatalities and in-patients.

The measure was also applied on 11,725km of rural access roads with a local government as road authority. The mean number of fatalities and in-patients per million-vehicle kilometre on these roads is 0,19. Consequently the number of victims would have been 728 casualties. We assume that the effect of the measure on these roads resulted in a reduction of 5% (Schoon, 2000); the number of casualties would have dropped to 692, a reduction of 36 fatalities and in-patients. The contribution of this measure to the reduction of the total number of fatalities and in-patients is $13 + 36 = 49$.

Total reduction

In 2002, the total number of fatalities and in-patients that was prevented as a result of these four measures was estimated as in between 1,200 and 1,300. This amounts for about 6% of the number of fatalities and in-patients. This means that the implementation of the Start-up Programme (incl. roundabouts) has contributed substantially to the registered reduction of the number of fatalities and in-patients in the Netherlands (see also *Figure 5.1*).

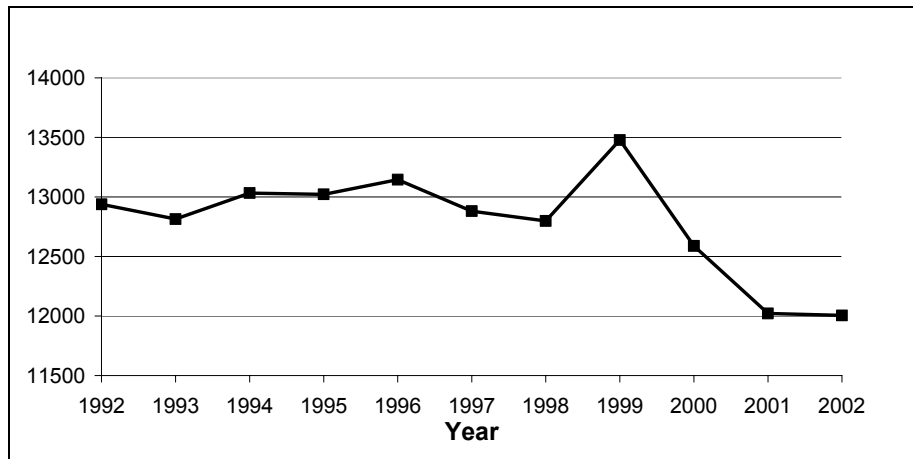


Figure 5.1. *Fatalities and in-patients over the period 1997-2002 (Source AVV-BI).*

6. Next steps

The process leading to full support of key-stakeholders to Sustainable Safety and especially to the Start-up Programme has been described elsewhere (Wegman & Wouters, 2002). From the introduction process, specific lessons could be learned to be at least supportive, or were even a prerequisite, for successful action:

- The conviction that the current policy was not sufficiently effective in reaching the road safety targets in the Netherlands. Thus something 'new' was needed.
- Road safety experts and the professional world should express themselves in full accordance with the new concept. If experts disagree, policy makers and politicians will feel uncertain and decisions might be postponed.
- The vision has to appeal in both the short term and the long term. Of course, no concept has been drawn up for eternity.
- From the start, the vision has to enhance creativity and not provoke resistance. An important element with respect to this: appealing directions and no obvious drawbacks.
- Road safety organisations and pressure groups (stakeholders and 'actors') have to consider the vision as offering them new opportunities.
- Implementation of the vision must be integrated in existing budget streams.
- Structural opportunities to connect the vision to other activities should be looked for and created: drafting guidelines for road design, education curricula for schools, etc.
- Last but not least: intelligent ways to commit stakeholders have to be found.

Sustainable Safety is the cornerstone of Dutch road safety policies and forms an integral part of Dutch transport and traffic policies. The Dutch government drafted a policy document on transport and traffic recently (Ministerie van Verkeer en Waterstaat, 2004). Road safety is an integral part of this policy and plans are being prepared to continue with the implementation of Sustainable Safety. In the meantime two further developments can be observed. Based on the successful action strategy in the past, prolonging the good and effective partnerships between the three tiers of government, and other important stakeholders, when it comes to the implementation of Sustainable Safety (until 2010 and even beyond that). New types of agreements have to be made given the fact that the responsibility for implementation of policies in the Netherlands has been devolved to provinces and municipalities. This also applies to road safety policy. Plans are in preparation to come to a new Road Safety Agreement in 2005/2006 (Wegman, 2004). The second development is the design of a next generation of Sustainable Safety measures. We expect to renew and update the Sustainable Safety publication (Koornstra et al., 1992), using the working title of Sustainable Safety version 2.0., late 2005.

7. Conclusions and recommendations

Early in the 1990s, a vision was developed to considerably improve road safety in the Netherlands: Sustainable Safety. The vision starts from the idea that safety should be a design principle for the road traffic system, and taking the human being as the reference standard. In a sustainably safe road traffic, human errors are drastically reduced through pro-active safety-conscious planning and design. Furthermore, where traffic crashes still occur, the process that determines the severity of these crashes (tolerances of the human body) should be influenced, so that serious injury is virtually excluded. This has to lead to very ambitious and large-scale adaptations of the existing road infrastructure.

The key to arrive at a sustainably safe traffic system lies in the systematic and consistent application of three safety principles: functionality, homogeneity and predictability. The functionality of the road system is important that it matches actual use with intended use, as designed by road authorities. This produces a road network with three functional road categories: through roads, distributor roads, and access roads. In this hierarchical network roads and streets may have only one function. The homogeneity of the road system is meant to avoid significance differences in speeds, driving directions, and mass (preferably by segregating incompatible traffic modes). Finally, it is of utmost importance that road users are familiar with the behaviour demanded by different road types, and what they may expect from other road users. Based on these three design principles functional and operational planning and design requirements are formulated and published in design guidelines.

In order to start the implementation of Sustainable Safety, all tiers of government in the Netherlands signed an agreement, the so-called *Start-up Programme for Sustainable Safety*. The agreement contained 24 measures and actions, which were implemented in 1998-2002. Six action plans were aimed at changing the road infrastructure: functional classification of the total road network in the Netherlands, extension of 30km/h zones and 60km/h zones, roundabouts, priority on intersections of distributor roads, and removing mopeds from the bicycle paths. For the implementation of the Start-up Programme, a subsidy of € 110 million from the central government was made available. To qualify for the subsidy, the road authorities had to supplement the subsidy with a matching amount.

Road categorisation plans were made for about 90% of the total Netherlands network. At the beginning of 2003 it was estimated that some 30,000 kilometers of 30km/h roads had been implemented, 10,000 kilometer more than agreed upon. Some 12,500 kilometers of 60km/h roads had been realized. The total length exceeds the original target with almost 10,000 kilometer. The priority for traffic from the right and priority control at intersections of distributor roads were changed in 2001. The number of roundabouts was increased by about 1,000, although no subsidies were given for this. Toward the end of 1999, mopeds were banned from bicycle paths inside urban areas. Without any doubt, this was a very successful result of this Start-up Programme.

Unfortunately, a formal evaluation of the Start-up Programme was not organised by Netherlands road safety authorities. However, it is estimated that the implementation of the Start-up Programme resulted in a reduction of the number of fatalities and in-patients of about 6%. This means that the first phase of Sustainable Safety has made a significant contribution to further improving road safety in the Netherlands.

From the introduction process of Sustainable Safety specific lessons have been learned to be at least supportive or were even a prerequisite for successful action. Intelligent ways to commit stakeholders have to be found a major one. Sustainable Safety forms an integral part of Netherlands transport and traffic policies. Plans are in preparation to come to a new Road Safety Agreement in 2005/2006. In this framework we plan to renew and to update the vision, using the working title Sustainable Safety version 2.0.

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