1. INTRODUCTION

To date road transport in the Netherlands has cost 100,000 lives and caused 1.5 million injuries costing the economy some 11.4 billion guilders per year. Since the early 1970's the Netherlands has actively applied road safety policies to curtail the problems. During this period the measures with largest positive effect were, in order of importance; new traffic legislation, the expansion of the freeway road network, vehicle safety (seat belts etc.) influencing road user behaviour and stimulating decentralisation. Irrespective of the enormous growth of private transport the effect of these policies has been positive and reduced fatalities from 3,000 in 1972 to around 1,100 in 1999. Consequently the Netherlands today is one of the safest countries in terms of road safety in Europe. However, further improvements are required a radically new approach to managing road safety. The product of this research was the Sustainable Safety strategy.

Historically road traffic safety has been a high priority on the political agenda in the Netherlands. Consequently policy has been well supported by focused programmes which now manifest themselves in a continual downward trend in road accident fatalities (Figure 1). Serious injury accidents (Figure 1) have remained relatively constant over the past nine years.
2. HISTORY

Since the mid-1980’s traffic safety policy was laid down in the long term road safety policy or MPV. The first (MPV-I) was issued in 1987 with the theme “More kilometres, less accidents”. This set a goal of a 25 per cent reduction in injury accidents over the period 1985 to 2000. To realise this certain spearheads or focus areas were defined and these targeted alcohol, speed, hazardous locations, children, the elderly and safety devices. In 1989 the MPV-II was released with the theme Ambitious but attainable. Besides further attention for the focus areas, the importance of participation by local and provincial road authorities and other stakeholders in the policy process was highlighted.

The second Structure Plan for Traffic and Transport (SVV-II) of 1990 laid down the road safety goals for 2010, namely a 50 percent reduction in fatalities and a 40 percent reduction in injury accidents over the period 1986 to 2010. However, in the early 1990’s doubts arose whether these goals would be met. The spearhead policies were effective but did not adequately address problems at the source. While overall reductions in road accidents were still evident, analysis of accidents on certain parts of the road network reflected that remedial actions were necessary to reduce the large discrepancies in fatality and serious injury accident rates on the different road classes. This resulted in the issuing of the “twin pronged” (twee sporen) policy of the MPV-III, the first aiming at the renewal and intensified application of the focus areas and the second at a preventative strategy now known as Sustainable Safety.

Figure 1: Fatal injury accidents (1986 -1998)
Figure 2: Serious injury accidents (1990 -1998)
3. PRINCIPLES OF SUSTAINABLE SAFETY

In contrast to the spearhead policy the sustainable safety strategy is characterised by a proactive and preventive approach. Whereas the spearpoint-policy was reactive (and curative) approach aimed at addressing problems when they occurred, sustainable safety has “prevention is better than aim” as its motto.

Sustainable safety recognises that 90 percent of road accidents are attributable (to a greater and lesser extent) to human error. Consequently sustainable safety realises that the human is the weakest link in the traffic and transport chain. Furthermore, human does not readily change or adapt and many attempts at influencing road user behaviour have failed or had merely short term effects. The limitations of the human remain evident. Motivation, attention, emotion, observation, prediction, knowledge and skills are all weaknesses that prevent the human from being the ideal traffic participant. All and all the human remains unpredictable and therefore is in itself not sustainable from a road safety perspective.

In a sustainable safe traffic system the human takes central role. Humans are (largely) unpredictable and influencing their behaviour cannot be sustained over the long term. They are therefor incorporated in sustainable safety as a reference against which other system elements are gauged.

Sustainable Safety is based on a system approach where all element of the traffic safety and transport system are geared to one another. At the highest level it is the interaction in the relation man, vehicle and infrastructure. At the next level it is the relation between function, form, legislation and usage.

Function relates to the use of the infrastructure as intended by the road authority. Form relates to the physical design and layout properties of the infrastructure. Legislation relates to regulatory requirements for the use of the infrastructure and usage relates the actual use of the infrastructure and behaviour of the road user within the system.

In summary a sustainable safe traffic system comprises

- a road environment with an infrastructure adapted to the limitations of the road user;
- vehicles equipped with technology to simplify the driving task and provided with features that protect vulnerable and other road users; and
- road users that are well informed and adequately educated.

3.1. Three road categories and three safety principles

Sustainable safety distinguishes three categories of road:

- roads with a through function (for the rapid movement of through traffic);
- roads with a distributor function (for the distribution and collection of traffic to and from different districts and residential areas);
- roads with an access function (providing access to homes and shops while ensuring the safety of the street as a meeting place).

Each category of road requires a design compatible with its function, while at the same time ensuring optimum safety. To meet the latter requirement, all road categories should comply with the following three safety principles:
1. functionality (preventing unintended use of the infrastructure);
2. homogeneity (preventing major variations in the speed, direction, and mass of vehicles at moderate and high driving speeds);
3. predictability (preventing uncertainty among road users).

Preventing unintended use of the infrastructure

It is very important to draw a clear distinction between roads with a through function and roads with an access function. Through traffic does not belong on roads with an access function, and local traffic does not belong on roads with a through function. This requirement has implications for the routing and design of roads: roads with an access function should not offer time-saving connections to through traffic (that is: traffic travelling to or from a location outside the immediate area); and roads with a through function should not offer direct access to homes, schools, offices, factories, sports facilities, etc.

Preventing variations in the speed, direction, and mass of vehicles at moderate and high driving speeds

The severity of road accidents is usually determined by differences and variations in the speed, direction, and/or mass of vehicles. In the Netherlands the safest roads are the freeways, where driving speeds are the highest but relatively uniform. Where there is little or no variation in direction and vehicle mass. Also relatively safe are the 30 km/h zones and residential areas, despite considerable variation in the directions and mass of vehicles using them. Their safety attributable to driving speeds and small speed differences between different road users.

Table 1: Road accident casualties on different road classes in the Netherlands (1986, SWOV)

<table>
<thead>
<tr>
<th>Road type</th>
<th>maximum speed</th>
<th>Mixed Traffic</th>
<th>At grade median separation</th>
<th>Casualty rate (Casualties/10^6 km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>30</td>
<td>Yes</td>
<td>Yes</td>
<td>0,20</td>
</tr>
<tr>
<td>Urban collector</td>
<td>50</td>
<td>Yes</td>
<td>Yes</td>
<td>0,75</td>
</tr>
<tr>
<td>Urban arterial</td>
<td>50/70</td>
<td>Yes/No</td>
<td>Yes</td>
<td>1,33</td>
</tr>
<tr>
<td>2-lane rural roads</td>
<td>80</td>
<td>Yes</td>
<td>Yes</td>
<td>0,64</td>
</tr>
<tr>
<td>Undivided 2-way rural roads (ltd. access)</td>
<td>80</td>
<td>No</td>
<td>Yes</td>
<td>0,30</td>
</tr>
<tr>
<td>Expressways</td>
<td>100</td>
<td>No</td>
<td>Yes/No</td>
<td>0,11</td>
</tr>
<tr>
<td>Freeways</td>
<td>100/120</td>
<td>No</td>
<td>No</td>
<td>0,07</td>
</tr>
</tbody>
</table>
The roads in between require special attention, since they are the most dangerous. These are the roads with a distributor function, on which vehicles travel at fairly high speeds and there is a great deal of intersecting traffic. Safety improvements on these roads requires the separation of motorised and non-motorised traffic (e.g. separate cycle lanes). This reduces variations in speeds and mass of vehicles. At locations where motorised and non-motorised traffic intersect, lower maximum speeds have to be introduced, or traffic has to be separated time-wise (e.g. traffic signals, roundabouts etc.). At intersections roundabouts are preferable. Traffic signals can cause large variations in driving speeds (e.g. when drivers ignore red lights). Although these are smaller than speed variations at uncontrolled intersections.

Preventing uncertainty among road users

To prevent uncertainty among road users, roads should be constructed and marked to make obvious what sort of behaviour is expected. In other words the road must be "self-explanatory". The number of road categories should therefore be limited, and their design and layout as uniform as possible. Road users will then have a better idea of what sort of driving behaviour is expected of them, and be better able to anticipate the driving behaviour of other road users. With self explaining roads, road users will know at which speed to drive, whether to expect traffic from side roads, and whether cyclists are likely to be on the road.

3.2. General design criteria

Applying the sustainable safety principles described above, design criteria were formulated (CROW, 1996) for the three (table 2) Important to not is that in urban areas only two road categories are provides for, namely distributor and accessroads (table 3).

Table 2: Operational requirements for roads outside built-up areas (CROW 1996)

<table>
<thead>
<tr>
<th>Operational criteria/design elements</th>
<th>Through roads</th>
<th>distributor roads</th>
<th>access roads</th>
</tr>
</thead>
<tbody>
<tr>
<td>maximum speed</td>
<td>120/100 km/h</td>
<td>80 km/h</td>
<td>60</td>
</tr>
<tr>
<td>directional signs</td>
<td>situation dependant on category</td>
<td></td>
<td></td>
</tr>
<tr>
<td>longitudinal road markings</td>
<td>full</td>
<td>partial</td>
<td>none</td>
</tr>
<tr>
<td>Number of lanes</td>
<td>2x1 or more</td>
<td>2x1 or more</td>
<td>1</td>
</tr>
<tr>
<td>Surfacing</td>
<td>impervious (asphalt or concrete)</td>
<td>impervious (asphalt or concrete)</td>
<td>pervious (pavingstone, brick)</td>
</tr>
<tr>
<td>connection with residential areas</td>
<td>no</td>
<td>Limited or none</td>
<td>yes</td>
</tr>
<tr>
<td>connection with residential areas</td>
<td>Physical median</td>
<td>difficult to traverse</td>
<td>none</td>
</tr>
<tr>
<td>interacions</td>
<td>grade separated</td>
<td>roundabouts/traffic control</td>
<td>intersections with speed control measures</td>
</tr>
<tr>
<td>parking</td>
<td>no</td>
<td>no</td>
<td>on carriageway</td>
</tr>
<tr>
<td>provisions for breakdowns</td>
<td>emergency lane</td>
<td>hard shoulder or turnouts</td>
<td>none</td>
</tr>
<tr>
<td>obstacle distance</td>
<td>large</td>
<td>medium</td>
<td>small</td>
</tr>
<tr>
<td>bicyclists</td>
<td>separated</td>
<td>separated</td>
<td>situation dependent</td>
</tr>
<tr>
<td>mopeds</td>
<td>separated</td>
<td>separated</td>
<td>on the carriageway</td>
</tr>
<tr>
<td>slow-moving motorised traffic</td>
<td>separated</td>
<td>separated</td>
<td>on the carriageway</td>
</tr>
<tr>
<td>speed reducing measures</td>
<td>no</td>
<td>suitable measures</td>
<td>yes</td>
</tr>
<tr>
<td>public lighting</td>
<td>dependant on situation and category</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational criteria/design elements</td>
<td>distributor roads</td>
<td>access roads</td>
<td></td>
</tr>
<tr>
<td>-------------------------------------</td>
<td>-------------------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>maximum speed</td>
<td>50 or 70 km/h</td>
<td>30 km/h</td>
<td></td>
</tr>
<tr>
<td>directional signs</td>
<td>dependant on situation and category</td>
<td>dependant on situation and category</td>
<td></td>
</tr>
<tr>
<td>longitudinal road markings</td>
<td>partial</td>
<td>none</td>
<td></td>
</tr>
<tr>
<td>Number of lanes</td>
<td>2x1 or more</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Surfacing</td>
<td>impervious (asphalt or concrete)</td>
<td>pervious (pavingstone, brick)</td>
<td></td>
</tr>
<tr>
<td>connection with residential areas</td>
<td>limited</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>carriageway separation</td>
<td>difficult to traverse</td>
<td>none</td>
<td></td>
</tr>
<tr>
<td>intersections</td>
<td>roundabouts or speed control measures and priority control</td>
<td>uncontrolled with speed control measures</td>
<td></td>
</tr>
<tr>
<td>parking</td>
<td>only in parking facilities</td>
<td>on carriageway</td>
<td></td>
</tr>
<tr>
<td>provisions for breakdowns</td>
<td>parking lane</td>
<td>none</td>
<td></td>
</tr>
<tr>
<td>obstacle distance</td>
<td>medium</td>
<td>small</td>
<td></td>
</tr>
<tr>
<td>bicyclists</td>
<td>separated</td>
<td>on the carriageway</td>
<td></td>
</tr>
<tr>
<td>mopeds</td>
<td>separated from 70 km/h</td>
<td>on carriageway</td>
<td></td>
</tr>
<tr>
<td>slow-moving motorised traffic</td>
<td>on the carriageway</td>
<td>on carriageway</td>
<td></td>
</tr>
<tr>
<td>speed measures</td>
<td>yes</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>public lighting</td>
<td>dependant on situation and category</td>
<td>dependant on situation and category</td>
<td></td>
</tr>
</tbody>
</table>
4. IMPLEMENTATION SUSTAINABLE SAFETY IN NETHERLANDS

To give Sustainable Safety the required impetus, a steering committee 1995 was formed and tasked with the implementation and further development of the then concept programme. Representatives from central Government, the Association of Dutch Local Authorities (VNG), the Union of Water Management Authorities (UvW) and the Interprovincial Consultation Body (IPO) were nominated to serve on the committee.

Shortly after the formation of the committee an investigation was commissioned and this concluded that the implementation of measures proposed by Sustainable Safety could not be realised within the short term. This resulted in the development of a detailed phased implementation programme for a future safe and sustainable traffic and transportation system. The strategies outlined in the implementation programme were incorporated into a convention (a multi-party agreement known as the “Convenant) between the government and other role players (the “convenant” partners).

The implementation phases

The first phase of the implementation programme covers the period 1998 through 2001. It entails the implementation of a comprehensive basket of measures that include infrastructure provision and adaptation, education, enforcement, enabling legislation and financing. The primary aim of Phase 1 of the programme is to nationally provide clarity and uniformity regarding the infrastructural measures to be provided on the revised road network. To this end local and provincial authorities are preparing detailed road classification plans. These will form the basis for short to long term infrastructure provision. The first phase will focus predominantly on the lower order urban and rural road network. The implementation of measures anticipated on these roads during Phase 1 is based on the principles of traffic integration. Due to the extent of new infrastructure to be provided, and the costs associated with total re-engineering, Phase 1 aims at infrastructure provision at only those locations which can, from a road safety point of view, be deemed dangerous or potentially dangerous. In the Netherlands this approach has been termed the “sober” approach (the ideal is the optimal approach where the road or area is completely transformed to the desired end-state).

For the execution of Phase 1 it has been estimated that an investment of approximately f400 million in new infrastructure is required. To facilitate the implementation, the government will, in the form of a subsidy, fund half of the total investment cost. The balance is to be paid by the other partners (i.e. local and provincial governments).

The second phase of the implementation programme concerns the period 2002 through 2010. Phase 2 entails the implementation of the Sustainable Road Safety principles on the entire Dutch road network. This in effect means the realisation of the road classification plans as submitted in 1999 and in accordance with standards and guidelines for infrastructure provision for all sustainable safety road classes.
Phase 1 - Start-up programme

The “Start-up programme (convenant) “ sets the short term action plans for the implementation of the first phase (start-up) of the Sustainable Safety programme. The 24 actions outlined were sanctioned by the partners and are currently being actively supported and implemented by road authorities. The action plan of the Start-up Programme includes:

Planning

Sustainable safety will be implemented in two phases. The first phase covers the period 1997 to 2001 and entails the implementation of a coherent basket of infrastructural and educational measures, a programme of supporting measures and the preparation of a detailed action plan for the implementation of Phase 2. As a contingency and given the extent of the programme, Phase 1 may be extended to the end of the year 2002. However, the detailed action plan for phase 2 must be completed and tabled by the end of 2001.

During 1999 decisions will be made regarding the implementation of a general 30 km/h speed limit in urban areas. In support of this ruling, stakeholders will be required to enter into agreements binding them to providing adequate levels of traffic law enforcement during and after the new limit is introduced.

Infrastructure

Road classification plans

Local and provincial authorities and the Union of Water Management Authority (UvW) will prepare concept road categorisation plans which distinguish between roads with a predominant traffic function and roads that have a mixed function and use. The criteria on which this distinction is based is that roads with a mixed function and use are such that they can be adapted to reduce the mobility of motorised traffic and thereby enhance the concept of shared use. The government supports the timeous amendment of the traffic legislation to introduce a general 30 km/h speed limit in urban areas. The legislation must make provision for exemptions to allow local authorities the flexibility to post higher speed limits on selected (predominantly) traffic routes (50km/h and 70 km/h roads). The implementation of this measure is dependant on the detailed implementation and road categorisation plans submitted by local authorities in 1999.

Expansion of 30 km/h zones

To compliment the implementation of the general 30km/h limit in urban areas, the length of roads and the number of 30 km/h zones will be increased. To this end the signatories agree to realise at least an additional 12,000 kilometres of infrastructurally adapted 30 km/h roads in the period 1998 to 2001.

The design standards (BABW) will be amended to relax the current design and layout requirements for 30 km/h zones. The standards presently apply to the provision of traffic calming devices in an optimal situation. Due to the cost implications of an optimal solution, it was decided to allow 30 km/h zones where only unsafe and potentially unsafe locations are treated with traffic calming devices (the sober approach).

60 km/h zones in rural areas

During the period 1998 to 2001 the length of infrastructurally adapted roads in 60 km/h zones will be increased by at least 3,000 kilometres.
Assigning priority on traffic arterials

By the end of the year 2000 priority at all intersections on traffic arterials will be controlled by means of road signs and/or other infrastructural means.

Roundabouts

By the year 2000 legislation will be amended to standardise priority at traffic roundabouts. From this time the rule will be that traffic on the circulating carriageway has right of way. At present there are still some (historical) roundabouts where traffic on the approach road has right of way.

Moped on the roadway

By the end of 1999 traffic legislation will be amended to make it mandatory for mopeds to drive on the roadway (and not on the cycle path as is currently the case).

Priority for cyclists from the right

By the end of 1999 legislation will be amended to introduce a general rule that all traffic (incl. cyclists, mopeds and vehicles for handicapped persons) approaching from the right has priority.

Financing

It is estimated that the introduction of articles 4 through 9 of the agreement will require a total investment of f400 million (€182 million). The government has committed itself to funding 50 per cent of the cost and has reserved f200 million in its design budget of 1998. This amount will be made available as a temporary subsidy to road authorities for:

- new 30 and 60 km/h zones
- assigning priority on traffic arterials
- roundabouts
- mopeds on the roadway
- priority for cyclist from the right
- other supporting actions

Enforcement

In order to achieve the objective set for 2000, there should be a genuine intensification of surveillance and traffic enforcement. This particularly to the 50 and 80 kilometre roads.

Local and provincial authorities will ensure that traffic law enforcement with regards to the Sustainable Safety programme is prioritised in the planning of the police and law enforcement agencies and that it becomes an agenda item for the three way discussion forums that currently exist. As a parallel action, a cabinet memorandum will be drafted on means to guarantee effective traffic law enforcement. This will include strategies for intensified law enforcement. The partners will enter into new agreements ensuring that this is applied and realised.

Education and communication

During the implementation of the start-up programme particular attention will be paid to communication with all organisations representing the various road user groups and with road users themselves. The signatories will ensure that large scale publicity and information campaigns are launched to inform road users of changes to the road traffic rules and legislation. These will be supported by educational campaigns at primary and secondary schools.
Supporting measures

A traffic and transport knowledge (technology transfer) centre will be established. To this end an information centre (Information Centre Sustainable Safety) dedicated to providing technical and other support to the implementation of the Sustainable Safety Programme will be established. The information centre will facilitate the exchange of knowledge, provide technical support (guidelines, layouts etc.) and be the medium where road authorities can exchange ideas and experiences during implementation.

Road authorities in consultation with practitioners (consulting engineers, police, road safety specialists etc.) will develop a protocol for the execution of Road Safety Audits. The development costs will be borne by central government. The VNG, UvW, IPO and the Ministry will ensure that local, provincial and national road authorities and practitioners are made aware of the road safety audit procedures and processes.

The state, in collaboration with road authorities, will ensure that CROW guidelines are published for the design and layout of Sustainable Safe roads. In consultation with road authorities, design criteria will be tested in pilot applications and demonstration projects. In 1999 definite design guidelines were published and circulated to end users.

Expected benefits

From previous research results the road safety effects expected from the implementation of the Start up programme have been extrapolated (table 4):

Table 4 Expected benefits of the measures

<table>
<thead>
<tr>
<th>measures</th>
<th>expected benefits for road safety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assigning and controlling priority on primary roads (freeways, expressways and distributors)</td>
<td>a reduction of 10 per cent of the total number of road accidents at intersections</td>
</tr>
<tr>
<td>Introduction of 30 and 60 km/h traffic restraint zones</td>
<td>The phase 1 expansion of 30 and 60 km/h traffic restraint zones is anticipated to yield a reduction of between 10 and 20 per cent of all accidents in the areas where the traffic restraint zones are introduced and the infrastructure adapted.</td>
</tr>
<tr>
<td>Uniformity in the layout and design of roundabouts</td>
<td>The conversion of the old “yield to approaching traffic” rule to the “yield to traffic on the circulating carriageway” rule and associated changes to the layout and design of the old style roundabouts will have a limited effect on road safety. However, uniformity in design and layout will have a positive effect.</td>
</tr>
<tr>
<td>Moped on the roadway</td>
<td>On routes where mopeds are displaced from the cycle path to the roadway the anticipated effect is a 50 per cent reduction in injury accidents involving moped riders.</td>
</tr>
<tr>
<td>Priority cyclist from the right</td>
<td>The introduction of this measure will have an indirect effect on road safety.</td>
</tr>
</tbody>
</table>

Phase 2 - the path to 2010

During 1999 a detailed action plan will be developed for the implementation of the second phase which covers the period 2002 to 2010. In essence the second phase will entail the realisation of the planned new road categorisation plans, design standards and guidelines for the new road network hierarchy determined for Sustainable Safety and the cementing of new funding streams for traffic safety.

Intrinsic to the second phase is the further expansion of the 30 and 60 km/h networks. Furthermore, the 30 and 60 km/h zones realised during the first phase will generally not comply to the concept of optimally traffic calmed. Due to financial constraints, most of these zones are realised on the basis of providing infrastructure at only those locations within the area that were designated as unsafe or potentially unsafe (the so called “sober” approach). In practice this may mean that between measures drivers are still able to exceed posted speed limits. A safe sustainable road network aims to make each road class unique and recognisable to the road user and equip it with infrastructure that elicits the correct behaviour. To achieve that over the length of
especially the access road network (30 and 60 km/h) implies that measures will need to be taken at short, regular intervals.

During the time frames set by Sustainable Safety there will undoubtedly be developments in transport, information and communications technologies (e.g. automatic vehicle guidance systems, Intelligent speed adaptation and other ITS applications). As these evolve and their possibilities in terms of enhancing road safety become clear, they can be incorporated into the longer term planning of the second phase.

Demonstration projects

To demonstrate the concept of sustainable safety to a broader public, a start has been made with implementation in practice. For that purpose four demonstration project were selected and are currently running. The objective of the demonstration projects is to show how road traffic accidents can be reduced by an approach focused on the tools of sustainable safety.

By disseminating information and knowledge gathered through the experiences with the demonstration projects, new knowledge can be brought to the notice of others and capacity built in this way. This new knowledge is important for the realisation of other projects.

The four demonstration projects selected were in the areas of West Zeeuws Vlaanderen, Grubbenvorst, Oosterbeek and KOVO. In addition there are two similar, although independent, initiatives running in the areas of Westland and West Friesland.

Short descriptions of the demonstration projects are given in Appendix 1.
5. TRAFFIC CALMING MEASURES

Traffic calming measures are integral to sustainable safety and their use is heavily dependent on the road category.

Roundabouts

The roundabout is a good example of a balanced infrastructural measure that prevents high driving speeds, reduces the number of conflicts, decreases speed differences and variations in effects caused by mass and direction.

Roundabouts have become common at intersections in the Netherlands. Their popularity is largely due to their effectiveness in reducing road accidents and their relatively high traffic capacity when compared to more traditional types of intersections and traffic control installations. New roundabouts are being constructed in the Netherlands at a rate of 50-60 per year.

Roundabouts have a considerable impact on road safety. A study (SWOV, 1995) has shown that where intersections have been converted to roundabout control, there is a 57 percent reduction in registered accidents and a 76 percent reduction in casualties. Where separate cycle tracks are constructed around roundabouts, the number of casualties falls by as much as 90 percent (table 5).

Table 5: Comparison of accidents before and after construction of roundabout (source: SWOV, 1995)

<table>
<thead>
<tr>
<th></th>
<th>Number of locations</th>
<th>Accident ratio (accidents after/accidents before)</th>
</tr>
</thead>
<tbody>
<tr>
<td>death</td>
<td>177</td>
<td>0.06</td>
</tr>
<tr>
<td>injuries</td>
<td>177</td>
<td>0.28</td>
</tr>
<tr>
<td>material damage</td>
<td>177</td>
<td>0.47</td>
</tr>
<tr>
<td>total</td>
<td>177</td>
<td>0.43</td>
</tr>
</tbody>
</table>

From this research it was evident that roundabouts always improved road safety, irrespective of the intersection control it replaced. At previous traffic signal controlled locations, roundabouts were found to reduce accidents by as much as 35 percent.

Table 6: Accidents and types of traffic control (source: SWOV, 1995)

<table>
<thead>
<tr>
<th>control</th>
<th>Number of locations</th>
<th>Accident ratio (accidents after/accidents before reconstruction of intersection to a roundabout)</th>
</tr>
</thead>
<tbody>
<tr>
<td>no traffic control</td>
<td>18</td>
<td>0.33</td>
</tr>
<tr>
<td>priority</td>
<td>150</td>
<td>0.42</td>
</tr>
<tr>
<td>signals</td>
<td>9</td>
<td>0.65</td>
</tr>
<tr>
<td>total</td>
<td>177</td>
<td>0.43</td>
</tr>
</tbody>
</table>

Roundabouts in the Netherlands have several important features:

- approach roads connect radially (90 degrees) to the roundabout;
- The central island is raised has a diameter of 13 - 30 m. The outer edge of the island is mountable to accommodate larger vehicles (in essence this is a raised inner lane of 1 - 2m with)
- lane width: 5-6 m;
- traffic on the roundabout has priority;
- ideally, the roundabout has a separate cycle track;
- maximum capacity: 20 to 25 thousand motor vehicles per day (3.500 - 4.000 vph).
Residential areas and 30 km/h zones

As table 1 shows, residential (access) roads are also relatively safe. These roads are constructed so that actual driving speeds cannot exceed 30 km/h.

In the Netherlands, a 30 km/h zone may be created only if the road environment, with possibly including traffic-calming measures, supports a maximum speed limit of 30 km/h.

A study conducted in 13 pilot areas showed that the creation of 30 km/h zones was a very effective way of improving safety and the quality of life in residential areas. The study found that:

- the number of movements by motor vehicles fell by 20-30 percent in the pilot areas;
- the number of accident casualties declined by 30 percent on average;
- 80 percent of local residents were satisfied with the creation of a 30 km/h zone.

To achieve appropriate behaviour in a residential area, traffic-calming measures are necessary. If higher speeds are possible, the maximum distance between measures should be around 80 m. Since all locations within the area also need to accommodate for larger vehicles, roads are designed and constructed for higher design speeds get with a layout supporting a 30 km/h limit. This makes the road's ambience important. The 30 km/h speed limit must be a logical product of the road's character and appearance.

The entrance to a 30 km/h zone usually demands special attention. It is very important to make road users aware of the change in the speed limit. In the Netherlands, this change is often marked by an exit construction. This is a raised construction on which the pavement and cycle track merge with the road, preventing vehicles from driving into or out of the 30 km/h zone at high speed.

There are several types of traffic-calming measure:

- intermittent road narrowing;
- humps (the raising of the road for a short distance);
- plateaus (raised surface, usually at junctions and intersections);
- full or partial diagonal closures;
- informal street furniture;
- chicanes;
- combinations of the above.

30 km/h humps

A common traffic-calming measure is the 30 km/h speed hump. Notwithstanding the increase in noise and vibrations, experiences have been good. The preferred design is the "sinusoidel" hump, which causes little inconvenience to cyclists. When several humps are located in succession in order to enforce the 30 km/h speed limit, the distance between them should be around 80 m - and in any case no more than 100 m.

Plateaus

A plateau is actually a kind of elongated hump with a trapeziodel profile. The length of its slopes determines its traffic-calming impact. A plateau can be combined with a crossing for cyclists or pedestrians or with a bus or tram stop. Plateaus can be installed in either 30 or 50 km/h zones.
Narrowing of the road on one side

The intermittent narrowing of the road on one side is a measure applied in 30 km/h zones in order to shorten the crossing distance for pedestrians. It is especially appropriate near public facilities such as schools and libraries. Preferably, the road should be narrowed on the side of the public facility itself.

Intermittent narrowing of the road on both sides in order to achieve a desired width

If the road paved with of a road in a 50 km/h zone is too wide, it is intermittently narrowed to a width of 5.5 m. The double sided narrowing is achieved by extending both kerbs into the roadway. Ideally the dimensions of the kerb extensions should be usual.

Narrowing by means of a central reserve

This measure has the same aim as the one described above namely: to make the road narrower where it is too wide. The advantage of constructing a central reserve (at least 1.5 m wide) over narrowing the whole road is that it causes less inconvenience to cyclists. A prerequisite is that shard traffic lanes are at least 2.6 m wide. Medians also present overtaking and accommodate staged pedestrians crossing movements.

Electronic means

It is not always possible to construct speed calming measures. When this is the case, electronic means are used to enforce the rules of the road. The Netherlands has conducted several experiments with permanent radar monitoring and with loops inductive buried in the road surface for electronic speed surveillance. These measures are often combined with the use of cameras to record the registration numbers of vehicles exceeding the speed limit. Also variable message signs are used to inform road users that they are driving too fast. These electronic measures have achieved very good results. Another electronic combination currently being experimented with is that of red traffic light cameras combined with speed cameras. Road users who fail to stop at a red light or who exceed the speed limit on the approach will be detected, recorded and fined.

Intelligent Speed Adaption (ISA)

ISA is a collective name for the systems used to actively monitor and regulate speeds of individual vehicles. In essence ISA monitors individual vehicle speeds in an area, compares that to the posted limits and automatically adjusts the vehicle speed if this is too high. ISA comprises an on board computer, a satellite linked route guidance system (digital GPS) and a speed governor.

ISA is currently being evaluated in a pilot project in Tilburg in the Netherlands. The system is also being tested in Sweden. The system in Sweden differ somewhat from the Dutch ISA. The Dutch ISA is active in the sense that if a vehicle exceeds the limit the system automatically controls the accelerator and reduces the speed. The other systems are in a sense passive and warn drivers that they are exceeding the limit.
6. REFERENCES

J. van Minnen, *Rotondes en voorrangsregelingen* ("Roundabouts and priority control") (SWOV, Leidschendam, Netherlands, 1995)

*Voorkomen blijft beter* ("Prevention is better") (a brochure published by the Ministry of Transport, Public Works and Water Management, 1995)

*Aanbevelingen stedelijke verkeers- en vervoersvoorzieningen* ("Recommendations on urban traffic and transport facilities") (CROW, Ede, Netherlands, 1986)

*Sustainable Safety - A preventative road safety strategy for the future* (traffic Research Centre, G. Schermers, Netherlands 2000)

*Road traffic safety in the netherlands; past and future* (traffic research centre. J. Kraay, Netherlands 1998)

*Influencing high driving speeds in built-up areas by infrastructural measures* (traffic Research Centre, P. van Vliet, Netherlands 1996)

*Design aspects for sustainable safe roads* (CROW, H. Talens, Netherlands 1999)

Handboel Categorisering van wegen op Duurzaam Veilige basis (CROW, Netherlands, 1996).
7. APPENDIX: SHORT DESCRIPTIONS OF DEMONSTRATION-PROJECTS

West-Zeeuwsch-Vlaanderen

This relatively small area has the highest number of accident fatalities in the Netherlands, mainly due to an inadequate major road network and the poor design and layout of roads presently functioning in this capacity.

Consequently the focus in this area is on the upgrading and provision of an appropriate road network infrastructure, particularly in the rural areas. A well defined road hierarchy linking cities/towns with the capacity to accommodate (large) volumes of through traffic is not evident. Consequently a new road network hierarchy has been developed on the basis of the new Sustainable Safety road categories (freeways, distributors and access roads) and this is currently being implemented. Seeing that the focus is on the rural road network the area has been divided into 9 sub-projects, seven of these focusing on infrastructure, one on enforcement and one on road user behaviour. An open plan procedure has been adopted to involve all role-players in the decision making process. The seven infrastructure sub-projects focus on the implementation of infrastructural measures (incl. traffic calming on 60km/h rural access roads) and these are being identified and selected with affected parties. The enforcement project focuses on speed, alcohol, crash helmets, seatbelts and vehicle standards. The road user behaviour element concentrates on communication, education and awareness. It is anticipated that once implemented the number of injury accidents in the area will be reduced by 55 - 60%.

Oosterbeek

This demonstration project focuses on the re-engineering of the urban road network of the town Oosterbeek, with major focus on a predominant major road in the town, carrying both large volumes of through and local traffic. The demonstration project has as aim the reduction of through traffic, improving public transport, improving road safety and operation on the major road, creating awareness and rallying support amounts residents and users for measures taken throughout the town, effect on road user behaviour, de-veloping a road network categorisation plan for the area. Once again there is a great amount of emphasis on infrastructure provision (incl. traffic calming) and upgrading, supported by public participation in planning and design and also by education/communication and training.

Grubbenvorst

Grubbenvorst has a major through road running through it and this has brought about numerous problems. Consequently it was decided to develop a longer term strategy to re-classify and re-engineer the existing network to be safe and sustainable, to adopt a safe mobility policy (incl. reduction of non-local traffic), integrated and safer land-use planning and safe road user behaviour. The focus of this demonstration is on promoting cycling and to a lesser extent public transport. To encourage this traffic calming measures are being used to discourage through traffic, reduce speed and modify behaviour.

This is actively supported by communication, training and promotion. Based on the provision of an integrated traffic and transportation plan a new road network designed on the basis of predominant modal splits is being implemented. This includes the provision of new infrastructure for through traffic (a ring road).
Kop van Overijssel

The KOVO project entails the development and implementation of measures designed around a new classification of the urban and rural road network hierarchy. The new classification was developed with extensive participation of all interested and affected parties. A series of workshops were held throughout the region to formulate a concept plan based on the Sustainable Safety classes and principles. This was then amended and adapted on the basis of other policies affecting traffic and transportation (environment, quality of life, mobility etc.). Based on long term traffic forecasts, a traffic assignment model was applied to evaluate the effects on the new network. From this a final hierarchy was developed and infrastructural measures selected to re-engineer the roads in accordance with the new function and class.

Westland

Problems underlying the road safety problem in this area include an old road network not designed and with an inappropriate layout for modern day traffic, poor functional differentiation of road types, limited separation of different modes, poorly distinguished rural/urban boundaries and large speed differentials between road users. An integrated approach involving engineering (infrastructure), education, promotion, communication and enforcement was adopted at the outset. Based on the identification of 100 road safety improvement projects in the area, an integrated implementation plan was developed, starting with the re-classification of the existing network, supported by traffic calming infrastructure, re-designed layouts enforcement programs on speed alcohol, seatbelts and crash helmets, education at schools and awareness amongst users and provision for cyclists and heavy goods vehicles. The plan is currently being implemented and aims to reduce accident casualties by 25% by 2000 (compared to 1986).

West Friesland

This area comprises some 400km of roads in predominantly a rural environment. It is one of the few areas in the Netherlands where the number of injury accidents has increased (by 14%). In this area particularly 50km/h without cycle paths and 80km/h roads have high accident rates. Consequently an integrated road safety plan (for all national, provincial and local authority roads) has been developed on the basis of the Sustainable Safety principles.

The plan integrates two approaches, firstly the reactive approach aimed at addressing all hazardous locations and secondly the pro-active approach to re-engineer the existing network to be safe, self-explaining and forgiving.

The emphasis in the region is on the provision of facilities and infrastructure, tourism and recreation with active support on creating awareness. Enforcement and education are not featured in the approach. To date a large number of roundabouts and traffic calming measures have been constructed. A 60km/h zone has also been realised.

Since 1996 slight injury accidents in the region have been reduced by 19% and serious injuries by 35%.