Country Report – the Netherlands

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Abstract

This paper provides an overview of the most significant developments in the area of road (geometric) design practices and standards and related research in the Netherlands in recent years. The paper describes the importance of the Sustainable Road Safety policy in this context. Furthermore, it provides a summary of a number of new initiatives and developments with respect to road and intersection design with a specific focus on related (road safety) research and its role in the development and application of guidelines.

Since 1998 the Netherlands has applied the principles of Sustainable Safety in road design and over the years these have been researched and in varying degrees been adopted into geometric design standards and guidelines. In recent years the strategic direction of road safety has shifted from being focussed on predominantly infrastructure to concentrating on regular traffic offenders and vulnerable road users and where technological innovation plays an important role. The newly adopted road safety strategy for 2020 is a testament of this shift. However, road authorities, standards and research organisations continue pursuing the long term vision set out by the Sustainable Safety programme by adapting the road environment and related standards and guidelines to meet the ongoing challenge of further reducing road accidents. To facilitate and support these developments, extensive research programmes have been carried out and these include driving simulator research into the (behavioural) effects of, for example narrow cross-sections, research into safe and credible speeds and research into the effects of road design and layout on road safety. The results of these research programmes are used in the development and/or amendment of road design guidelines and standards. Examples discussed in the paper include the implementation and evaluation of the essential characteristics for the recognition of road infrastructure, the further expansion of 30 and 60km/h zones and 2+1 roads.

The paper further elaborates on the following significant and related developments:

- Optimising the use of available road space through innovative design and traffic management procedures (e.g. network approach; emergency lane etc.)
- the planned new guidelines for national highways
- guidelines for signing and marking at road construction zones
- the guidelines for essential characteristics for the recognition of road types
- experiences related to the use and design of turbo-roundabouts (traffic circles) and subsequently adopted design guidelines
- design guidelines for 2+1 roads
- the Dutch traffic safety handbook
- the relationship between road design and (direction) signing and in-car/roadside information systems
- Human factor guidelines (the so called Golden Rules). The focal point of Sustainable Safety is that the human and consequently human factors still play an increasingly important role in road design in the Netherlands.

The Sustainable Safety programme has been around since 1997 and has had a major impact on infrastructure design and the way in which the Netherlands approaches road safety. This has resulted in 10 years of re-engineering major parts of the Dutch road network and making a significant contribution to the 300 to 400 fewer road traffic fatalities in 2007 when compared to 1997. This paper will briefly touch on these effects. The paper closes with an overview of other future developments and their possible consequence on road design practices in the Netherlands.

1 Introduction

Up until the early 1970s the major road network in the Netherlands consisted of primarily two-lane rural roads, which with the increased traffic demand began to experience the negative effects of congestion and of poor road safety. In an attempt to address these growing problems the Netherlands embarked upon an extensive programme to provide a high quality national road network of motorways. The structure of this network was largely determined by existing origin-destination patterns and by new emerging patterns resulting from large-scale newer developments. These roads were designed and built to the highest geometric standards and this, in conjunction with other policy initiatives, contributed to reversing the increasing trend in serious road accidents whilst improving traffic flow. However, the increasing traffic demand fuelled by rapid economic growth in the 80s and 90s soon manifested safety related problems on especially the underlying networks. This culminated in the development of the Sustainable Safety policy, which took a radical new look at the structure of the road network and proposed significant modifications to redress the situation. Since 1998, the principles of Sustainable Safety have been adopted in most of the design guidelines in the Netherlands and the effect of this can be seen on the existing road network.

Recent shifts in especially the National road transport policy arena have resulted in adapted work procedures and processes which impact directly on the quality of the future road network. This country report attempts to provide an overview of the most significant and recent developments relating to road infrastructure design and operations in the Netherlands. The paper supplements and builds upon an overview presented at the previous Symposium on Highway Geometric Design (Stembord and Kwint, 2005).

1.2 Background to sustainable safety

Following the road safety policies aimed at legislation and infrastructure provision in the 1970's through measures aimed at passive safety and behavioural changes in the 1980's, the Dutch Ministry of Transport set out a spearhead policy in 1988. This targeted the reduction of black spots, speeding, drink driving and accidents involving heavy vehicles, cyclists or mopeds. The spearhead policy set out a target to decrease fatal accidents by 50% and serious injury accidents by 40 % by 2010, using 1986 as the reference year. In the early 90's it was evident that these goals would not be reached and this resulted in the development of Sustainable Safety (Koornstra et. al. 1992). Its underlying philosophy was that the human being is central and that the system should be designed to accommodate for the limitations of humans in a road traffic system. Furthermore, Sustainable Safety advocates a preventative approach rather than a curative one. The original sustainable safety concept was based on three safety principles:

1 Functionality: to prevent unintended use of the infrastructure
2 Homogeneity: to prevent major variations in speed, direction, mass of vehicle at moderate and high driving speeds
3 Predictability: to prevent uncertainty among road users

The above principles were translated into concrete measures aiming at creating:

- A road environment with infrastructure adapted to the limitations of the road user. Three classes of roads are defined: roads with through function for rapid movement of through traffic; roads having a distributor function for distribution and collection of traffic to and from different districts and residential areas; roads with an access function providing access to property whilst simultaneously providing a relatively safe space for different road users to interact and for people to meet. Each of these road classes has to comply with certain functional requirements making each category different and readily recognisable to the road user.
- vehicles equipped with technology to simplify the driving task and provided with features that protect vulnerable and other users
- Road users that are well informed and adequately educated.

The first phase of Sustainable Safety was implemented in the period 1998-2002. Amongst others road authorities were asked to develop new, functional road network categorisation plans, to re-engineer their road networks in accordance with these plans (especially increasing the number of 30km/h zones in urban areas and 60km/h zones in rural areas), to assign priority at all intersections along distributor roads, to provide measures to accommodate mopeds on the roadways and to improve the layout of all roads in such a way that these became recognisable to road users.

The second phase (2003-2010) not only focussed on infrastructure improvements but also on road user education and information dissemination, stricter enforcement, vehicle technologies (alcohol lock, EuroNcap), spatial planning and specific measures aimed at the commercial road transport sector (safety culture in freight transport).

Although the first phase of the Sustainable Safety programme proved successful, it was felt that the momentum was to an extent lost in the transition between the first and second phases. This resulted in the strategy being reviewed (Wegman and Aarts, 2005) to provide a new stimulus. The original vision was still supported although it was defined more precisely. The human being was given an even more prominent role. Firstly, to prevent fatal and serious injuries, the homogeneity principle was elaborated by defining "safe speeds" for a variety of impact conditions. Secondly it is accepted and recognised that human beings make errors in observation, decision making and implementing decisions (Reason, 1990). Based on the "Swiss Cheese model" of Reason (1990), Sustainable Safety strives to create an environment for road users that reduces human error and when these are unavoidable, provide an infrastructure that is forgiving. Consequently two additional safety principles, based on scientific theories and research, were added to those mentioned above and served to strengthen the philosophy of Sustainable Safety. These principles are:

1. Forgivingness of the road environment. Provide a road environment that minimises the risk of injury and allows for road users to adequately anticipate to given dangerous situations
2. State awareness. Road users must be able to assess their own task capabilities for any given traffic situation.

From a road design perspective, Sustainable Safety has the ultimate goal of realising a road network in which the relationship between function, form and use are in harmony. In effect this strives for monofunctionality of roads where the design of each category accommodates its own traffic demands and allows for the safe and reliable movement of people and goods. An inherent design principle is that each road type actively strives to minimise the consequences of road accidents, that is to say eliminating fatal accidents and reducing the severity of injuries (i.e. the design lends support to the theories of the forgiving roadsides and self explaining roads).

2 Policy developments

The Dutch Government sees mobility as a prerequisite for economic growth and as an established right which gives people the opportunity to develop and enjoy themselves. Since the 1960s, the number of kilometres travelled by vehicles has increased tenfold. Under a high growth scenario, mobility over the period 2000 – 2020 is expected to increase by a further 40% (Ministry of Transport, Public Works and Water Management, 2004). Consequently the Dutch Government has developed transport policy that aims at achieving greater reliability, speed and safety from door to door. The Mobility policy document sets ambitious accessibility goals, focusing on three aspects: reducing congestion, increasing reliability and shortening door-to-door travel times. These goals are quantified as follows:

1. Traffic jam severity (expressed as delays, namely lost vehicle hours) on the main road network may in 2020 not exceed the 1992 levels;
2. Reliability on the main road network must improve so that travellers in 2020 are on time in 95% of peak-hour trips;
3. Travel times must be acceptable, with the following target values applying to the main road network:
    - For motorways between cities, the average travel time during peak hours is no more than one and a half times longer than at off-peak times. On motorways with 100km/h speed limits and assuming a distance of 50 kilometres, this would imply a journey time of no longer than 45 minutes;
    - On motorways around cities and non-motorways that are part of the main road network, the average peak-hour travel time is no more than twice as long as at off-peak hours. For a distance of 10 kilometres this implies an average travel time of no more than 12 minutes.

To achieve these goals the policy relies on three pillars: Construction of new road space, Road pricing, and better utilisation of existing road space. This paper elaborates on the pillars road pricing and utilisation.

2.1 Road pricing: Different Payment for Mobility

The current system for road user charging in the Netherlands is based on taxes, namely a fixed annual road tax (MRB) based on vehicle mass and fuel type, and purchase tax (BPM), a tax that that is levied on every new vehicle sold. Both these taxes will be abolished in the coming years. They will be replaced by a charge per kilometre travelled and include all roads, from motorways to roads in residential areas. Motorists will pay road taxes based on how much they actually drive their vehicles as opposed to paying a flat rate for owning a vehicle. The proceeds from the kilometre charge (a Dutch version of road pricing) will not exceed the combined proceeds from the 'old' taxes. Motorists who drive relatively little, will benefit from the system. The proceeds from the kilometre charge will go to a new infrastructure fund for financing investments in roads, railways and related infrastructure.

By applying a kilometre charge, road users will become more aware of their mobility patterns. In order to pay less they will need to drive less thereby reducing congestion, emissions and improving traffic flow and road safety. Research has shown that the number of kilometres travelled will be reduced by up to 12% and the number of traffic jams will be halved as a result of the kilometre charge. In addition, the number of people killed on the roads is expected to drop by up to 7% (Schermers and Reurings 2009). Road users will start to use alternative forms of transport as a result of which the use of public transport will go up by 6%. The environment also stands to benefit from the kilometre charge, CO_2 and fine particle emissions will be reduced by more than 10%.

Approximately nine million road users will be affected by the introduction of the new system. Pilot studies have been carried out to test the technology and price sensitivity in practice (Ministry of Transport and Water Management, 2009). The ambitions for this cabinet period include completing the legislative process and testing the technology. Until then, the Minister and the Lower House have set clear decision points in order to enable the kilometre charge to be systematically developed.

2.2 Better Utilisation of existing road space

Utilisation is one of the pillars of the Mobility Document (Ministry of Transport, Public Works and Water Management, 2008). This pillar does not yet have an integrated programme approach, as is the case with construction and road pricing. Those two pillars are set out in structural programmes such as the Infrastructure, Space and Transport Multi-Year Programme (MIRT) and the Different Payment for Mobility programme. These pillars are currently in the process of being implemented and this is expected to take several years before full implementation is achieved. The third pillar, utilisation, has a shorter-term focus and the Mobility Document expresses the expectation that it can contribute to better reliability, speed and safety. Utilisation focuses on making the best possible use of available road capacity.

Utilisation is defined in the Policy framework as the best possible management of traffic demand (a given demand) over a road infrastructure supply (a given supply) by

- Optimising road capacity in relation to current traffic demand;
  This is aimed at eliminating problem locations that compromise the handling and flow of traffic in the existing road network. Specifically this refers to small infrastructural adjustments such as extending weaving sections and entry or exit lanes, improving interchanges or providing peak hour lanes.
- Optimising traffic management (longitudinally, laterally and at intersections);
  This is aimed at making traffic flow smoother, e.g., by providing traffic lights, freeway management systems, 80km/h speed limits incorporating average speed surveillance on urban freeways to lower vehicle emissions; roundabouts , using signals to warn oncoming traffic of low speeds ahead of them, and to warn of dangerous locations and situations (tight curves, wind, slippery roads, etc.). This also includes in-car systems that can support the driving task, directly or otherwise (e.g. adaptive cruise control (for longitudinal handling) and lane departure warning (for lateral handling).
- Spreading traffic demand over the network and over the day by informing road users and potential road users;
  This includes aspects such as starting a trip earlier or later, choosing different means of transport or a different route. The idea is to strengthen the ability of traffic to organise itself.
- Guiding and directing traffic, especially in unique situations
  This involves finding the best possible distribution of traffic over the road network. It is not the self-organising ability of traffic that is of primary importance here but channelling and directing of traffic. This assumes that it will be necessary under certain conditions for a road administration to take action to manage traffic. This will be the case when there is (a) a major shortage of road capacity, (b) unwanted

violations of acceptable limits to liveability and safety or (c) serious sudden disruptions. Based on jointly agreed choices (as set out in a rule strategy), the diminished road capacity will be redistributed

2.3 Road safety strategy

In 2008, the Ministry of Transport, Public Works and Water Management published its 'strategic road safety strategic plan 2008 –2020; from, for and by everyone which elaborates on the policy outlined in the Mobility Policy Document (Ministry of Transport, Public Works and Water Management, 2008)).

The short term (2010) road safety goal is to reduce the number of traffic fatalities and seriously injured in the Netherlands to a maximum of respectively 750 and 17,000. Compared to 2002, this equates to a 30% decrease in the number of fatalities and a 7.5% decrease in the number of seriously injured. The aim for 2020 is a maximum of 500 fatalities and 12,250 seriously injured.

The road safety policy is based on the three successful cornerstones that made the safety policy successful over the past years: cooperation, an integral approach and 'sustainable safety'. Two approaches can be identified in the policies for the coming years, based on these three cornerstones. The first approach uses generic measures to continue building on what has successfully been done for years. The second approach focuses on specific areas that require targeted attention. The focal areas were identified analysing accident data and researching trends that may influence road safety in the coming years. The analyses clearly show a number of vulnerable groups. To reduce the risks these groups face, targeted measures will be introduced in the coming years to supplement the more generic measures.

A tough approach will be taken on people who cause unsafe traffic situations, Innovative solutions are an integral part of the range of measures. Using new technologies will help to realise the road safety ambitious for the coming years.

2.4 Improving Planning procedures

The average planning time (time from feasibility to the start of construction) for major road infrastructure projects in the Netherlands is about 12 years (Commission Elverding, 2008). In an attempt to reduce this, a commission was established in 2007 and tasked to investigate the causes for the long turnaround time and to recommend new or adapted work procedures to shorten the feasibility and design stages of major projects.

The Commission established that the decision making process was too drawn out with the primary causes for the delays being attributed to:

– Management culture; poorly prepared project briefs, lack of expertise and budget constraints
– Decision making; inadequate feasibility studies, planning studies were over detailed and based on quasi scientific methods, permits and license requirements
– Judicial factors; sectoral and complex laws (especially environmental) require extensive supporting studies which are used by the courts to test project compliance. Non-compliance or omissions are automatically rejected leading to long delays.

To expedite the process the Commission recommended (Commission Elverding, 2008):
1. Improving the management and administrative culture
2. Improving the decision making process
3. Improving legislation

As was the case in the past, the proposed planning process does not explicitly consider road safety as an item in the decision making process. Steps have been taken to ensure that road safety becomes an integral part of the planning process and by which the road safety effects of planning and design of new, or rehabilitation of existing, road infrastructure are made transparent.

3 Supporting and enabling research

3.1 Driving simulator studies of the relationship between design elements and behaviour

The successful introduction of advanced driver-support systems, dynamic traffic management systems, or complex road designs depends strongly on how road users are capable of, or willing to, deal with such systems. This requires knowledge of people's performance and behaviour in complex and dynamic task environments. Human factors research offers a wide range of methods, each having their own strengths and weaknesses (Alferdinck et al., 2002). The choice for the most suitable method involves a trade-off between similarity to the real world on the one hand, and flexibility and interpretability of experiments on the other. Typically, interactive driving simulators are positioned 'in the middle' on both aspects.

Driving simulators have the advantage of having control over experimental conditions, including light and weather conditions and behaviour of surrounding traffic. Driving simulators enable a dynamic assessment of new infrastructure designs (such as tunnels) through analysis of road-user behaviour in relation to their traffic-management measures and in interaction with other traffic (Van der Horst, Hoekstra & Theeuwes, 1995). Sometimes driving simulator studies are especially suited to research aspects that affect road safety. Consider for example the state of a driver due to a behavioural change caused by drowsiness, alcohol or diabetes (Stork, 2006).

In the Netherlands a wide variety of driving simulator studies have been carried out, ranging from fundamental perceptual and cognitive aspects (e.g. Alferdinck, 2006; Martens, 2005, 2007;) to the design, development and testing of various kinds of in-car driver-support systems and related HMI issues (e.g. Rook & Hogema, 2005; Van Driel, Hoedemaeker & Van Arem, 2007). Driving simulator research has provided extensive input into the drafting of road design criteria (e.g. Van der Horst & De Ridder, 2007; Martens & De Ridder, 2002).

3.2 Safe and credible speed limits

The link between speeds as a primary contributor to accidents and the severity of accident outcome is well established. In the Netherlands, the Sustainable Safety principles strive to optimally manage speeds through design. However, the ultimate vision of a complete road network equipped with road infrastructure that, in addition to being self explaining and forgiving, also complies with the concept of providing self enforcing speed limits is still a long way from being realised. Consequently SWOV developed a vision on safe and credible speed limits (SaCredSpeed, Aarts et. al. 2009), which at the request of road authorities was further developed into a decision support tool.

The SaCredSpeed algorithm considers the type of road users, geometric layout (such as cross-sectional elements), conflict potential and stopping sight distances to derive a so-called "safe" speed for any given set of conditions. This so-called safe speed is based on theoretical considerations supported by research. However, this says nothing about compliance, which in itself is an indicator of the credibility of the set limit. The credibility of the limit is determined by ten supporting design and operational characteristics which research has shown to lead to increases or decreases in driving speeds. These include aspects that relate to the way in which different road users mix; horizontal alignment; road and lane widths, road surface and the surrounding environment. Enforcement plays an important role and the SaCredSpeed approach provides an algorithm to assess the need and type of enforcement required. However, it is recognised that enforcement is a temporary solution to apply in situations where a more permanent infrastructure solution has not yet been implemented.

The SaCredSpeed approach is unique in the sense that it starts from the principle of minimising injury risk in the event of an accident occurring. It makes use of new (sustainable safety) design principles combined with current layout and road environment to set a safe and credible limit. In instances where these cannot be achieved, it proposes enforcement strategies as a short term alternative to ensuring speed compliance.

3.3 Road safety at road works

As part of revising the guidelines for road safety at road works (CROW, 2005), a total of 50 roadwork locations throughout the Netherlands were investigated for compliance with current requirements (Weijermars, 2009). The locations of the sites varied from typical urban to remote rural streets and intersections. The study revealed that the majority of the sites did not fully comply with the requirements stipulated by the guidelines. Lack of compliance was especially evident with regards to signing and marking, provision of separate and protected facilities for vulnerable road users (especially cyclists), speed limits, clear zones and barriers.

The study recommended training programmes for road workers and road authorities in conjunction with targeted publicity/education campaigns. Furthermore, regular inspections should be incorporated to ensure on-site compliance. This is in itself not easy since there are situations where one is forced by circumstances to deviate from guideline recommendations. These situations must be understood and subsequent decisions for a particular solution must be transparent. Excessive and inappropriate speeds at work zones are a problem and need to be specifically addressed in the new guidelines. The study also recommends that the existing guidelines be revised to include specific provisions for crossing cyclists and situations where both cyclists and pedestrians are forced to share road space.

3.4 Relationship between design, signage and in car technology

The concept of the sustainable road safety approach in the Netherlands gives the contours for an inherently safe road traffic system with a balanced interaction between the road user, the road environment, and the vehicle. An integral systems approach also allows for a smart combination of traditional cost-effective road design and operational measures and innovative solutions based on future cooperative road-vehicle/driver systems with optimal interaction between smart road, smart cars, and driver support systems.

In a large-scale Field Operational Test to evaluate Lane Departure Warning Assistance (LDWA) Systems for buses and trucks, the combination of LDWA with narrow motorway lanes was evaluated in a driving simulator study (Hoedemaeker & De Ridder, 2003). It was found that LDWA improves driving behaviour on narrow lane widths, compensates for the effects of a secondary cognitive task, but at the cost of more strenuous driving. In the Roadwise project in-vehicle information (warning to road conditions, driver support information etc), linked to road design and layout, was evaluated using a driving simulator environment before going to field trials (Hogema, 2005).

4 New guidelines

4.1 Signing and marking during construction

When a road is under reconstruction three things are of vital importance: the safety of the road worker, the safety of the road user and maintaining the traffic flow as much as possible. Incorporating the work described earlier (Section 3.3), new guidelines for design and safety at road works were developed. In the guidelines a distinction is made between short and long-term activities.

For the long-term activities a work zone completely separated from traffic is recommended, especially to protect road workers. For example, on motorways this means the closure of one part of the road and putting all traffic on the remaining part of the road (e.g. 4-0 system, a system whereby one carriageway is closed for maintenance/reconstruction whilst the other is reconfigured to accommodate 4 lanes of traffic, two in each direction). A concrete or steel barrier to ensure the safety for road users should physically separate the two directions. Combining numerous roadwork activities (such as renewing asphalt, maintenance on guardrail, lighting, direction signs etc.) makes it worthwhile closing down half the road.

Also for short-term activities emphasis is placed on the safety of road workers. For example, if work is being done on the emergency lane of a motorway, the adjacent lane will also be closed to traffic to provide a safety or buffer zone for the workers. The lane closest to the work zone will be assigned a speed limit of 70 km/h and the farthest lanes will have a 90 km/h limit. Road users will be informed about this in advance.

On motorways the traffic volumes are so high that closing down a lane during the daytime could easily cause major problems. Road works are scheduled to take place during the evening and night time. Although traffic volumes are lower, special measures such as illuminating the work zone and the road leading to the work zone will need to be taken to protect road workers and road users alike.

4.2 Essential Recognisability Characteristics (EHK)

One of the principles of Sustainable Safety is that a road should have a recognisable design and a predictable road course (alignment), eliciting more predictable behaviour from road users (i.e. road users know which behaviour is expected of them and what they can expect from others). This contributes to the prevention of errors and road crashes.

By introducing a unique set of road markings for each road category, an affordable solution has been created with which to distinguish road types for the road user:. rural access roads, if sufficiently wide (>4.5 m), have a driving lane with broken edge marking; distributor roads have a broken edge marking plus double continuous centreline; and regional through roads have a continuous edge marking and double continuous centreline with a green marking in-between (Figure 1).



through road distributor road access road

Figure 1: Examples of EHK markings

In 2004, a guideline on EHK (CROW, 2004a) was developed and published. Road authorities have been given 15 years to implement these recommendations. However, the maximum levels of safety based on Sustainable Safety approaches will not be reached by implementing only EHK. EHK is meant to be an intermediate step to a sustainable safe road design.

4.3 Turbo roundabouts

Roundabouts are now commonplace in the Netherlands and are generally of the traditional single lane, radial approach design. Generally priority on roundabouts is given to (motorised) traffic on the circulating carriageway. However, the many cyclists in the Netherlands necessitates special cyclist provisions at roundabouts. As a rule, on single lane roundabouts in built up areas cyclists are subjected to this same priority rule (i.e. entering/exiting traffic has to yield). Because of the higher driving speeds on roads outside built up areas, the rule is reversed and cyclists have to yield to motorised traffic entering/exiting the roundabout. This has caused a fair bit of discussion in the Netherlands, especially as far as uniformity in design is concerned. Consequently, some road authorities have opted to always give priority to motorised traffic whereas others apply the recommendation in the guidelines. Where cyclists on a segregated cycle path do have priority over motorised traffic, it is recommended to bring the cycle path away from the roundabout so that cyclists cross the approaches at a 90^0 angle thereby improving the visibility of the cyclists, especially for exiting traffic.

Multilane roundabouts are not encouraged from a safety point of view although there are situations where more capacity is needed and these are sometimes constructed. However, to provide a safer alternative to traffic signals or multilane roundabouts, the turbo roundabout design was developed by a local Dutch traffic engineer, Mr L.G.H Fortuyn and has since been widely applied. Consequently new guidelines specifically for turbo-roundabouts have recently been issued (CROW, 2008).

Turbo roundabouts, which are multi lane roundabouts with spiral road markings and separated circulatory lanes (Figure 2), perform much better on capacity and safety, while they do not need extra space. The use of multi lane roundabouts is discouraged and where these exist they are being replaced with the turbo roundabout.

The main characteristics of a turbo roundabout are:

1. A turbo roundabout has more than one approach and circulatory lane;
2. The correct lane has to be chosen before entering the roundabout;
3. Entering traffic has to give way to circulating traffic;

4. On the roundabout itself no weaving or lane changing is possible;
5. The roundabout can only be left via the previously chosen lane.
6. As a rule motorised traffic has priority over cyclists. Where deviations from this are necessary special provisions have to be made to ensure the safety of cyclists.


Figure 2: Turbo roundabout

The main reasons for choosing a turbo roundabout above other intersection control types are (CROW, 2008):

- The capacity of a turbo roundabout is higher than a single lane roundabout (1½ to 2½ times as high) or a two-lane roundabout (1 to 1½ time as high).
- The capacity of a turbo roundabout is equal or higher than a signalised intersection. The delays are lower than at a signalised intersection.
- A turbo roundabout is safer than a priority controlled intersection (± 70% fewer fatal and serious injury accidents) and safer than a signalised intersection (about 50% lower).
- A turbo roundabout is less safe than a single lane roundabout (20% to 40% more accidents) but has higher capacity and is still safer than signalised intersections with similar traffic demands.
- The area occupied by a turbo roundabout is about the same as that needed for a signalised intersection (taking into account that it is possible to pass the intersection with two trucks simultaneously, in all directions).
- The construction costs of a turbo roundabout are higher than an intersection with traffic lights, but the life cycle costs and social costs are lower.

4.4 2+1 roads

Many rural distributor roads, and some through roads, do not comply with the newer design requirements stipulated by Sustainable Safety. Furthermore, traffic volumes on distributor roads, although low when compared to through roads, are relatively high for two lane, single carriageway roads (volumes in excess of 20.000 veh/day are quite usual) and consequently these roads have a comparatively poor accident rate. In the longer term many of these roads are candidates for upgrading to dual carriageway standard whilst in the short term actions are needed to improve safety and comfort. A cost effective solution applied extensively in other countries, especially Sweden was the 2+1 road, a single carriageway rural road with three lanes where the centre lane is alternatively used to provide overtaking opportunities in each direction (Schermers, 2004). These experiences resulted in the formation of a CROW working group tasked to develop guidelines for the application of these roads in the Netherlands (CROW, 2008). The guidelines, based predominantly on German and Swedish design standards were published in 2008, following shortly after the implementation of the first 2+1 road in 2007, the N50 between Kampen and the A28 motorway.

The 2+1 road to a large extent solves the problems related to overtaking accidents (frontal), especially when a physical separation of the driving directions is introduced as part of the design solution. Since capacity is only marginally improved, the 2+1 road in the Netherlands has a limited service life considering the already high traffic demand. Nevertheless, the 2+1 road is seen as an interim solution to ultimately providing a dual carriageway. Bearing the ultimate solution in mind, the designer is encouraged to design the 2+1 section as one of the carriageways and to make provision for a second carriageway in the overall design (especially ensuring that bridges/overpasses etc. allow for this). In this way construction costs are spread whilst the design provides the necessary flexibility to introduce the second carriageway when traffic demand warrants it. The construction of the second carriageway then causes minimal disruption to existing traffic.

4.5 Road Safety Manual

All information related to road safety has been published in one manual. The 'Road safety manual' is the English version of the Dutch CROW-publication 261 'Handboek verkeersveiligheid' (CROW, 2008) (http://www.crow.nl/shop/productDetail.aspx?id=1066).

This manual clusters all the knowledge about road safety in the Netherlands. It consists of three parts.
Part 1: understanding road safety: theory; trends and developments; policy; data collection and data analysis; and practical research.
Part 2: making traffic safer: spatial planning and the road environment; infrastructure; vehicle safety; traffic education and traffic enforcement.
Part 3 dangerous behaviour, dangerous groups, and measures to address these: risk-taking behaviour, specific groups of road users, practical examples

4.6 Road categorisation

As mentioned earlier, most roads in the Netherlands are classed into one of the three road types: through road, distributor road or access road. This classification principle supports the concept of monofunctionalty (i.e. a road has either an access or a traffic flow function). Each road category has specific functional requirements which determine road layout and traffic operation. However, some roads outside built-up areas and many roads inside built-up areas have more than one function (access and traffic) and due to various constraints cannot be made to comply with the design requirements for that class of road. These roads are called "grey roads", roads for which each road authority is attempting to develop their own unique solution within the concept of the categorisation plans outlined by the guidelines (CROW, 1997).

In order to give road authorities tools to handle this problem in the same way as other road authorities, new guidelines are being developed. In these guidelines solutions will be presented closely related to the system of the three road types. The setting of appropriate speed limits will play an important role in this (see section 3.2). When these guidelines are used throughout the country road users will get only a limited amount of road categories presented. This will help make the distinction between categories of roads clear to the road users.

5 From guidelines to implementation

Since the introduction of the Sustainable Safety programme in 1997 significant progress has been made towards implementing the required changes to the road infrastructure. By the end of 2008, the following progress could be reported (Weijermars and van Schagen, 2009):

- In excess of 90 % of all road authorities had developed new road classification plans and used these as the basis for future planning studies. The majority of the road authorities had made extensive use of the CROW guidelines (CROW, 1997) for road classification.
- Approximately 70% of the total length of urban roads had been allocated speed limits of 30km/h and of these roughly 70% were provided with speed reducing measures, either only at the intersections or on both road sections and intersections. These vary from low cost solutions such as markings and signing to more expensive raised intersections, humps and reconstructions.
- Approximately 57% of the rural road network had been allocated speed limits of 60km/h and 45% of these were provided with supporting speed reducing measures, either at intersections only or at both intersections and road sections.
- Most intersections on urban distributor roads were assigned some form of intersection control, sometimes in combination with measures that reduce speed. Approximately half of these roads still provide direct access to adjacent properties, a characteristic that is not suited to this type of road. Roundabouts, priority control and signals, sometimes in combination with speed humps or speed tables, typically control intersections between distributors. Uncontrolled intersections are also still exist and are sporadically applied.
- Approximately 40% of the rural distributor road network had been provided with the so-called essential road marking strategy (EHK) outlined by the guidelines (CROW, 2004). Intersections between rural access roads and distributors are largely priority controlled whereas intersections between rural distributors are

mainly roundabout, priority or signal controlled. Over the period 1998 – 2005 the number of roundabouts in the Netherlands increased from 1442 to 3451.

5.1 Improved utilisation of freeway infrastructure.

As mentioned earlier, peak hour lanes on the Dutch freeway network were introduced to reduce the growing congestion on certain parts of the network. To facilitate this, legislation was passed making it possible to affect these changes without following the normal time consuming procedures required for new infrastructure (Stembord and Kwint, 2005). In essence these are projects where the emergency lane is used as a traffic lane during periods of high demand. These roads have to comply with stringent requirements set out in guidelines (AVV, 2004) which include designs elements, lower speed limits (using Variable Message Signing), automatic incident detection, Freeway Management, turnouts and other related measures.

In the period 2002 – 2009, 12 projects of this type have been introduced and the implementation of a further 30 projects is expected by May 2011.

6 Other developments

6.1 Human factor guidelines

Human error is considered to be a major contributing factor in the occurrence of accidents. Even if people are highly motivated to behave safely, they will make errors that, consequently, may result in accidents (Wegman and Aarts, 2005). A human-centred design and an integrated road traffic system taking the human capabilities and limitations into account can minimize both the occurrence and consequences of human error. Recently, the Dutch Ministry of Transport came up with a popular version of ten golden human factor rules to take the road user into account to help road designers and traffic engineers reduce the probability of human error in road traffic (Wildervanck, 2008). A more elaborate theoretical background for these rules, including several examples of implications for safe road design and traffic management is provided by Kuiken et al. (2009). The rules include information elements on the road and roadside, the interaction between different information elements, the situational context, traffic and the driving task, and characteristics of the road user as a human being.

6.2 European Directive on Road Safety Management

The European Union published a directive on road infrastructure safety management (Commission of European Communities, 2008) and which was passed into legislation in November 2008. The Directive makes it compulsory for all road authorities responsible for the Trans European Road Network (TERN) to apply a minimum set of procedures seen as essential for the safe operation of these roads. The procedures covered by the Directive include Road Safety Impact Assessments, Road Safety Audits, Network Safety Management and Road Safety Inspections. The implementation of the Directive (which will be finalised by the end of 2010) is estimated to save 600 fatalities and 7000 serious injuries per year once all the procedures have been adopted and applied to the TERN.

Since TERN roads in the Netherlands fall predominantly under the control of the Rijkswaterstaat (RWS), they are currently developing the procedures to adopt and implement the Directive. This is expected to be in place and tested during 2010 (Twijnstra Gudde, 2009). Provincial and municipal roads are essentially excluded from the provisions of the Directive. Developing and implementing a similar system for roads falling under these administrations should be seriously considered to maximise the potential positive effects.

6.3 Quality assurance

Towards a Sustainable Safe Road Traffic (Wegman and Aarts, 2005) recommends a system of quality assurance for road infrastructure design, maintenance and operations. Quality assurance is based on a systems approach and strives to achieve a high degree of uniformity. However, there are three factors which have a material impact on the quality of the road traffic system:

- There are many organisations (both public and private) involved in the provision and management of road infrastructure and of traffic. This may lead to inconsistent design, a lack of uniformity and different approaches to problem solving.
- Road safety has to be considered against other interests and priorities. These processes need to be transparent to reflect both the complex decision making processes and complex social environment.
- Given the diversity in political and other priorities, compromises in the policy and decision making processes in the transportation sector are almost inevitable. However, from a safety point of view these may lead to a deviation from the Sustainable Safety vision, culminating in non-optimal solutions being implemented.
- A quality assurance system for road authorities strives to provide procedures for planning, design, evaluation and analyses of potential defects. The system facilitates the development of expertise and will make clear to all parties involved in road safety that ongoing commitment and improvement is paramount to success. Quality assurance should be entrenched as an integral part of the working procedures within those organisations responsible for road safety. All products and processes related to providing road infrastructure and traffic management should be subjected to quality reviews.

Some of these topics are also covered by the recently introduced EU Directive on road traffic safety management and are being introduced as standard procedures for all projects affecting the national road network. As far as Dutch road authorities are concerned the Rijkswaterstaat (RWS) has taken a leading role in the area of quality assurance in safety and design by:

1. Developing and implementing a code of practice for the design and construction of infrastructure
2. Developing, implementing and evaluating a RWS Safety Management system
3. Developing procedures for adopting the EU Directive on road safety management

7 Conclusion

Over the past ten years the Netherlands has widely implemented the vision and ambitions embedded and inspired by the Sustainable Safety programme. Although the Netherlands is small in scale, this is arguably one of the most ambitious road safety plans to be realised in modern times, certainly if one considers the fact that the entire road network has been re-classified and that more than 70% of the urban network has been converted (many of these roads with some form of physical speed control measures) to 30km/h zones and nearly 60% of the rural network to 60km/h zones (approximately half of which have physical speed control measures). In addition significant strides have been made to realise the Essential Recognisability Characteristics (EHK) with more than 40% of the 80km/h distributor roads and 70% of the 60km/h access roads being provided with markings complying with these new guidelines. Add to that all the supporting activities related to the programme including the construction of some 2000 roundabouts. This concerted effort has resulted in a significant reduction in the number of fatalities on Dutch roads, estimated at between 300 and 400 deaths saved per year.

The road network in the Netherlands is becoming increasingly congested as the need for mobility continues to grow. Since the country already has one of the densest road networks in the world, simply building new roads is no longer a viable or sustainable option. Consequently, in addition to new roads, Dutch policy strives to make optimal use of existing infrastructure whilst simultaneously introducing new road pricing strategies aimed at reducing the demand for private transport, particularly the motor vehicle.

Quality assurance is a topic that is becoming increasingly important in the infrastructure design and operations processes. These processes aim at providing the highest design and safety standards on Dutch roads and not only focus on compliance with design standards and guidelines, but also on general road safety issues and how these are dealt with in the life cycle of a road. The importance of quality assurance in road design and road safety has manifested itself in the newly promulgated EU guidelines for road safety management, the RWS safety management system and the new design processes for national roads. To ensure this new way of working, lower road authorities will need to follow suit and procedures and guidelines will need to be developed to support them in an ongoing process of optimising road design and improving road safety.

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