# Ten Years of Sustainable Safety in the Netherlands

## An Assessment

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**In the 1990s, the Institute for Road Safety Research (SWOV) in the Netherlands introduced the vision of sustainable safety. In a sustainably safe traffic system, crashes are prevented as much as possible, and when prevention is not possible, the probability of severe injury is reduced to almost zero. In 1998, implementation of the vision commenced with the start-up program. Ten years after the start-up program, there was an investigation of how implementation of the measures that emanated from or were in line with the vision of sustainable safety had progressed and what effects these measures have had on safety. The assessment indicated that a substantial number of traffic safety measures were implemented from 1998 through 2007. Many actions taken within the framework of the start-up program were aimed at improving infrastructure safety; the most important actions were categorization of the road network and traffic calming measures such as the construction of 30- and 60-km/h zones. In addition, traffic enforcement increased as a result of the establishment of dedicated regional traffic enforcement teams. The crashworthiness of vehicles also improved. These measures had a positive effect on traffic safety. Each individual measure prevented casualties. Moreover, the fatality rate decreased from 7.3 fatalities per billion kilometers traveled in 1998 to 4.7 per billion in 2007. It is estimated that together the measures prevented 300 to 400 fatalities in 2007 (32% to 34% fewer than expected) and 1,600 to 1,700 fatalities from 1998 through 2007. Finally, a benefit–cost analysis indicates that the measures were also cost beneficial (benefit–cost ratio 3.6:1).**

In the 1990s, the Dutch Institute for Road Safety Research (SWOV) introduced the vision of sustainable safety for road safety vision. This vision aims for inherently safe road traffic (a concept used in rail and air traffic and also in energy production). In a sustainably safe traffic system, crashes are prevented as much as possible and if not yet possible, the probability of severe injury is reduced to almost zero. Sustainable safety is a proactive approach to traffic safety. Proactive means that measures are taken as early as possible in the chain of system design to traffic behavior. Human errors and serious outcomes of crashes can be averted by preventing system errors; road safety thus becomes less dependent on the individual choices of road users. The reference standard is a human: a sustainably safe traffic system has an infrastructure that is adapted to the capabilities and limitations of humans through proper planning and road design, has vehicles that are equipped to simplify the driving task and offer protection to the vulnerable human being, and has road users who are properly educated and informed and whose driving behavior is regularly checked.

In 1991, the sustainable safety approach was introduced in traffic safety policy in the Netherlands. Various actions were then taken to implement the sustainable safety vision. Together with other research institutes, SWOV worked out the vision (*1*). A steering committee, consisting of representatives of all tiers of government, was appointed and developed an implementation strategy. It was decided to implement sustainable safety in two phases. The first phase, the start-up program, started in 1998 and comprised 24 actions that were agreed upon by all tiers of government. In the second phase, a systemwide implementation and application of sustainable safety principles was foreseen. This far-reaching ambition is still subject to political decision making.

Ten years after the start-up program, SWOV decided it was time to assess the results. Therefore, an investigation was conducted on how implementation of the measures that emanated from or were in line with the sustainable safety vision has progressed and what road safety effects these measures have had. This paper discusses the results of the assessment. The next section delves into the sustainable safety vision in more detail and the third section describes traffic safety policy in the Netherlands from 1998 through 2007. The fourth section provides an overview of the measures that were implemented, and the fifth section discusses the traffic safety effects of these measures. The sixth section discusses limitations of the research, and conclusions are presented in the final section.

## SUSTAINABLE SAFETY

Worldwide, sustainable safety is the first example of the so-called Safe System approach (*2*) being put into practice. This approach has four characteristics:

- It recognizes that prevention efforts notwithstanding, road users will remain fallible and crashes will occur.
- It stresses that those involved in the design of the road transport system need to accept and share responsibility for the safety of the system, and those who use the system need to accept responsibility for complying with the rules and constraints of the system.
- It aligns safety management decisions with broader transport and planning decisions that meet wider economic, human, and environmental goals.

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**TABLE 1 Five Principles for Sustainable Safe Traffic System**

| Principle of Sustainable Safety | Description |
|---|---|
| Functionality of road | Monofunctionality of roads, as through roads, distributor roads, or access roads, in a hierarchically structured road network |
| Homogeneity of mass or speed and direction | Equality in speed, direction, and mass at medium and high speeds. At locations where traffic uses high speeds, different types of road users and road users driving in different directions should be physically separated from each other as much as possible to prevent conflicts that lead to severe injury. |
| Predictability of road course and road user behavior by recognizable road design | Road environment and road user behavior that support road user expectations through consistency and continuity in road design |
| Forgivingness of environment and road users | Injury limitation through forgiving road environment and anticipation of road user behavior |
| State of awareness of road user | Ability to assess one's own task capability |

- It shapes interventions to meet the long-term goal, rather than relying on traditional interventions to set the limits of any long-term targets (*2*).

Five principles are now considered crucial for a sustainably safe traffic system (Table 1). The original sustainable safety vision had three principles: functionality of roads, homogeneity of mass or speed and direction, and predictability of road course and road user behavior by a recognizable road design. In 2005, the sustainable safety vision was updated (*3*) and two principles were added: forgivingness of the environment and of road users and state of awareness of road users.

## TRAFFIC SAFETY POLICY

The process leading to key stakeholders' full support of sustainable safety, resulting in the start-up program, is described elsewhere (*4*). In December 1997, the Association of Netherlands Municipalities, the Association of Water Boards, the Association of the Provinces of the Netherlands, and the Ministry of Transport—representing all tiers of government in the Netherlands—signed an agreement on the so-called start-up program for sustainable safety, which contained 24 measures and actions to be implemented between 1998 and 2002. The central government made available a 110 million Euro subsidy for implementation of the start-up program (€1 = $1.13 in 1997 U.S. dollars). To qualify for financial support, the other levels of government had to supplement the subsidy with an equal amount.

The start-up program also contained an outline of intentions concerning the decision-making process required for the second phase, a full-scale implementation of sustainable safety. The second phase did not get off the ground, partly because of decentralization of policy making in general in the Netherlands. General agreements concerning traffic safety are made on a national level. However, implementation of policy takes place on a local level, as the responsibility of regional governments. Although the second phase did not get off the ground, the idea of sustainable safety is still incorporated in national, regional, and local road safety policies.

## TRAFFIC SAFETY MEASURES

Partly as a result of cooperation among all stakeholders, a wide variety of traffic safety measures were implemented from 1998 through 2007. This section discusses the measures for different policy areas: infrastructure, enforcement, public information campaigns, education, and vehicle safety.

### Infrastructure

Many actions in the start-up program were aimed at improving infrastructure safety, the most important being functional categorization of the road network and construction of 30- and 60-km/h zones. Furthermore, the sustainable safety principles of functionality, homogeneity, and predictability were translated into design standards for roads. From 1998 through 2007, other infrastructure measures that are in line with the sustainable safety vision were also implemented; for example, the number of roundabouts was increased.

Road characteristics of all Dutch roads are not stored in a single database. To provide an idea of the extent to which roads have been given a sustainable safety design, SWOV distributed a questionnaire among road authorities that asked them about the length and design of access roads, distributor roads, and through roads; 45% of all 468 road authorities responded to this questionnaire (*5*). The data obtained through this questionnaire were compared with data from previous studies (*6, 7*) to track changes in the safety level of the infrastructure.

From 1998 through 2007, almost all road authorities designed a categorization plan, and it is estimated that more than 41,000 km of 30 km/h roads and more than 33,000 km of 60 km/h roads were constructed, which means that about 70% of all urban roads have a speed limit of 30 km/h and almost 60% of all rural roads have a speed limit of 60 km/h. It was estimated that 80% of urban and rural roads and streets have an access function. This number implies that almost 90% of urban and 75% of rural access roads were redesigned. In addition, more than 2,300 roundabouts were constructed between 1998 through 2007.

Table 2 shows the characteristics of the road categories. At access roads, the speed should be reduced at intersections and on road sections. Urban (50 km/h) distributor roads must have separate bicycle tracks and mopeds must ride on the carriageway to prevent conflicts. Moreover, roadside parking on these roads is not recommended and access control (limited number of property entrances) is recommended. Rural (80 km/h) distributor roads should also have separate bicycle tracks or parallel roads and access control. Furthermore, these roads should be closed to slow (motorized) traffic, have a (difficult to cross) direction divider, have obstacle-free zones, and have (semi)hard shoulders. In general, access and distributor roads outside urban areas comply less well with the sustainable safety standards than roads inside urban areas.

TABLE 2 Characteristics of Roads, 2008

| Road Category | Percentage of Road Length with Given Characteristic |
|---|---|
| 30 km/h urban access roads | 29%, no speed management<br>31%, speed management only at intersections<br>41%, speed management at intersections as well as road sections |
| 50 km/h urban distributor roads | 59%, separate bicycle tracks (on more than 75% of these roads, mopeds ride on the carriageway)<br>49%, no access control<br>44%, parking allowed |
| 60 km/h rural access roads | 55%, no speed management<br>25%, speed management only at intersections<br>20%, speed management at intersections as well as road sections |
| 80 km/h rural distributor roads | 10%, difficult-to-cross direction divider or dual carriageway<br>About 25%, no access control<br>About 65%, not closed for slow motorized traffic<br>Few roads with obstacle-free zones or (semi)hard shoulders |

## Enforcement, Public Campaigns, and Education

The start-up program stimulated municipalities and provinces more explicitly to include traffic enforcement in the priority setting of police tasks. The national government supported this approach. The establishment of dedicated regional traffic enforcement teams from 1996 through 2003 is in line with this goal. Regional traffic enforcement teams consist of about 30 full-time equivalents per police region (750 full-time equivalents total) who spend all their time on enforcement in the following priority areas: helmet use on motorized two-wheelers, seat belt use, red light violations, driving under the influence of alcohol, and speeding. Establishing these regional traffic enforcement teams resulted in a considerable increase in traffic enforcement from 1998 through 2007 (Figure 1). Enforcement has also become more efficient because of the introduction of section controls, improving the licensing system for moped riders, and digitalization of speed and red light cameras.

Traffic enforcement is accompanied by public information campaigns about, for example, the use of seat belts and driving under the influence of alcohol. Furthermore, permanent traffic education has been introduced. Permanent traffic education means that people are educated not only when their traffic role changes (e.g., when they start cycling or when they get a driver's license) but also while they fulfill a certain traffic role. This policy has resulted in several education projects for different age groups.

## Vehicle Safety

The start-up program did not contain actions on vehicle safety. Most improvements with regard to vehicle safety are due to European regulations and initiatives of the car industry that are, for example, encouraged by the European New Car Assessment Program (Euro NCAP) to improve vehicle safety. These developments cannot be attributed to sustainable safety but fit into the vision very well. From 1998 through 2007, active vehicle safety improved because of an increasing proportion of vehicles that are equipped with electronic stability control. Moreover, passive vehicle safety increased as more vehicles are equipped with different types of airbags and (audible) seat belt reminders. Finally, some measures are being taken to decrease the number of blind spot crashes involving trucks.

# SAFETY EFFECTS

This section discusses the effects of the measures introduced in the previous section and of sustainable safety in general. Preferably, safety effects are described in terms of fatalities and injuries. However,

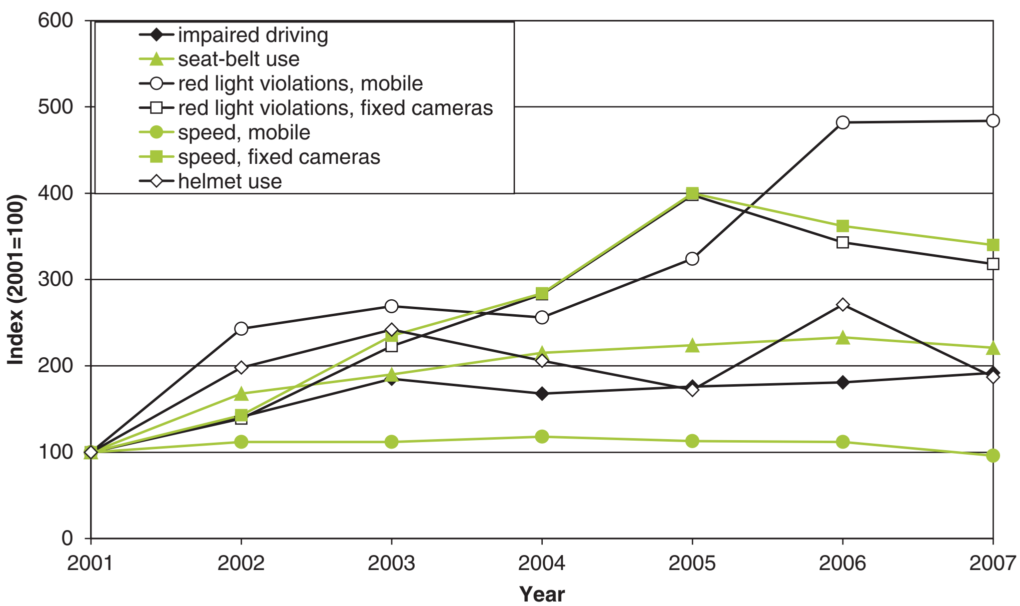


FIGURE 1 Development in traffic enforcement levels (indexed number of road users checked, reference year = 2001).

a major problem in the Netherlands is the growing underregistration of severe injuries; the registration level declined from 74% in 1993 to 58% in 2008. For this reason, it was decided to restrict this study to an estimate of safety effects by using only the number of fatalities. Further research will be carried out on the severely injured, using a definition that is based on the maximum abbreviated injury scale score.

## Safety Effects of Individual Measures

Formal evaluation studies are available for some of the measures discussed in the previous section. For these measures, the number of fatalities the measure prevented in a certain year (in relation to the base year 1998) was calculated by multiplying the measured reduction factor, the level of safety in 1998, and the increase in penetration level. Moreover, in some cases, safety performance indicators can be applied to assess the effects of individual measures or of a combination of measures. Safety performance indicators, such as speed and use of safety devices, provide insight into specific aspects of traffic safety and form a causal link between traffic safety measures and fatalities (*8, 9*). Finally, developments in relation to certain groups of fatalities or crashes have been studied to analyze the effect of certain traffic safety measures.

### *Infrastructure*

For the infrastructure measures, the safety effects of the construction of 30 and 60 km/h zones and of roundabouts were calculated. Construction of 30 km/h zones was found to reduce the number of severe crashes by an estimated 20% to 30% (*10, 11*). Multiplying by the average number of fatalities per road length inside urban areas (6.2 fatalities per 1,000 km) and the 41,000 km increase in road length of 30 km/h roads resulted in a reduction of 50 to 75 fatalities in 2008. Construction of 60 km/h zones results in an estimated reduction of serious crashes of 24% (*12*). Multiplying by the average number of fatalities per road length on rural roads (7.6 fatalities per 1,000 km) and the 33,000-km increase in road length of 60 km/h roads results in a reduction of about 60 fatalities in 2008. Churchill et al. (*13*) determined the effect of roundabouts by comparing the development in the number of fatalities at all intersections that were reconstructed into roundabouts with the development at intersections that were not reconstructed. They concluded that the construction of a roundabout decreases the number of fatalities by 71%. According to Churchill et al. (*13*), all roundabouts constructed in the period 1999 to 2005, approximately 1,600, resulted in a reduction of 11 fatalities in 2007.

Wegman et al. (*14*) estimated the effect of the construction of 30 and 60 km/h zones by comparing fatality rates (number of fatalities per kilometer driven) in 1998 and 2002 on urban and rural roads, respectively. This study estimated the effect of all measures on urban and rural roads in a similar way. As data on the number of kilometers driven by road type are not available, the numbers of fatalities per road length were compared. A correction was made for a change in total urban or rural road length by multiplying fatality rates from 1998 by road lengths in 2008. By comparing the number of fatalities that result from this multiplication with the actual number of fatalities in 2008, it was estimated that all measures on urban roads saved about 190 lives in 2008 and all measures on rural roads saved an additional 190 lives.

### *Enforcement, Public Information Campaigns, and Education*

To estimate the effects of the intensified enforcement, public information campaigns, and education, developments in safety performance indicators on driver behavior were analyzed. With results from literature, which established the relationship between behavior and fatality rates, reduced numbers of fatalities were estimated based on improved driver behavior. The following indicators were considered:

- Alcohol offenders on weekend nights,
- Speeds driven on motorways,
- Speed offenders on different road types,
- Seat belt use by car and van drivers and passengers,
- Helmet use by moped riders, and
- Red light offenders.

Seat belt use increased from 1998 through 2007 and the percentage of alcohol offenders decreased. Other safety performance indicators did not point to clear improvements or were difficult to interpret because of small numbers of vehicles checked or large year-to-year fluctuations in enforcement levels.

The effect of the decrease in the percentage of alcohol offenders was estimated by using odds ratios from a case control study that was performed within the European research program IMMORTAL (*15*). On the basis of these odds ratios, it was concluded that approximately 25% of inpatients were drivers under the influence of alcohol, approximately 75% of whom had rather high blood alcohol concentrations ≥0.13%. If these results are assumed to be valid for the whole of the Netherlands and if it is assumed that the percentages of alcohol-related inpatients are equal to those for all fatalities, the number of alcohol-related fatalities in 1998 and in 2007 can be calculated by using the percentages of offenders in both years. To isolate the effect of driving under the influence of alcohol, the decrease in the percentage of alcohol-related fatalities was related to the number of fatalities in 1998 instead of in 2007. It was estimated that a decrease in alcohol use resulted in a decrease of about 130 fatalities. However, this estimation is sensitive to small unreliable percentages of offenders with blood alcohol concentrations ≥0.13%. Therefore, the effect of the decrease in alcohol use was also estimated on the basis of the proportion of alcohol-related crashes in relation to the total number of crashes. In the Netherlands, however, the share of alcohol-related crashes is underestimated in the police crash registration. If it is assumed that the registration level is constant in time, the share of alcohol-related crashes can be used to estimate the effect of a decrease in the proportion of alcohol offenders. From the crash records, it can be concluded that, although the number of alcohol-related crashes decreased, the proportion of alcohol-related crashes in relation to the total number of crashes did not change much. Therefore, on the basis of these data it is concluded that the decrease in the percentage of alcohol offenders had no effect. Both estimations presented are based on assumptions, and, unfortunately, on data that are not optimal. As it was not possible to know which of these two approaches was best, the average of both effects (65 fatalities) was taken as the final estimation of the effect of a decrease in the percentage of alcohol offenders.

The effects of increased seat belt use were estimated with reduction factors of 40% for seat belt use by drivers and passengers in the front of the vehicle and 30% by passengers in the rear seat of the vehicle

(*16, 17*). With Equation 1, it was estimated that increased seat belt use prevented 55 fatalities in 2007:

$$N_{2007} = N_{1998} * \frac{(1 - S_{2007} * \text{RF})}{(1 - S_{1998} * \text{RF})} \quad (1)$$

where

$N$ = number of road deaths,
$S$ = seat belt rate/implementation level of measure, and
RF = reduction factor.

### Vehicle Safety

With regard to vehicle safety improvements, only the effects due to increased implementation of electronic stability control (ESC) and airbags have been calculated. Other vehicle improvements may also have had a positive impact on traffic safety, but these improvements are not monitored or studied well enough in the Netherlands to allow for a well-founded estimate of the road safety effect. Indirectly, an effect for seat belt reminders can be estimated. Seat belt reminders are known to increase seat belt use (*18, 19*), and therefore the increased penetration level of seat belt reminders most likely contributed to the 55 road deaths that were saved because of increased seat belt use. Development of the following safety performance indicators for vehicle safety was monitored according to Hakkert et al. (*9*):

- EuroNCAP scores as an indicator for the crashworthiness of vehicles and
- Shares of motorcycles and heavy goods vehicles and mass differences between cars as indicators for the incompatibility of vehicles.

On the basis of American and European studies, it can be concluded that cars equipped with ESC are involved in at least 30% fewer single vehicle crashes (*20*). Furthermore, ESC also appears to reduce the number of crashes involving two or more vehicles (*21*). For the Netherlands, a conservative reduction factor of 25% is applied for all road deaths in cars and vans (*22*). By applying Equation 1, it is estimated that in the Netherlands the observed increase of penetration of ESC from 0% to 7% saved about 10 road deaths in 2007.

Front airbags are found to reduce the number of road deaths among car drivers by 12% when seat belts are not used (*17, 23*) and by 8% when seat belts are used. McCartt and Kyrychenko (*24*) estimated the fatality reduction effect of side airbags to be 30% for side impacts. The penetration level of driver airbags increased from 22% to 79%, of passenger airbags from 5% to 58%, and of side airbags from 3% to 37%. To estimate the number of road deaths saved, Equation 1 was applied. In 2007, about 30 road deaths were saved by increased implementation levels of different types of airbags.

From 1998 through 2007, the proportion of vehicles with four and five EuroNCAP stars increased, whereas the proportion of vehicles with two or three stars decreased. An increase in the number of stars has a positive effect on traffic safety (*25*). Therefore, vehicles have become safer. On the other hand, the share of motorcycles, heavy goods vehicles, and vans increased as well as the mass differences among passenger cars. This increase results in greater incompatibility among vehicles, which has a negative traffic safety effect. Unfortunately, it was not possible to quantify the safety effects of these changes in vehicle safety.

**TABLE 3 Safety Effects of Individual Measures**

| Measure or Behavioral Aspect | Number of Fatalities Prevented in 2007–2008 in Relation to 1998 |
|---|---|
| Construction of 30 km/h zones | 50–75 |
| Construction of 60 km/h zones | 60 |
| Construction of roundabouts | 11 |
| Increased seat belt use (partly as a result of seat belt reminders, enforcement, and public information campaigns) | 55 |
| Decreased percentage of alcohol defenders (partly as a result of enforcement and public information campaigns) | 65 |
| Electronic stability control | 10 |
| Airbags | 30 |

## Total Safety Effects of All Measures

Table 3 summarizes the effects of the individual measures discussed in the previous section. These effects cannot simply be added, as they partly concern the same groups of fatalities. Various approaches are available for estimating combined effects of various traffic safety measures (*26*). More important in this case, it has not been possible to estimate the safety effects of all measures discussed in the section on traffic safety measures. Therefore, it was not possible to determine how many fatalities were prevented by implementation of all measures together based on the individual effects of individual measures. To overcome this lack of knowledge, another approach was developed: the actual development of the fatality rate was compared with the development that was expected had the measures not been taken. The effect was calculated for two baseline scenarios:

- Continuing the traffic safety policy pursued from 1988 through 1997 (continuation scenario) and
- Maintaining the status quo and making no additional investments in traffic safety (status quo scenario).

Before the effects of all measures together are discussed, this section describes the development in fatality rates. The fatality rate decreased from 7.3 deaths per billion kilometers traveled in 1998 to 4.7 per billion kilometers in 2007. The average annual decrease was larger than in the preceding 10 years; the number of registered traffic deaths per billion kilometers traveled decreased by an average of 5.8% per year from 1998 through 2007 and by an average of 2.6% per year from 1988 through 1997. (The average decrease per year is estimated by means of a log-linear trend.) The decrease in fatality rate was largest for car occupants: 7.6% per year as opposed to 6.4% for pedestrians and 4.1% for cyclists.

As mentioned earlier, the effect of all measures together was estimated for two baseline scenarios. In the first baseline scenario (continuation scenario), it was assumed that the risks for different modes of transport would continue to decrease at the same pace as they did from 1988 through 1997. In Figure 2, the expected development in the number of fatalities (age 12 years or older) that results from this assumption is compared with the actual development in the number of fatalities. The actual number of fatalities in 2007 was about 300 (32%) lower than the number of fatalities that was expected

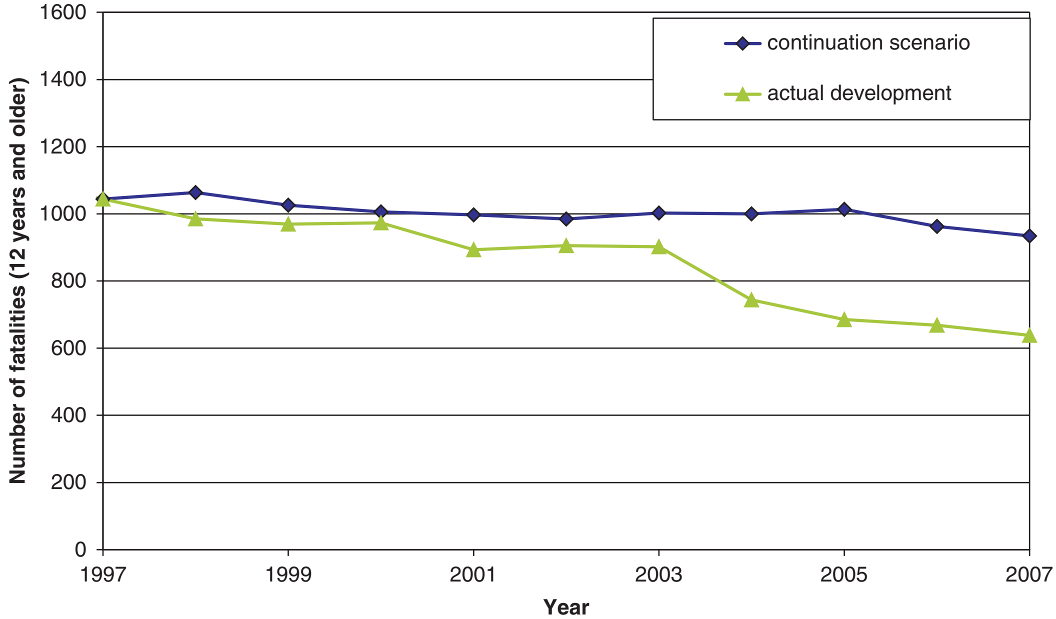


FIGURE 2 Actual development in number of fatalities according to continuation scenario.

in the continuation scenario. Approximately 1,600 fatalities were prevented in the 10-year period from 1998 through 2007.

In the second baseline scenario (status quo scenario), it was assumed that fatality rates for different modes of transport would remain constant after 1998. In Figure 3, the expected development of the number of fatalities (all ages) that results from this assumption is compared with actual development in the number of fatalities. The actual number of fatalities in 2007 was about 400 (34%) lower than the number of fatalities that was expected in the status quo scenario. About 1,700 fatalities were prevented from 1998 through 2007.

## Benefit–Cost Analysis

For the status quo scenario, a benefit–cost analysis was carried out. Additional investments made in traffic safety were estimated and related to the monetary value of the fatalities and inpatients that were prevented. It was estimated that in 2007 €530 million was invested to implement sustainable safety and thus to increase the level of traffic safety. These investments prevented about 400 fatalities and 1,080 inpatients. These effects were monetized and corrected for differences in the duration of effectiveness between different types

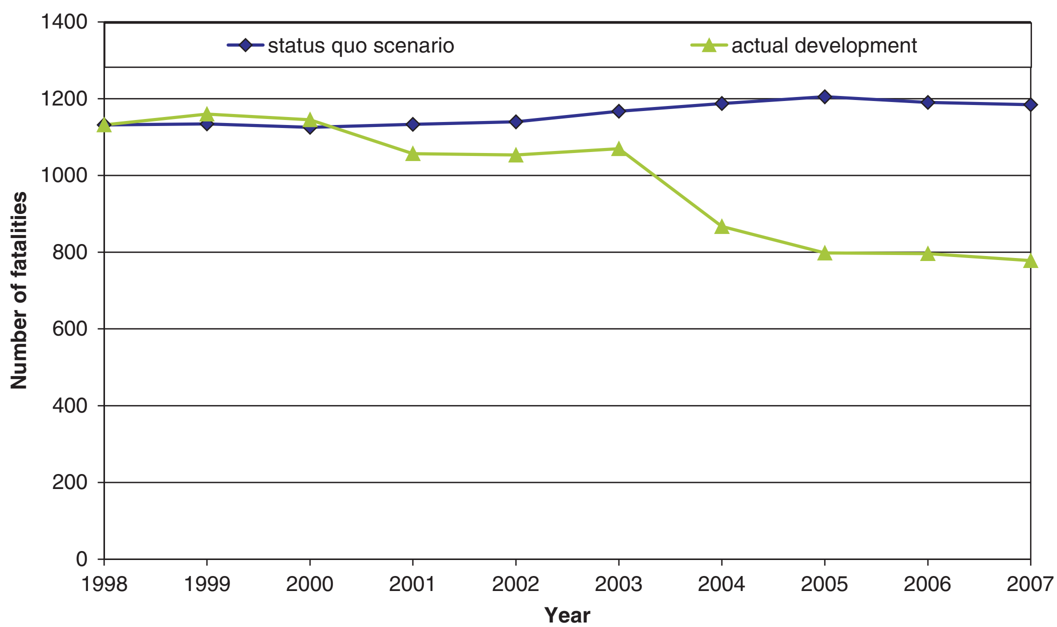


FIGURE 3 Actual development in number of fatalities according to status quo scenario.

of measures; infrastructure measures are assumed to be effective for 30 years, vehicle-related measures are assumed to last for 10 years, and enforcement and public campaigns are assumed to have a duration of 1 year. Depending on assumptions about the distribution of effects among different types of measures, the present monetized value of the effect is €1.9 or €2 billion. The benefit–cost ratio is 3.6 or 3.7. Therefore, the measures are concluded to be cost-effective. To determine whether the results are robust, a sensitivity analysis was carried out. In the case of pessimistic assumptions about costs and effects, the measures are concluded to be cost-effective (the benefit–cost ratio was higher than 1 in all cases).

## DISCUSSION OF LIMITATIONS

The research described in this paper has the objective of presenting a comprehensive estimate of safety effects of the implementation of sustainable safety in the Netherlands. This research encountered some limitations. First, sustainable safety is a vision and therefore cannot be translated directly into traffic safety policies or measures. Dutch traffic safety policy is not based entirely on the sustainable safety vision. Although the vision was a key component of Dutch road safety policies during the last decade, it cannot be claimed that all improvements were directly related to sustainable safety. For example, regional traffic enforcement teams had been formed before the start-up program began. Furthermore, developments related to vehicle safety were introduced at the European level or by the car industry. The measures described here were directly or indirectly influenced or inspired by sustainable safety and all the described interventions fit into the vision very well.

Second, it was not possible to provide a complete overview of all measures implemented from 1998 through 2007. For permanent traffic education, for example, an overview of all the projects carried out is not available and the number of participants involved in all projects is not known. Furthermore, the data that were used have limitations. Most information about infrastructure measures was gathered with a survey among road authorities. Although the response was quite high (45%), the sample was less representative for rural distributor roads and the results are based on estimates of road authorities. With regard to police enforcement, only enforcement carried out by regional traffic enforcement teams is included. It has not been documented which enforcement activities were carried out by the regular police force in addition to the enforcement activities of the regional traffic enforcement teams. Finally, penetration levels of vehicle safety systems were estimated by using implementation levels in new (the 50 most sold) vehicles.

Third, it was not possible to estimate the effects of all measures on traffic safety and therefore it was not possible to estimate the combined effect of all measures. Therefore, the total effect was estimated on the basis of the development in fatality rates for different modes of transport. However, these rates are also influenced by other, confounding factors, such as the increased experience of drivers, an increase in the use of mobile phones, or increasing mass differences among vehicles. These and other developments were not taken into account. The effect of all measures together was estimated for two baseline scenarios. These baseline scenarios are based on certain assumptions about the development of fatality rates. It is unknown how fatality rates would have developed without sustainable safety or without following the measures discussed in this paper. This research is considered more as a work in progress than as a mature, developed methodology. However, on the basis of the authors' experience it is believed that strong and weak elements can be identified in this approach and SWOV plans to carry out further research and data collection.

## CONCLUSIONS

This paper discusses an evaluation study of the effects of traffic safety measures that emanated from or fit well into the vision of sustainable safety. In a sustainably safe traffic system, crashes are prevented as much as possible and when not possible, the probability of severe injury is limited to almost zero. Sustainable safety is the first example of the so-called safe system approach put into practice. The vision of sustainable safety was developed in the early 1990s and implementation of traffic safety policy began in 1998 with the start-up program. This program comprised 24 actions that were agreed upon by all tiers of government.

In the start-up program, many traffic safety measures were implemented from 1998 through 2007. Many actions within the start-up program were taken to improve infrastructure safety, the most important being categorization of road networks and construction of 30- and 60-km/h areas. Furthermore, more than 2,300 roundabouts were constructed from 1998 through 2007. Together these measures prevented an estimated 120 to 145 fatalities per year. Regional traffic enforcement teams were established to improve enforcement. As a result, traffic enforcement increased considerably from 1998 through 2007. These increased traffic enforcement levels, in combination with public campaigns, probably contributed to a decrease in the percentage of alcohol offenders and an increase in seat belt use, which resulted in preventing an estimated 65 and 55 fatalities, respectively. An increase in implementation level of ESC prevented an estimated 10 fatalities and increased implementation of airbags prevented about 30 fatalities. Moreover, the increased implementation of seat belt reminders probably contributed to increased seat belt use.

Also, in aggregate, positive effects of the measures can be observed. The fatality rate decreased from 7.3 deaths per billion kilometers traveled in 1998 to 4.7 per billion kilometers in 2007. The average annual decrease was more than double (1.8% per year vs. 5.3% per year) that of the preceding 10 years. It is estimated that all measures together prevented 300 to 400 fatalities in 2007 and 1,600 to 1,700 fatalities from 1998 through 2007. From a benefit–cost analysis, it is concluded that the measures were also cost-effective. Benefits are approximately four times higher than costs and in the case of pessimistic assumptions about costs and effects, the measures are concluded to be cost-effective.

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