wrong-way driving

by

ir. g. a. brevoord

no. 36/1984
WRONG-WAY DRIVING

Driving the wrong way on one-way roads and specifically motorway carriageways

Description of the magnitude and nature of the problem and of measures which may reduce the incidence of this phenomenon, with particular reference to roads

by

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Wrong-way driving has been a matter of concern to the Public Works Department for some considerable time. Since 1960 a great deal of thought has been devoted to this aspect in the design of motorways and motorway equipment. This is reflected, for example, in the very smooth design of the motorway network and in the design, signposting, marking and lighting of junctions leading to motorways.

Despite this, wrong-way driving became a subject of public interest and concern around 1980. This gave rise to the present study, which not only provides information on wrong-way driving but also explains which supplementary measures were selected and why.

Even before the study was completed, the measures it recommends were introduced following the publication of an interim report. The effects of the supplementary measures taken are discussed in the last chapter, from which it is apparent that they have been successful, the number of accidents involving wrong-way drivers having fallen very substantially. This cannot unfortunately be said of the number of fatal accidents.
Summary

The study begins with an analysis of wrong-way driving. It is not known how common this phenomenon is in the Netherlands. There was no nation-wide system of collecting information on either incidents or accidents involving wrong-way driving. To gain an insight into the phenomenon, a list of fatal accidents caused by head-on collisions on motorways from 1968 to 1980 was compiled. The number of fatal accidents involving wrong-way drivers fluctuates between 1 and 3 per year, the only significant departure from this pattern occurring in 1977. If the 1977 figure is ignored, fatal accidents involving wrong-way drivers average 2.2 per year and thus account for just over 0.02% of all motorway accidents, which is a very small percentage in relative terms. A comparison with other countries shows that the situation in the Netherlands is comparatively favourable.

A description of motorway design and potential problem areas is followed by a discussion of information obtained from the available literature, all published in the USA and West Germany.

The study then considers supplementary measures which may reduce the incidence of wrong-way driving, with specific reference to roads. Finally, a selection of these supplementary measures is proposed on the basis of a global analysis of cost-effectiveness and other factors.

These measures are:
- a special inspection of junctions with motorways with a view to preventing wrong-way driving;
- the placing of two 'no entry' signs, each surmounting a sign reading GO BACK, on motorway exit roads facing potential wrong-way drivers, and were taken by the Public Works Department during the latter half of 1980.

These supplementary measures have been successful, the number of accidents involving wrong-way drivers having fallen substantially. The same is unfortunately not (yet) true of the number of fatal accidents.
1 Introduction

A wrong-way driver is a road-user who drives along a one-way carriageway against the traffic. This complies with the West German and American definitions. Figure 1 shows a motorway with three lanes on each carriageway. Although wrong-way driving can occur on any dual-carriageway road (Figure 2), any road with isolated sections of dual-carriageway (Figure 3) and any one-way single-carriageway road (a type of road that is largely confined to urban areas; Figure 4), the phenomenon is best known from motorways since the relatively high speeds at which vehicles travel on motorways increase the likelihood of accidents having fatal consequences. This publication is principally concerned with wrong-way driving on motorways and focuses on methods of reducing its incidence through modifications to signs, markings, etc. Although certain aspects of the human factor are also considered in Chapters 2 and 4 to complete the picture, few conclusions are drawn in this respect in the discussion of measures and their effects in Chapter 5.

Figure 1  Diagram of a motorway with three lanes on each carriageway
I am grateful to the many people who have helped with the preparation of this publication. I should therefore like to thank the following organizations for their cooperation:

- the Institute for Road Safety Research (SWOV);
- the Institute for Perception TNO;
- the Motorway Police and the Aviation Branch;
- the Road Safety Inspectors of the Public Works Department;
- the Royal Dutch Touring Club (ANWB).

My sincere thanks also go to the many members of the staff of the Transport and Traffic Engineering Division (DVK) who have helped me to compile this publication.
2 The magnitude and nature of the problem

2.1 General

The records that have been kept of accidents involving and reports of wrong-way drivers do not reveal the situation nation-wide. The nature and incidence of wrong-way driving were therefore not known. Information on fatal accidents involving wrong-way drivers over a number of years can, however, be obtained by an indirect method. In addition, a special police operation in 1980 produced data on accidents involving and reports of wrong-way drivers in that year.

2.2 Fatal accidents involving wrong-way drivers

The Institute for Road Safety Research (SWOV) has collected data on fatal accidents from 1968 to 1980 which, according to the official records, followed head-on collisions on the through-lanes of motorways. A joint analysis was then made to establish the number of fatal accidents involving wrong-way drivers. Given the information available for the years after 1974, the numbers of such accidents occurring since that year shown in Table I can be considered fairly accurate.

The data for these seven years are not, however, very revealing. In view of the relatively low annual figures – with the exception of 1977 – there is a great need for information relating to a longer period.

The DVK consequently analysed the fatal accidents occurring from 1970 to 1973 on the basis of the data provided by SWOV and with the aid of its own accident records. The figures shown in Table I for these years can be regarded as fairly accurate. The 1968 and 1969 figures could only be estimated. All these data are shown in Table I and Figure 5.

The following conclusions can be drawn from the figures given in Table I and other data:

- The number of fatal accidents involving wrong-way drivers fluctuates between 1 and 3 per year. The only clear departure from this pattern occurred in 1977, and this is significant for the other years, when the pattern was reasonably consistent. Assuming a Poisson distribution of fatal accidents involving wrong-
<table>
<thead>
<tr>
<th>Year</th>
<th>Fatal accidents involving wrong-way drivers</th>
<th>Number of fatalities in these accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1968</td>
<td>2</td>
<td>not known</td>
</tr>
<tr>
<td>1969</td>
<td>2</td>
<td>not known</td>
</tr>
<tr>
<td>1970</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>1971</td>
<td>2</td>
<td>3</td>
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<td>1972</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>1973</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>1974</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>1975</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1976</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1977</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>1978</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>1979</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>1980</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>37</td>
<td>46</td>
</tr>
<tr>
<td>Average</td>
<td>2.85</td>
<td>4.18</td>
</tr>
<tr>
<td>Average excluding 1977</td>
<td>2.25</td>
<td>3.10</td>
</tr>
</tbody>
</table>

Table 1: Fatal accidents involving wrong-way drivers from 1968 to 1980

Figure 5: Number of fatal accidents involving wrong-way drivers from 1968 to 1980
way drivers, the chance of an outlier occurring as it did in 1977 is very slight. No specific explanation could be found for this deviation. However, the total number of fatal accidents on motorways in 1977 was also far higher than in other years.

If 1977 is included in the calculation, the average number of fatal accidents involving wrong-way drivers is 2.85, the standard deviation being 2.27. Taking the 13 years as a basis and assuming a Poisson distribution, the chance of an outlier occurring as it did in 1977 is 100 to 1. For purely statistical purposes, the 1977 figure should be included, but if a more general picture is to be obtained, it is better to ignore a 100-to-1 outlier. The average number of fatal accidents involving wrong-way drivers is then 2.25 per year and the standard deviation is 0.75.

- The average number of fatal accidents involving wrong-way drivers (excluding 1977) is just over 2 per year, equivalent to slightly more than 0.02% of all motorway accidents, which is a very small percentage in relative terms. Fatal accidents involving wrong-way drivers account for a far higher proportion – 2.6% – of all fatal motorway accidents because of the high incidence of fatalities in wrong-way accidents.
- The figures given in Table I do not reveal a trend, simply a fluctuation within certain limits.

During the above-mentioned period the motorway system underwent various developments:
- the length of the motorway network increased (Figure 6);
- vehicle-kilometres on motorways rose (Figure 7);
- the total number of accidents on motorways increased (Figure 8);
- the incidence of accidents – the number of accidents per million vehicle-kilometres – fell (Figure 9).

![Figure 6](image-url)  The expansion of the motorway network from 1945 to 1980
In Figures 7, 8, 9 and 10 the year 1974 has been omitted since a number of specific circumstances occurred in and around that year, making it impossible to suggest a general trend.
Despite the growth of the motorway network, the increase in vehicle-kilometres and also the – relatively slower – increase of accidents, the number of fatal accidents involving wrong-way drivers does not appear to have risen. The safety of motorways is revealed most clearly by the incidence of accidents. The generally downward trend in the years considered (a slight increase occurring only in the latter years) does not seem to apply to fatal accidents involving wrong-way drivers. Unfortunately, a detailed comparison cannot be made with data on other countries (see 4.3 and 4.7.3). In view of the length of the Dutch motorway network on the one hand and developments in other countries on the other, it can be said, however, that the position as regards the number of accidents involving wrong-way drivers is relatively favourable in the Netherlands compared with other countries.

2.3 A more detailed analysis of fatal accidents involving wrong-way drivers

A closer examination has been made of the 37 fatal accidents in which wrong-way drivers were involved, including, therefore, the accidents in 1977, which do not distort the general picture.

LOCATION

In view of the locations at which the fatal accidents occurred and on the reasonably justified assumption that wrong-way driving is of relatively short duration, it can be said that:

Having regard to the variations in the density of the motorway network and levels of traffic density, the distribution of the fatal accidents across the country seems fairly normal. Slightly more of these accidents occurred on the somewhat older motorways, but they carry the highest density of traffic and are not all of uniform design.

AGE

A comparison of the age of fatally injured wrong-way drivers with that of persons killed in road accidents outside built-up areas reveals that younger drivers are underrepresented and older and elderly drivers overrepresented.

ALCOHOL CONSUMPTION

Alcohol consumption was a factor in few of the fatal accidents considered. The only conclusion that can be drawn is that the influence of alcohol seems to be far less significant a factor in fatal accidents involving wrong-way drivers than in other countries. It is however not certain that blood samples were taken for this purpose.

WEATHER CONDITIONS

Rain (a wet road surface) does not appear to be a significant factor.
VISIBILITY
Of the 37 fatal accidents, nearly 60% occurred at dawn or dusk or at night. This is far higher than the percentage of fatal accidents occurring outside built-up areas at dawn or dusk or at night. In addition, 25% of all driving is done at dawn or dusk or at night. Particularly effective action must therefore be taken to prevent accidents occurring at such times.

DAY OF THE WEEK
A comparison of the spread of fatal accidents involving wrong-way drivers over the various days of the week with the spread of fatal accidents outside built-up areas shows that fatal accidents involving wrong-way drivers are underrepresented at weekends and overrepresented on Tuesdays and Thursdays.

DISTANCE BETWEEN THE SCENE OF THE ACCIDENT AND THE WRONG-WAY DRIVER'S HOME
The distance between the scene of the accident and the wrong-way driver’s home (information which can only be obtained from the accident records for the years 1974 to 1978) varied from comparatively short to a score or more kilometres. This does not allow any conclusions to be drawn on the driver’s lack of familiarity with the locality.

2.4 Accidents involving and reports of wrong-way drivers in 1980
At the request of the Public Works Department, the police collected data on accidents involving and reports of wrong-way drivers in a number of districts in 1980. Forty-five incidents were recorded, 12 accidents and 33 reports. The data available vary from brief to fairly complete. This information does not therefore permit conclusions on all aspects. What conclusions can be drawn from the data for this one year match the reports on the fatal accidents, with one major exception: the percentage of cases in which alcohol played a part is, at about 30%, higher than that revealed by an analysis of the fatal accidents. This also corresponds far more closely to all the other information available.

The following should also be noted:
- The occupations and thus the social status of the persons concerned, where known, vary widely. The absence of a common factor in this respect is also revealed by other research.
- Wrong-way drivers are not only car-drivers but also lorry-drivers and motorcyclists. This too is a conclusion generally drawn in the literature.
- Foreigners are also involved.
As regards location, about half of all wrong-way driving incidents seem to begin at intersections. Few occur at interchanges. Roughly a quarter of the incidents considered here began on the carriageway itself (as a result of U-turns). The remainder took place in a wide variety of locations. Although the data concern only one year, they correspond closely to the general picture obtained from the literature.

A global extrapolation based on the number of kilometres of motorway in the districts concerned indicates that there were some 20 accidents involving wrong-way drivers and 80 reports of wrong-way drivers on Dutch motorways in 1980.

### 2.5 Other areas of concern on motorways

As already stated in section 2.2 the Institute for Road Safety Research has compiled a list of fatal accidents occurring on the carriageways of motorways and classified as head-on collisions.

<table>
<thead>
<tr>
<th>Number</th>
<th>Average p.a.*</th>
<th>% of total</th>
<th>Number of fatalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal accidents on carriageways of motorways</td>
<td>927</td>
<td>84.3</td>
<td>-</td>
</tr>
<tr>
<td>Fatal accidents classified as head-on collisions</td>
<td>119</td>
<td>10.8</td>
<td>100</td>
</tr>
<tr>
<td>crossed to other carriageway</td>
<td>32</td>
<td>2.9</td>
<td>27</td>
</tr>
<tr>
<td>on single-carriageway section</td>
<td>18</td>
<td>1.6</td>
<td>15</td>
</tr>
<tr>
<td>road works in progress</td>
<td>10</td>
<td>0.9</td>
<td>8</td>
</tr>
<tr>
<td>wrong-way driving</td>
<td>32</td>
<td>2.9</td>
<td>27</td>
</tr>
<tr>
<td>unclassifiable remainder</td>
<td>27</td>
<td>2.5</td>
<td>23</td>
</tr>
</tbody>
</table>

* As this is a comparison, the 1977 figures have been included
** This figure includes 1968 and 1969, an estimate based on proportionality has been made for these years

Table II  Fatal accidents and head-on collisions with fatal consequences on the carriageways of motorways from 1968 to 1978

The data available for the years 1968 to 1978 were sufficient for a more detailed analysis of these accidents. This revealed the occurrence of the following fatal accidents classified as head-on collisions:

- accidents classified as head-on collisions but actually involving vehicles traveling in the same direction, the ‘head-on collision’ occurring as a result of skidding or some other factor (this group could not be quantified by the analytical method used);
- head-on collisions where vehicles cross over to the other carriageway;
- head-on collisions on single-carriageway sections (where there is consequently no central barrier);
- head-on collisions where road works are in progress and where the two streams of traffic are very probably not separated by a barrier;
- head-on collisions caused by wrong-way drivers;
- a residual group which cannot be broken down with any accuracy.

An overview of this situation is given in Table II. Clearly, as wrong-way driving is not the only cause of head-on collisions, the authorities should also be turning their attention to situations in which the following may occur:
- vehicles crossing over to the other carriageway of a dual-carriageway road;
- vehicles crossing over to the wrong side of a single-carriageway section;
- vehicles crossing over to the wrong side of the carriageway where road works are in progress and meeting oncoming traffic on the same carriageway.
3 The design of motorway access and exit points

3.1 General

Motorways head the list of highway types. They display a high degree of uniformity and are extremely safe. Their safety is revealed, for example, by the incidence of accidents on motorways and other roads as shown in Figure 10. The motorway network is characterized by grade-separated links to other motorways or roads, with a distinction made between interchanges and intersections. An interchange links motorways at different levels, while a grade-separated intersection gives access to another type of road. For the sake of simplicity, interchanges will be taken to include intersections in the remainder of this report. In addition, motorways are adjoined by such service areas as parking areas, petrol stations, restaurants and combinations of these amenities. It should be noted that this is a reference to road-side services rather than facilities which are accessible only by leaving the motorway.

The above will be discussed in greater detail later, since it may help to provide a better understanding of situations in which wrong-way driving might occur. At motorway interchanges the following elements are to be found in addition to the carriageways: divergence points, convergence points and slip roads.

Design of a single-lane deceleration lane

Design of a two-lane deceleration lane with a taper

Figure 11 Deceleration lanes
Divergence points are points at which a change of route occurs. They take the form of deceleration lanes (Figure 11) and forks (Figure 12).

Convergence points are points at which traffic flows merge. They can be subdivided into acceleration lanes (Figure 13) and at-grade confluences (Figure 14).

Where a convergence point is closely followed by a divergence point, a weaving section occurs (Figure 15). Convergence points, divergence points and slip roads are used in the construction of interchanges. The layout of various types of interchange are shown below.

Splitting a three-lane carriageway into a single-lane and a two-lane carriageway

Splitting a three-lane carriageway into two two-lane carriageways

Splitting a four-lane carriageway into two two-lane carriageways

Splitting a two-lane carriageway into two single-lane carriageways

Figure 12 Forks
Design of a single-lane acceleration lane

Design of a two-lane carriageway leading to a single-lane acceleration lane

Design of a two-lane acceleration lane with a taper

Figure 13  Acceleration lanes

Confluence of two-lane carriageways to form a four-lane carriageway

Confluence of a two-lane and a single-lane carriageway to form a three-lane carriageway

Confluence of two single-lane carriageways to form a two-lane carriageway

Figure 14  Confluences
Two lanes

Three or more lanes

Figure 15  Weaving sections

Four variations of the cloverleaf are shown in Figure 16 and a number of other types of interchange in Figures 17 and 18. Diagrams then follow of the two best-known types of interchange with roads other than motorways, the diamond (Figures 19 and 20) and the partial cloverleaf (Figures 21 and 22). Figures 23 and 24 show examples of interchanges and Figure 25 a service area.

Wrong-way driving occurs when drivers:
- trying to reach a motorway take the exit road rather than the access road;
- drive on to the wrong carriageway at the beginning of a motorway;
- circumvent a convergence or divergence point;
- take the wrong road out of a service area;
- turn and drive against the traffic; this may happen both on the motorway itself and on slip roads;
take the wrong carriageway at the end of a section where road works are in progress. The above incidents are illustrated in Figure 26.

Figure 16 Four types of cloverleaf interchange
Figure 17  Other types of interchange
Figure 18  Trumpet interchanges
Figure 19  Diamond interchanges

Figure 20  Design of the diamond interchange
Figure 21  Various partial cloverleaf interchanges

Design of a partial cloverleaf (looped slip road before a viaduct)

Design of a partial cloverleaf (looped slip road after a viaduct)

Figure 22  Design of the partial cloverleaf interchange
Figures 23, 24  Examples of interchanges
3.2 Potential problem areas

To gain an insight into potential problem areas, a count was made of motorway access and exit points. The findings are reproduced in Table III, which calls for a number of comments. The Standards for the Design of Motorways (ROA) state a preference for the clear and logical diamond. The policy pursued in this respect has produced positive results. The standards advise against incomplete intersections, although they are relatively common.

From Table III it can be estimated that the following problem areas exist (the figure in brackets being the percentage of the total):

- 689 motorway exit roads which can be entered in the wrong direction (30%);
- 283 service area exit roads which can be entered in the wrong direction (13%);
- 1288 convergence points in main carriageways, auxiliary lanes and slip roads (57%).
Figure 26  Points at which wrong-way driving may begin
<table>
<thead>
<tr>
<th>Type</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade separated intersections*</td>
<td>374</td>
<td>51</td>
</tr>
<tr>
<td>Diamond</td>
<td>201</td>
<td>54</td>
</tr>
<tr>
<td>Partial cloverleaves</td>
<td>119</td>
<td>32</td>
</tr>
<tr>
<td>Mixed designs</td>
<td>26</td>
<td>7</td>
</tr>
<tr>
<td>Other designs</td>
<td>28</td>
<td>7</td>
</tr>
<tr>
<td>Interchanges</td>
<td>63</td>
<td>9</td>
</tr>
<tr>
<td>Cloverleaves</td>
<td>19</td>
<td>30</td>
</tr>
<tr>
<td>Trumpet junctions</td>
<td>35</td>
<td>56</td>
</tr>
<tr>
<td>Other designs</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>At-grade junctions</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Roundabouts</td>
<td>5</td>
<td>83</td>
</tr>
<tr>
<td>Intersections</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>Service areas</td>
<td>285</td>
<td>39</td>
</tr>
<tr>
<td>Parking areas</td>
<td>110</td>
<td>39</td>
</tr>
<tr>
<td>Parking areas with petrol station</td>
<td>100</td>
<td>35</td>
</tr>
<tr>
<td>Petrol stations</td>
<td>64</td>
<td>22</td>
</tr>
<tr>
<td>Combinations of restaurant, petrol station and parking area</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>728</td>
<td>100</td>
</tr>
</tbody>
</table>

* 16% incomplete

Table III  Motorway access and exit points

Divergence points are not considered here since their circumvention does not appear to be a common cause of wrong-way driving. In view of the number of points where wrong-way driving can potentially begin, the figure of almost two million vehicles joining and leaving motorways every day (600 × 10⁶ entries and exits p.a.) and the magnitude of the problem, it can be said that the motorway is generally a safe way of getting from A to B.
4 Review of the available literature

4.1 General

To obtain an overview of the relevant literature, the International Road Research Documentation System was used. Most of the literature on wrong-way driving comes from the USA, where, in about 1960, the authorities in a number of States began to regard accidents caused by wrong-way drivers as a significant aspect of the road safety problem. A considerable amount of research was carried out in California. The American literature is almost alone in evaluating measures taken. It was not until some time later that publications on this subject appeared in Europe, principally in West Germany, where research into wrong-way driving began in 1976. Since 1978 various papers and reports on specific aspects of the problem have been published. In 1981 these reports were combined to form a final report (Schlussbericht). The nature of the research carried out in West Germany, where data relating specifically to wrong-way driving were similarly not available, is discussed elsewhere.

In France nothing has been published on this subject. It is not considered to be a problem according to a recent letter from SETRA (Service d'Etudes Techniques des Routes et Autoroutes) in reply to a request for more detailed information on wrong-way driving on French motorways. It is pointed out that France differs substantially from most other European countries in having many toll roads which, to facilitate operations, usually have different types of access and exit roads.

In the United Kingdom, according to conversations with the staff of the Transport and Road Research Laboratory, wrong-way driving is not considered a problem, and no research has therefore been carried out in this area.

Wrong-way driving is considered below against the background of the available literature, the following aspects being discussed:
- the incidence of wrong-way driving;
- accidents involving wrong-way drivers;
- more detailed information on wrong-way driving;
- measures relating to road signs, markings, etc.

4.2 The incidence of wrong-way driving

In 1965 the American Bureau of Public Roads surveyed all the States to gain a better understanding of the problem of wrong-way driving. The reaction from 15% of the States was that wrong-way driving on their major roads was a problem.
Information was also provided on action that had been taken and, in some cases, on the number of incidents and accidents.

For his evaluation of motorways, Tamburri uses the number of wrong-way driving incidents per 100 exits/year. When interpolated, his calculations indicate 27 recorded incidents per 100 km p.a.

Estep estimates that every year some 70,000 drivers enter an exit road in the wrong direction and that one in 60, or 1,200 drivers p.a., reach the motorway. This gives 25 incidents per 100 km of motorway. He also estimates the number of correct movements per day at 4 million, or 1,500 million p.a.

In West Germany there were 6,600 km of motorway and 1,787 reports of wrong-way driving in 1978. This is equivalent to 27 reports per 100 km motorway. In 635 of these 1,787 cases, the police were able to find the culprit, the remaining 1,152 cases remaining unsolved.

In 1977 Switzerland had 730 km of motorway and 172 reports, equivalent to 24 reports per 100 km of motorway.

In the absence of any information on vehicle-kilometres, however, the above figures cannot be compared.

4.3 Accidents involving wrong-way drivers

A paper on the Interstate Highways in the USA puts the length of this network at about 30,000 miles (about 48,000 km). The number of accidents from 1968 to 1971 was 12,387, of which 626, or 5%, were caused by wrong-way drivers. In these accidents 1,019 people were killed and 1,030 were injured. Table IV shows the figures in given years, with figures for various years in the case of California.

In West Germany wrong-way drivers caused 111 accidents and 29 fatalities in 1978. A later analysis puts the figure at 133 accidents. Of all accidents on German motorways in 1978, 30.7% resulted in injuries, 1.5% in fatalities. In the same year, 48% of accidents involving wrong-way drivers resulted in injuries, 12% in fatalities.

In Switzerland there were eight accidents involving wrong-way drivers in 1977. It is estimated that every year ten accidents are caused by wrong-way drivers, resulting in one or two deaths and ten other casualties. Table IV summarizes these data and also includes figures on the Netherlands. What is striking here is the variation of these figures. It should also be noted that:

- the problem in the USA seems to vary quite considerably from one state to another;
- in California (the most documented state) the problem of wrong-way driving has been far more serious in the past than it is now in the Netherlands, although the situation there is now very much better.

A tentative comparison with other countries indicates that the situation in the Netherlands as regards wrong-driving is relatively favourable.
<table>
<thead>
<tr>
<th>Country or State</th>
<th>Length of motorway network in km</th>
<th>Accidents (involving injury) on the motorway network</th>
<th>Reports of wrong-way drivers</th>
<th>Number of accidents involving wrong-way drivers</th>
<th>Number of fatal accidents involving wrong-way drivers</th>
<th>Number of fatalities caused by accidents involving wrong-way drivers</th>
<th>Accidents involving wrong-way drivers per 100 km</th>
<th>Fatal accidents involving wrong-way drivers as % of all reports of motorway accidents causing injuries</th>
<th>Accidents involving wrong-way drivers as % of all reports</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1968–1971</td>
<td>48,000</td>
<td>3,097</td>
<td>156</td>
<td>255</td>
<td>0.325</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>California</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1961</td>
<td>1,485</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1963</td>
<td>1,900</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1964</td>
<td>2,605</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1970</td>
<td>4,800</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1971</td>
<td>5,123</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1976</td>
<td>6,105</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Germany</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1978</td>
<td>6,600</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1977</td>
<td>730</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1978</td>
<td>1,716</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Interstate network

** Incidents reported. The figure has been interpolated for period 1961–1964

*** General estimate

**** Average for 1968 to 1978, excluding 1977

Table IV Summary of information on reports of and accidents involving wrong-way drivers
4.4 Further information on wrong-way driving

4.4.1 General

In the following a number of factors associated with wrong-way driving are discussed on the basis of the literature consulted. Each of these factors is considered in terms of:
- the highway;
- the environment;
- the driver.
Various features of accidents involving wrong-way drivers are also described.

This section concludes with a discussion of the general approach adopted in research in West Germany, where, as stated above, no data relating specifically to wrong-way driving were available when research began.

4.4.2 The highway

WHERE WRONG-WAY DRIVING BEGINS AND THE MANOEUVRE INVOLVED

Figures on the point at which wrong-way driving incidents begin are to be found in Tables V and VI.

In the West German study the figures shown in Table V are related to the number of locations. Seen from this angle, interchanges and frontier-crossing points are particularly sensitive areas, if only because they come under more frequent police surveillance.

Many American studies state a preference for the diamond interchange. Partial cloverleaves appear to give rise to rather more incidents of wrong-way driving. This is quite clearly true of half and other incomplete interchanges and significant departures from the standard designs.

| Point where wrong-way driving began         | Research in     |
|                                          | West Germany | California |
|                                          |              |            |
| Grade-separated intersections            | 42%          | 70%        |
| Interchanges                              | 29%          | 6%         |
| Service areas                             | 6%           |            |
| Frontier-crossing points                  | 3%           |            |
| Beginning of motorway                     | 6%           |            |
| On carriageway                            | 14%          |            |

Table V  Points on motorways where wrong-way driving began, in %
Interchange where wrong-way driving began

<table>
<thead>
<tr>
<th>Interchange Type</th>
<th>Number of Incidents of Wrong-Way Driving per 100 Exits/Year in California</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete Interchange</td>
<td>5.13</td>
</tr>
<tr>
<td>Incomplete Interchange</td>
<td>9.46</td>
</tr>
</tbody>
</table>

*Gabriel* notes that 70% of accidents are caused by wrong-way driving which begins at a location of less common design.

Table VI Wrong-way driving at interchanges

In California this resulted in a ban on a number of designs which clearly departed from the norm and their removal from the State’s highway standards. Special reference is also made to specific problems which may occur at an interchange. Some data on the type of manoeuvre that leads to wrong-way driving are shown in Table VII.

The literature consulted allows the following conclusions to be drawn:
- wrong-way driving does not begin only at interchanges, and where it does, an at-grade intersection is not always the point of departure;
- uniformity of design has a distinctly positive effect on the incidence of wrong-way driving;
- incomplete interchanges increase the incidence of wrong-way driving;
- departures from standard designs substantially increase the incidence of wrong-way driving;
- smoothly designed motorway exits and accesses reduce the likelihood of wrong-way driving occurring at convergence and divergence points.

<table>
<thead>
<tr>
<th>Wrong-way Driving Manoeuvres at the Point of Origin</th>
<th>Research in California</th>
<th>West Germany</th>
<th>Switzerland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entered motorway via exit road</td>
<td>52.7%</td>
<td>23%</td>
<td>68%</td>
</tr>
<tr>
<td>At interchange or beginning of motorway</td>
<td></td>
<td>28%</td>
<td></td>
</tr>
<tr>
<td>U-turn on carriageway</td>
<td>19.3%</td>
<td>23%</td>
<td>32%</td>
</tr>
<tr>
<td>Turned right on carriageway round convergence point</td>
<td>5.8%</td>
<td>24%</td>
<td></td>
</tr>
<tr>
<td>Turned left from slip road round nose</td>
<td>9.1%</td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td>Entered motorway via exit road but turned right round nose</td>
<td>3.0%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crossed central reserve</td>
<td>3.7%</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Other turning manoeuvres</td>
<td>6.4%</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Other, including service area</td>
<td></td>
<td>6%</td>
<td></td>
</tr>
</tbody>
</table>

Table VII Wrong-way driving manoeuvres at the point of origin (see also Figure 26)
THE EXTENSION OF THE MOTORWAY NETWORK

In the USA it was initially felt that a further extension of the motorway network, combined with greater familiarity with this type of road, would be followed by a reduction in wrong-way driving. This has not been the case. Gabriel considers it necessary for measures taken to be kept in good repair and continually inspected.

NEW ROAD SECTIONS

On various occasions it has been found that newly opened road sections cause relatively more problems. This is partly due to the difference in the situation between phases of the roadwork and the final situation. A particular problem has been posed by exit roads which were (partly) used as access roads while work was in progress.

VISIBILITY DISTANCES

Tamburri has calculated that 50% of the accidents occurred where the visibility distance was less than 1,000 ft (about 300 m). He argues that a minimum visibility distance of 1,200 ft (about 400 m) is required on main carriageways.

California later increased the required visibility distances on main carriageways. Visibility problems may also occur at interchanges (see also 4.7.2). The study in West Germany similarly refers to visibility problems at interchanges where there has been wrong-way driving.

4.4.3 The environment

LIGHT CONDITIONS

The various studies unanimously agree that the incidence of wrong-way driving is higher at night than during the day, both relatively and in terms of vehicle-kilometres. Incidents or accidents occurring at night account for over 50 to 80% of the total. In general, the percentage of accidents is higher than that of incidents at night, and accidents which occur at night are relatively more serious where wrong-way driving is involved. An example of the spread of incidents and accidents over the 24 hours of the day can be seen in Figure 27.

WEATHER CONDITIONS

In general, weather conditions, and specifically rain (a wet road surface), do not appear to have any significant effect on the incidence of wrong-way driving.

DAY OF THE WEEK

At the weekend (variously defined) the incidence of wrong-way driving is comparatively slightly higher. In West Germany it has been found that four incidents occur per weekday and six per weekend.
Figure 27 The spread of wrong-way driving incidents and accidents on divided highways over the 24 hours of the day

THE ENVIRONMENT
The environment, and specifically traffic density, also has an effect. In general, wrong-way driving occurs less frequently in a busy environment. This does not seem illogical, given the greater chance of one vehicle following another. Tamburri notes that 8% of wrong-way driving incidents began when traffic was heavy, compared with 7% in the West German study.

4.4.4 The driver

THE DISTANCE DRIVEN THE WRONG WAY
The following figures, calculated by the authorities in Virginia, apparently concern wrong-way driving incidents. The minimum distance driven the wrong way is 200 ft (about 70 m), the maximum 25 miles (about 40 km), the average being 2 to 3 miles (about 3 to 5 km). (On roads other than motorways the distances are significantly shorter). Tamburri states that 19.5% of wrong-way drivers drove no further than the length of the exit road.

Table VIII shows the breakdown of cases investigated by the police in West Germany, while data collected by Tamburri and Bierwas et al. on the distribution of incidents/accidents by lanes are shown in Table IX.
### Table VIII  The distance travelled by wrong-way drivers

<table>
<thead>
<tr>
<th>Distance</th>
<th>Percentage</th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td>up to 0.5 km</td>
<td>60.4%</td>
<td>60.4%</td>
</tr>
<tr>
<td>0.5 to 1 km</td>
<td>8.4%</td>
<td>68.8%</td>
</tr>
<tr>
<td>1 to 5 km</td>
<td>17.4%</td>
<td>86.2%</td>
</tr>
<tr>
<td>5 to 10 km</td>
<td>8.0%</td>
<td>94.2%</td>
</tr>
<tr>
<td>10 to 15 km</td>
<td>2.4%</td>
<td>96.6%</td>
</tr>
<tr>
<td>over 15 km</td>
<td>3.4%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Table VIII  The distance travelled by wrong-way drivers

### Table IX  Distribution of wrong-way drivers by lanes

<table>
<thead>
<tr>
<th>Lane</th>
<th>Tamburri</th>
<th>Bierwas et al.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>73.1%</td>
<td>80%</td>
</tr>
<tr>
<td>Middle</td>
<td>25.0%</td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>1.9%</td>
<td></td>
</tr>
</tbody>
</table>

Table IX  Distribution of wrong-way drivers by lanes

### THE EFFECT OF AGE

Most studies conclude that older people are overrepresented among wrong-way drivers. Various studies provide detailed breakdowns into age groups to demonstrate this.

*Bierwas et al.* also state that, while older drivers are responsible for only 3% of all accidents, they cause 20% of all accidents involving wrong-way drivers. The middle-aged are most likely to cause an accident by driving the wrong way.

### SEX

*Tamburri* notes that, in terms of driving licences held by men and women, men are more frequently involved in wrong-way driving. He does point out, however, that women drive less at night and generally consume less alcohol than men.

*Bierwas et al.* attribute 15.5% of wrong-way driving to women, which is slightly higher than the proportion of female driving-licence holders, 12%. The difference is too small to allow any conclusions to be drawn.

### OCCUPATION

*Tamburri* refers to a relatively large number of blue-collar workers among wrong-way drivers, but does not relate this to the incidence of other factors, such as the number of blue-collar workers as a proportion of all drivers. Relatively few professional and military drivers are involved in wrong-way driving.

*Bierwas et al.* calculate that passenger cars are involved in 92.4% of all wrong-way driving incidents/accidents, various types of vehicle accounting for the remainder.
ROADWAY USE
*Tamburri* also provides the following information on the frequency with which drivers had previously used the road on which they were involved in a wrong-way driving incident:
- Regularly: 25%
- Occasionally: 23%
- Rarely: 27%
- Never before: 75%

BIOGRAPHICAL BACKGROUND OF WRONG-WAY DRIVERS
From his studies of both incidents and accidents *Tamburri* concludes that few wrong-way drivers are mentally or physically handicapped. He did find, however, that:
- they had relatively more traffic convictions and
- they had been involved in more accidents than the average driver.

At a later date, *Estep* claimed that the typical wrong-way driver is a heavy drinker and has little respect for the law or social customs. In Michigan a significant number of wrong-way drivers had been fined over 10 times. In West Germany wrong-way drivers were found not to have any specific features as individuals or as a group. Foreigners account for 24% of all incidents/accidents.

ALCOHOL CONSUMPTION
Most studies refer to effect of the use, or abuse, of alcohol. *Tamburri* found that alcohol was involved in 43% of accidents and 80% of fatal accidents. Somewhat later, *Estep* also refers to this high percentage. He also reports that the level of alcohol in the blood of 31 persons involved in accidents in 1971, where known, varied from 0.13 to 0.34%, the average being 0.21%. The percentage of road-users under the influence of alcohol and involved in incidents was lower.

In Michigan drinking was a factor in 50% of accidents. *Vaswani* found that the proportion of drivers who had been drinking and were then involved in incidents was far higher during the hours of darkness than during daytime. *Bierwas* et al. state that, of 1,264 drivers examined to see if they were under the influence of alcohol, 198 (16%) were found to have been drinking. It was possible to determine the alcohol content in the blood of 189 of the wrong-way drivers concerned. It varied from 0.8 to over 3‰, the average being 1.91‰. The analysis of the accidents indicates that 33% of the wrong-way drivers involved in accidents were under the influence of alcohol.

INFLUENCING FACTORS
*Bierwas* et al. give a breakdown of 444 cases of wrong-way driving by causes, and
this is shown in Table X. However, various factors influence wrong-way driving. The West German study illustrates this with a number of brief reports of interviews with wrong-way drivers. This shows that the factors given in Table X were more or less dominant. Analysing this table in greater depth, Bierwas et al. say that disorientation is a not insignificant factor.

<table>
<thead>
<tr>
<th>Cause</th>
<th>Incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intentionally driving the wrong way:</td>
<td></td>
</tr>
<tr>
<td>- after missing an entry or exit</td>
<td>220</td>
</tr>
<tr>
<td>- for special reason (e.g. lost something)</td>
<td>117</td>
</tr>
<tr>
<td>- because of technical fault, shortage of fuel</td>
<td>75</td>
</tr>
<tr>
<td>- because of unusual traffic conditions (e.g. turning to avoid traffic jam)</td>
<td>17</td>
</tr>
<tr>
<td>Unintentionally driving the wrong way:</td>
<td></td>
</tr>
<tr>
<td>- having lost the way</td>
<td>182</td>
</tr>
<tr>
<td>- having misunderstood direction markings (e.g. because of unclear signposting)</td>
<td>120</td>
</tr>
<tr>
<td>- unaware of being on a motorway</td>
<td>21</td>
</tr>
<tr>
<td>- environmental factors (visibility obstructed, distraction)</td>
<td>19</td>
</tr>
<tr>
<td>- following example of preceding wrong-way driver (imitation effect)</td>
<td>11</td>
</tr>
<tr>
<td>Other</td>
<td>42</td>
</tr>
<tr>
<td>Total</td>
<td>444</td>
</tr>
</tbody>
</table>

Table X  Factors influencing wrong-way driving in West Germany

From this it can be concluded that the highway authorities should ensure that roads do not allow drivers to become confused. Points worth considering in this context are:
- lack of continuity in signposting;
- poor visibility – particularly through the positioning of traffic signs;
- confused design;
- inconsistency of the information provided.

Other research carried out in West Germany indicates that wrong-way drivers are not distinguished by any particular features as individuals or as a group or by any specific circumstances. However, they do include a comparatively large number of people who are less familiar with motorways. From Tamburri’s findings and other factors it can be concluded that lack of familiarity with the specific features of and rules governing motorway driving clearly increases the risk of wrong-way driving.

As regards '(un-)intentional' wrong-way driving, it can also be said that wrong-way drivers could be broken down into those who act unconsciously (without malice) and those who act deliberately. The latter can be subdivided into the following groups:
- Those who unconsciously make a mistake (drive into an exit road) and consciously try to make amends by driving on in the hope of an early opportunity of correcting their mistake.

- Those who deliberately make a mistake, usually to save time. This may happen at partial interchanges and after a divergence point has been passed. It should be remembered that in other countries the distance between interchanges is generally greater than in the Netherlands and that mistakes cannot therefore be corrected so quickly.

The following example may serve to illustrate this. A Dutch family stopped at a parking area on a French motorway. Unnoticed, their dog left the car and disappeared. It was only when they were back on the motorway that they discovered the dog was missing. They left the motorway at the next exit, drove back on via the access road and returned via another interchange to the parking area – a distance of 210 km!

- Those who plan to drive the wrong way from the outset to save time. The American literature gives a striking example of frequent wrong-way driving along an exit road at a partial interchange to save about 2 km.

- Others.

4.4.5 Other features of the accidents

TYPES OF ACCIDENT

Scifres gives a breakdown by types of accident in Indiana, which shows that almost 80% of accidents took the form of head-on collisions.

VEHICLES INVOLVED

Bierwas et al. also provide some information on the number of vehicles involved:

1 vehicle (alone)  9%
2 vehicles       63%
3 vehicles       18%
4 vehicles       9%

4.5 The study methods used in West Germany

A general and nation-wide study of wrong-way driving began in West Germany in 1976. In view of the lack of data, the limited time allowed for the study because of the need for action to be taken relatively quickly, and the low incidence of wrong-way driving, the following approach was adopted:
a report procedure using forms to record all cases of wrong-way driving, in which the highway authorities, police, road patrol personnel and lessees of service facilities cooperated;

- a supplementary study by two scientific institutions into the sociological and psychological background to wrong-way driving;

- a special multi-annual accident analysis to provide an insight into the spread of wrong-way driving incidents/accidents over several years.

The report period lasted from 1 January 1978 to 31 December 1979, during which 3,502 cases of wrong-way driving were reported. Of these, 204 resulted in accidents. Fairly extensive, but not always complete, police reports are available on 1,321 cases. Although the remaining 2,181 cases had been reliably reported, the information on them is limited. The incidents occurred throughout the Federal Republic, and there were no regional concentrations.

A number of wrong-way drivers were interviewed on a purely voluntary basis. A limited number of these interviewees then took part, again voluntarily, in a more detailed study involving, for example, on-the-spot investigations and tests.

Various interim studies appeared over the years, with all the findings summarized in the final report published in 1981.

4.6 General Summary

The following is a summary of the information provided thus far.

- The outcome of accidents involving wrong-way drivers is far more serious than that of other accidents. A large proportion take the form of head-on collisions.

- Wrong-way driving may begin anywhere in the motorway system.

- Incomplete interchanges and a non-standard design increase the likelihood of wrong-way driving.

- The smooth design of motorway exits and accesses is a favourable factor.

- Apart from the driver himself, the highway is an important factor.

- There is no such thing as the typical wrong-way driver: every road-user is a potential wrong-way driver.

Factors which increase the likelihood of wrong-way driving are the following:

- age: older drivers are far more likely to be involved in accidents of this kind;

- limited experience of motorway driving;

- lack of familiarity with the highway code, especially as it concerns motorways;

- the situation during the hours of darkness;

- the use of alcohol;

- inconsistency of different signs, correct though they may be in themselves, and other indications for the road-user.
- Much wrong-way driving is of short duration.
- Apart from the problem of wrong-way driving, thought should be given to situations where road work is in progress and to single-carriageway sections (i.e. without a central reserve).

In addition to analysing the situation in West Germany, Bierwas et al. review the foreign literature, comparing it with the findings of research in West Germany. They conclude that the basic features of wrong-way driving accidents are the same everywhere. This and the preceding remarks indicate that the above general conclusions largely apply to the Netherlands.

4.7 Measures and effects

4.7.1 General

The American literature discusses specific measures and their effects, while the West German literature focuses primarily on measures to reduce the incidence of wrong-way driving. Some of the measures considered in the USA have been introduced and tested on varying scales. Two studies, conducted in California and Virginia, are particularly worthy of note. The California study began in 1961 and was carried out by Tamburri. (So far most studies appear to have been conducted in California.) The study in Virginia was made by Vaswani.

Measures described in the West German study are then discussed.

4.7.2 Tamburri's study in California

Tamburri conducted his study in three phases, each lasting nine months. A number of subsidiary studies were also carried out.
Phase I took the form of a pilot study. Phase II consisted of a study into various aspects of wrong-way driving, on ordinary roads as well as motorways. During this period a study was also made of a number of measures, some of which were introduced on a large scale. In Phase III the measures taken were evaluated.

After the first study, which, as has been said, took the form of a pilot study, special arrows were painted on exit roads. During Phase II a more detailed study was made of wrong-way driving, after which measures were taken on a large scale. These measures included the following:
- the placing of black-on-white DO NOT ENTER and white-on-red WRONG WAY signs on all exit roads (Figure 28);
Figure 28  The signs initially used in California

Figure 29  The special arrow for use on exit roads
– the painting of arrows on exit roads. These arrows were especially designed to make them clearly visible to wrong-way traffic (Figure 29);
– the placing of white-on-green ENTRANCE signs and the painting of arrows on access roads.

Measures were also taken on dual-carriageway roads and at transitions from dual-to single-carriageway roads, while additional measures, consisting of an additional set of signs on exit roads and large reflecting arrows on the road surface, were taken in a smaller area.

Having evaluated these measures, Tamburri describes their effect as follows. On motorways incidents were reduced by 60%, accidents by 30% and fatal accidents by 60%. The effect was most pronounced at exit roads, the reduction in incidents being 72% for all exit roads and 81% for those at which all the measures had been taken. The publicity given to the measures taken and the fact that they were seen regularly also played a part during this period. The measures taken were most effective during the hours of darkness.

Major positive effects were also achieved on roads other than motorways. Although comparing the various phases of this three-phase study posed certain problems, the effects seem perfectly clear. Tamburri recommends further study into the influence of design.

AN EXPERIMENT WITH VEHICLE-RELATED INFORMATION AT ONE EXIT ROAD

On one exit road an experiment was carried out with vehicle-related warnings consisting of:
– a GO BACK - YOU ARE GOING WRONG WAY sign, which lit up only when a wrong-way driver approached;
– a red light operating in the steady mode;
– two horns, one continuous, the other pulsating;
– an inductive loop in the road surface to detect wrong-way drivers;
– a film camera to record wrong-way driving incidents and so reveal the effect of the experiment.

Once a wrong-way driver had been detected, the whole of the above procedure took 20 seconds. This experiment was accompanied by a great deal of publicity, one consequence of which was that young people went out of their way to ‘test’ the equipment. After the introductory period, Tamburri found this measure to be 89% effective. The remaining wrong-way drivers may have turned out of camera shot.

Five people interviewed, who had all turned back after driving the wrong way, included some drinkers and disoriented persons. This is said to indicate that even such people can be influenced. People living in the adjacent area found the noise of the horns very annoying.
SUBSIDIARY STUDY
Using a driving simulator, Hulbert and Beers studied various types of signs, four with the inscription DO NOT ENTER, two ordinary black-and-white signs and two circular red signs.
Black-on-white signs and red-on-white (circular) signs with a white bar had the same effect. For practical reasons, the black-and-white combination was chosen. The addition of the message WRONG WAY (in white on red) was considered advisable.
This study also makes a general assessment of arrows painted on the road surface. It was found that the standard arrow is seen less clearly by wrong-way drivers than right-way drivers, a point which is not developed further.

4.7.3 Further research in California

GENERAL
In 1970 three serious wrong-way driving accidents occurred in the space of four days in California. They received intensive news coverage and prompted the traffic engineers to reconsider the problem.
The first step was to make an inspection, both during the day and at night, which revealed considerable room for improvement in the siting of signs and the direction in which they pointed. Moving back the ‘nose’ of the partial cloverleaf was similarly effective. A great deal of care was taken over visual guidance. To ascertain whether the lay-out was optimal, exit roads were closed and then driven along in the wrong direction.

COUNTING WRONG-WAY DRIVERS
Early 1971 saw the start of a large-scale research programme involving the installation on exit roads of counters which recorded wrong-way movements only. Each counter was linked to a camera, which took a photograph after a wrong-way movement had been detected. The photograph served two purposes: firstly, to verify that the vehicle was proceeding in the wrong direction, not simply rolling back momentarily, and secondly, to provide information on the direction from which the wrong-way driver was coming.
The counters consisted of two pneumatic tubes and electronic circuitry, which ensured that only wrong-way movements were recorded. The camera was of a simple type. All the equipment was installed in a steel box.
Initially, 150 counter units were constructed. As the initial period proved very promising, a further 150 counters were added (with Federal financing). The counters were left on each exit road for about 30 days. There being 4,200 exit roads, the programme lasted 4 years.
The whole programme was based on the researcher’s hypothesis that measures
taken on exit roads would have an above-average effect. The counters were used
to record the number of wrong-way driving incidents on each exit road over a
time period of some 30 days. It was found that on 7% of exit roads 5 or more cases of
wrong-way driving occurred in the 30-day period. This was the standard for
'problem' exit roads. The figure was far higher on some exit roads.
On 233 of the 257 'problem' exit roads (90%) it was possible to reduce the number
of wrong-way movements to an acceptable level (two or fewer per 30-day period)
by installing the standard sign package and, where necessary, taking minor sup­
plementary measures. The remaining 24 exit roads, where problems persist, requi­
re further research, which will entail, for example, the introduction and testing of
other special measures and possibly a change of design.

SETTING PRIORITIES
To establish which exit roads should be given priority, the following 'incident
index' (i.i.) formula was developed:

\[
i.i = \frac{(\text{wrong-way movements by day}) + (4 \times \text{wrong-way movements by night})}{\text{(number of counting days) \times (all vehicles using access roads at interchange)}} \times 10^6
\]

This 'incident index' thus places added emphasis on incidents occurring at night
and forges a link with the use of the interchange as a whole, thus enabling the
likelihood of an incident occurring to be calculated.
The researchers conclude that the method described is successful and recommend
that this type of research be continued, especially in the case of 'problem' exit
roads until an adequate solution is found. The level of research should be related
to the number of accidents attributed to wrong-way drivers. The surveillance of
newly constructed interchanges is also recommended.

GENERAL MEASURES
The following general measures were found to be effective:
- a standard package at access and exit roads, consisting of the following:
  * on access roads, a 'totem pole' combination of signs indicating freeway
  entrance, the route number, the direction and an arrow pointing towards the
  access point. This 'totem pole' is usually placed on both sides of the road;
  * arrows on access roads;
  * on exit roads, the international no-entry sign with DO NOT ENTER written
    on it and a WRONG-WAY sign beneath;
  * signs showing an arrow with ONE WAY written on it, placed particularly low
    (20 to 60 cm above ground level) so as to be clearly seen at night in a car's
    headlights;
- at the ‘nose’ of partial cloverleaves, an additional KEEP RIGHT sign with an arrow;
- arrows on exit roads.

A ‘do not enter’ package must always be visible to the road-user in the headlights of his car. The use of ‘no left turn’ and ‘no right turn’ signs is discouraged: drivers under the influence of alcohol might mistake them for directional arrows. All signs must be carefully related to the relevant traffic movements. It is emphasized that as much thought must be given to the design, marking, signposting and lighting of access roads as to warnings on exit roads. Positive guidance is at least as important as measures designed to reduce wrong-way driving.

It is also recommended that incomplete interchanges be avoided and that exits on the left side of carriageways be eliminated because of its close resemblance to an access road. The package of measures described above has thus proved effective in most situations.

SUPPLEMENTARY MEASURES

The following supplementary measures, though not generally applied, were also found to be effective:
- internally illuminated FREEWAY ENTRANCE signs;
- additional trailblazers (small signs inscribed with the route number and an arrow) on access roads;
- repeat WRONG WAY signs 50 to 100 m from the end of exit roads;
- an additional lighting column on access roads to increase their visual attraction;
- reducing the size of the exit-road throat with kerbs and markings; physical and painted triangle islands separating traffic turning left from traffic turning right are discouraged.

Of the other measures discussed, some have been used occasionally, others not at all. They include:
- painting the curbs of exit roads red and white, those of access roads green and white. This measure is not enough in itself;
- painting stripes on superfluous road surface;
- making the white reflecting studs on carriageways red on the other side. Not only were most drivers unfamiliar with the significance of these studs, it was also found that they acted as a guide for drivers under the influence of alcohol. The use of red reflectors has therefore been reduced, and in general they are now only placed near exit roads;
- using reflecting studs to guide drivers to access roads at intersections;
- installing especially eye-catching DO NOT ENTER signs equipped with small mirrored lenses. As these signs were not retroreflective and relatively expensive, they are no longer used;
- installing a series of trailblazers (small signs showing a route number and an arrow) in the middle of local roads to guide drivers to access roads (occasional use);
- a constant red light. Reference is made to the possibility of drivers regarding this as a traffic signal, stopping and then continuing, confident that they are travelling the right way. Its use is not considered desirable;
- a pulsating neon sign on an exit road was not satisfactory;
- occasional use was made of a series of signal heads continuously changing from green balls to arrows. This measure was effective;
- red warning lights embedded in the road surface and actuated by a detector. This measure was still being evaluated at the time of the report, but initial experience was very encouraging;
- bumps designed to give the wrong-way driver a noticeable jolt while sparing right-way traffic as far as possible. Not introduced;
- additional signs and markings where drivers mistake an exit road for another, parallel road usually proved enough to overcome the problem.

MOVABLE BARRIERS
Movable barriers, possibly equipped with spikes, have attracted considerable attention. It was the most frequently suggested solution, partly because spikes had been successfully used to prevent wrong-way entry to car parks. Seven trial runs at speeds up to 100 kph were made over standard spikes. In six of the runs no effect was noticed after five minutes. To improve their effectiveness, a ‘fish-hook’ barb was welded to the end of each spike. This led to tyre deflation within 30 seconds. However, the strength of the tyre casing caused a permanent bend in the spike. Another problem was that at speeds over 40 kph it could not be seen in which direction the spikes were pointing. Some right-way drivers tried to take evasive action. Spikes also entail the considerable risk of a driver, having discovered his mistake, no longer being able to move his vehicle because the tyres are flat. In California all ideas of introducing movable barriers have now been rejected because they also affect right-way drivers and might harm the vehicle, its passengers and anything it may be carrying, which is not considered desirable.

It is also emphasized that it is not possible to prescribe blanket usage of any of the supplementary measures and that great care is needed in selecting the right device for a given location.

EFFECT OF THE MEASURES
The effect of all the measures taken in California is revealed by the following data. From 1963 to 1976 motorway mileage increased by 190% and traffic intensity by 230%. The following figures on accidents involving wrong-way drivers in these 13 years have been calculated by analytical regression:
- fatal accidents increased by 20%;
accidents in which injuries only were sustained increased by 27%;
- accidents causing material damage rose by 86%;
- taken together, accidents causing injuries and fatalities increased by 25%.

The number of accidents involving wrong-way drivers per million vehicle-miles on the motorway network fell by 54%. The equivalent figure for all accidents was 36%. (See also Figure 30). From these data it is concluded that the measures taken during the 13 years from 1963 to 1976 were successful.

Figure 30  Accidents involving wrong-way drivers from 1963 to 1976 related to the total length of the motorway network and vehicle-miles

GENERAL USE OF SIGNS AND ARROWS
The 1977 and 1978 editions of the American Manual on Uniform Traffic Control Devices show the standard signs and markings for interchanges which include one-way roads. An example of an exit road is shown in Figure 31.

4.7.4 Vaswani’s study in Virginia

Vaswani made a study of wrong-way driving in Virginia and examined the design of motorway interchanges. Based on the findings of these investigations, a number
of case studies were carried out. The measures taken were later introduced on a fairly large scale. Wrong-way driving incidents were reduced by 50%. Growing public awareness of the problem may have contributed to this reduction.

The measures taken were the following:
- Two retroreflecting arrows on exit roads and one on access roads. The first arrow on the exit road must be close to the intersection. This arrow appeared to be particularly effective.
- The elimination of unnecessary flares at intersections. This was usually achieved in the first instance by painting stripes on the road surface. This measure was also effective.
- As incomplete interchanges were also very ‘sensitive’ in Virginia, a stop line was painted on the road surface at every exit from such interchanges.
- The continuation of the road edge line across the exit road junction to discourage the inattentive driver from following the edge line into the exit road.
- Double (yellow) lines on the local road.
- Additional guidance at new interchanges, especially in the form of road surface arrows which, once installed, do not need repairing.
- Gaps in the physical division of local roads should be no wider than absolutely necessary.
- Signs indicating the division of the carriageway and similar situations.
- No gaps in the central reserve opposite minor exits on dual-carriageway roads and clearly visible signs to guide drivers to the right.
- Reflectors across exit roads to attract the driver’s attention.
Figure 32 Examples of Goodman's 'ears'
4.7.5 Various American studies

GOODMAN'S 'EARS'

Goodman proposes that diamond interchanges should include 'ear roadways' which automatically lead the wrong-way driver back on to the exit road (Figure 32a).

Examples of other applications of the ear roadway can be seen in Figure 32b. This measure appears to have been rarely used or evaluated. Elsewhere a 'sand pit' is proposed to bring the wrong-way driver to a halt (Figure 33).

![Figure 33 Example showing how the wrong-way driver is guided into a 'sand pit'](image)

REFLECTING STUDS ON EXIT ROADS

Shepard laid seven rows of seven reflecting studs in the surface of exit roads at two locations in Virginia. The positioning of the studs in the row was arbitrary. The aim was to attract the driver's attention so that he would be more likely to look round and notice signs.

Of the persons interviewed, 91% found that this measure made them more attentive.

RED REFLECTING STUDS ON CARRIAGEWAYS

In Case's opinion the pattern of red reflecting studs on main carriageways was too regular to alarm the wrong-way driver. Having tried various patterns on a driving simulator, he recommended an erratic pattern. This study was also widely discussed.

It was also found that six of the seven people involved in the test did not know
that a normal white-reflecting stud reflects red on the other side, although they might have realized this in an appropriate situation.

DESIGN OF INTERSECTIONS

Scifres recommends that central reserves should be kept narrow and have as small gaps as possible. In addition, exit roads should, where possible, join local roads at an angle of 90°.

NO LEFT TURN AND NO RIGHT TURN

Various studies refer to the advantages of NO LEFT TURN, NO RIGHT TURN and ONE WAY signs (The Californian authorities have reservations about NO LEFT TURN and NO RIGHT TURN signs).

GENERAL APPLICATION OF MEASURES

Several studies state that wrong-way driving occurs throughout the road network. Few refer to concentrations. This would imply that any measures taken should be introduced throughout the motorway network. From this it must be inferred that no measure may be too expensive.

4.7.6 Measures taken in West Germany

GENERAL

Action designed to prevent wrong-way driving in West Germany can be divided into measures relating to the highway and measures to improve the conduct of road-users.

It is recommended that the first steps should be:
- an inspection of intersections and interchanges;
- the placing of ‘no entry’ signs on exit roads from interchanges.

Other measures:
- must be simple;
- should be compatible with present, familiar signs and markings;
- must be unambiguous and as uniform as possible.

THE LIST OF MEASURES

On the basis of the above criteria, a list of measures has been compiled and distributed. These general measures include the following:
- the enlargement of existing signs;
- the installation of additional ‘no entry’ signs and two signs indicating the direction to be followed;
- greater attention to the separation of traffic flows where work is in progress on one carriageway with oncoming traffic.
Supplementary measures mentioned are:
- arrows on slip roads;
- especially eye-catching signs through the use of background shields or by position- ing them at a higher level;
- repetition of ‘no entry’ signs;
- additional direction signs at interchanges.

Further possibilities are:
- an increase in the number of arrows on access and exit roads;
- high direction signs;
- additional signs MOTORWAY;
- closure of factory and emergency exits.

These measures should be assessed continually and as far as possible seen through the eyes of road-users unfamiliar with the locality. The importance of uniformity throughout the motorway network is again emphasized. Many suggestions are also made by such third parties as private citizens and institutions. They concern the teaching of roadcraft, the increased use of existing signs and delineation devices, and new signs. Frequent reference is also made to automatic detectors linked to signals and various types of barrier which can only be passed in the right direction. Some suggestions raise problems, while others had already been included in the list of measures. An important criterion when measures are assessed is that they must not be disadvantageous to right-way drivers.

PLANNING AND DESIGN
Planning and design are also considered.
- After taking the wrong exit at an interchange, a driver should be able to turn at the next intersection via the exit and access roads.
- Whether access and exit roads at partial cloverleaves should be physically separated from the outset is a difficult question to answer. Measures designed to prevent two types of wrong-way driving are incompatible in this case.
- The physical separation of access and exit roads after the beginning of the access road on partial cloverleaves must be clearly visible.
- There should be no junctions in the vicinity of intersections giving access to motorways, so as to avoid confusion with motorway access and exit roads.
- The following is recommended for interchanges:
  - sufficient distance should be allowed between divergence points;
  - auxiliary lanes should preferably be limited to one lane so that they do not obscure slip roads leading off to the right;
  - access roads should join local roads at a very sharp angle.
- In parking areas the parking spaces should be so arranged that drivers always drive off in the right direction, i.e. nose-to-tail parking or parking at an angle of considerably less than 90°.
TEACHING ROADCRAFT
It is also claimed that a great deal could be done to solve the wrong-way driving problem by concentrating on road-users, with the emphasis on the correct use of motorways. It is important in this context that the driver should:
- prepare for his journey by noting road numbers, interchanges where he will be changing from one motorway to another and the name of the exit where he will finally leave the motorway;
- use good and recent road maps that make a clear distinction between types of road, display road numbers and the names of interchanges and intersections in an easily legible form and indicate the course to be followed at intersections and interchanges.

One problem connected with the use of maps is that many people have difficulties in using them. This should be borne in mind during driving instruction. Instruction should also be given on situations that occur where road work is in progress, the right course of action after a driver has taken the wrong road and what he must do when he discovers that he has become a wrong-way driver.

TRAFFIC INFORMATION BY RADIO
In West Germany reports of wrong-way drivers are broadcast on the radio, principally to warn other road-users (these broadcasts have done a great deal to increase the publicity given to and public interest in wrong-way driving). Such information is of benefit only to drivers who have radios in their vehicles and know where they are. In addition, as little time as possible must elapse between the report of a wrong-way driver and the broadcast. Not enough experience had been gained to give a general recommendation on the benefits of radio reports in this respect.

EVALUATION
In view of the information required for a good before-and-after study and other factors, it will not be possible for a study of this kind to be nationwide. Experience from the ‘provinces’ indicates that effective action can certainly be taken. Recent information indicates that measures are highly effective. A global analysis of the costs incurred as a result of wrong-way driving accidents and the cost of measures to combat wrong-way driving is made.

It is also stressed that, despite the wrong-way driving problem, the motorway is by far the safest type of road.

4.7.7 Various measures
‘ESCAPE ROADS’
A solution that has received considerable publicity in the Netherlands was propos-
ed by A. Thysse of Alphen a/d Rijn (Netherlands), see Figure 34. Wrong-way drivers on diamond interchanges are diverted into a sand-pit, a solution that matches American ideas on the subject.

Figure 34  Thysse's proposal for an escape lane and gravel pit

On partial cloverleaves an opportunity for taking corrective action is provided by enabling the wrong-way driver to move from the exit to the access road.

YELLOW LINES AT THE END OF EXIT ROADS
It has been suggested by Dr. Kolkman that a curved yellow line should be painted on the road surface at the end of exit roads, as illustrated in Annex IV. This measure is less direct and likely to be less effective in unfavourable weather conditions. Road-users will also have to learn the meaning of the yellow line.
5 Supplementary measures taken in the Netherlands with particular reference to roads; the selection of supplementary measures

5.1 General

Having regard to the undesirability of wrong-way driving on the one hand and the generally high degree of uniformity already achieved in the motorway network on the other, no more than supplementary measures can be taken. A wrong-way driving incident can begin anywhere in the motorway network, although the area of chief concern in the Netherlands, where motorways are of a very smooth design, is the transition from other types of roads to motorways. Furthermore, it is far more difficult to take measures on motorways – particularly at points where deceleration lanes, weaving sections and confluences are found – than at the at-grade intersections.

5.2 Types of supplementary measures relating specifically to roads

A distinction can be made between the following types of supplementary measures:
- static information by means of delineation, marking and signposting;
- information triggered off by vehicles;
- physical means;
- design and highway devices;
- inspection.

5.2.1 Static information by means of delineation, marking and signposting

This group of measures includes the permanent provision of information by means that as a rule already exist. Various options are described below.

ARROWS ON EXIT ROADS

Arrows indicating the right direction can be painted on exit roads. This method has the advantage of being relatively simple and inexpensive. However, in less favourable conditions (at night and/or when the road surface is wet), markings are less easily seen. Furthermore, special arrows that can be clearly seen by wrong-way traffic are needed. An example is shown in Figure 29.

When the use of such arrows is being considered, account should also be taken of the legal consequences (the obligation to proceed straight ahead), although this
need not affect a specific design. Nor should the arrows clash with left- and right-turn arrows, used for preselection.

A practical disadvantage of arrows is that they have to be repainted at regular intervals.

Before the start of a new section of road works, the road can be painted with additional arrows, which do not need repainting on the completion of the road works.

LANE MARKING

It has been suggested on a number of occasions that lanes should be marked in such a way that road-users know whether they are on a one-way or two-way road. This is a logical idea since drivers would always have such marking in their field of vision.

A system of this kind was discussed during the preparations for the amendment of Chapter IV, Road Markings, of the Vienna Convention (Figure 35), particularly in view of the introduction in the USA of a marking system whereby lanes with different directional flows were separated with yellow lines because the distinction between one- and two-way roads was a major problem in the USA. This distinction is also a problem in the Netherlands, as an investigation into the subject by the Royal Dutch Touring Club (ANWB), for example, has revealed.

![European rules concerning road traffic, signs and signals](image)

Figure 35 The cover of the Vienna Convention and supplements

Initially, a number of countries, including the Netherlands, were very enthusiastic about the American solution. From Figure 36 it can be seen that a system of this kind had advantages provided that it is widely known. It was not introduced, however, because a closer inspection revealed insurmountable problems.
Figure 36  Examples of yellow markings dividing traffic streams
The most serious problem was that in Europe white and yellow lines are not, or not always, identified as such and the failure to identify yellow lines in particular could have serious consequences.

Such failure might be due, for example, to the narrow angle from which markings are seen, visibility at night and/or in bad weather and the use of sodium lighting and yellow headlights. Permanent markings are at present white. Temporary markings and markings indicating parking restrictions are in other colours.

The idea of using markings to indicate one- or two-way traffic remains attractive. The Ministry of Transport and Public Works regularly receives suggestions to this effect, calling, for instance, for small arrow-heads to be painted on the centre line and for the centre line itself to be painted in various crescent shapes. The introduction of such measures would, however, raise a number of problems. The implementation of most of these ideas would affect the whole of the road network, which would have major implications as regards practical feasibility. Difficulties would also arise during the transitional period.

In addition, these are relatively subtle measures, which would be less effective in unfavourable weather conditions (at night and/or when the road surface is wet). At all events, agreement should, or indeed must, be reached on the above suggestions at European level.

REFLECTORS
The Dutch Road Delineation and Marking Standards recommend the placing of reflecting posts at the sides of roads as a supplement to road markings particularly at night and/or in bad weather. The major roads in the Netherlands now have these posts. The reflectors on the posts are white and red.

Red is used on the right in analogy with the rear lights of preceding traffic, which is passed on the left. White is used on the left in analogy with the headlamps of on-coming traffic, which passes on the left. Reflecting posts on single-carriageway roads have one reflector on each side.

On motorways the reflectors are seen only by the traffic on the carriageway concerned. This policy can be maintained. Five reflector posts with a number of green reflectors are placed on the noses of divergence points on motorways. This is commensurate with the meaning of the colour green on traffic beacons as shown in the Dutch Rules concerning road traffic, signs and signals, viz. pass on both sides.

One or more reflectors could be attached to the rear side of reflecting posts, particularly on exit roads. Red reflectors or reflectors of another colour, blue for example, could be used for this purpose. This measure seems subtle and is indirect. Another possibility would be to place red reflectors across exit roads. This is a less subtle measure but might cause motorcyclists problems handling their machines. It would also entail a considerable amount of work and maintenance.
Additional traffic signs can be in the form of existing or completely new signs. As the meaning of a new sign usually has to be learnt, the use of existing signs is preferable. 'No entry' signs at some distance from the end of exit roads might be suitable. This sign is well known. To make it conspicuous, it should be placed on both sides at the height at which it will be clearly seen in a car's headlights. The sign should also be large and, as the hours of darkness are particularly hazardous, coated with high-quality retroreflecting material except where the wide-angle effect of such material is a disadvantage. As the siting of these signs is unusual – the normal alternative of another road or side-road does not exist – and in view of the overall situation, a second sign should be placed beneath them to provide specific information, e.g. GO BACK, possibly preceded by information of an explanatory nature (Figure 37).

![Example of 'no entry' signs above GO BACK signs](image_url)

This measure is comparatively inexpensive and provides information in a conspicuous way. At the at-grade junction the driver's attention will after all have to be drawn to a considerable number of factors, such as other road-users and informative devices. On exit roads there is, apart from these signs, little else requiring the driver's attention. Special care must be taken over the location of signs at partial cloverleaves to prevent them from being seen from access roads. The right-hand sign should always be shielded with vegetation or an appropriate screen so that it

1 See also Annex 1
is invisible from the access road. It would also seem advisable not to use material with a wide angle of retroreflection on the left-hand sign. A large ‘start of motorway’ sign might be placed on every access road.

5.2.2 Information triggered off by vehicles

Devices can be used on exit roads to detect the passing of a wrong-way driver and automatically activate illuminated signs and flashing lights. Devices of this kind have been used very occasionally in other countries but have proved quite effective.

An important factor in such options is a supply of energy, either from batteries or the mains. Batteries have to be replaced at set intervals, and the laying of cables is a not insignificant cost factor if mains electricity is to be used. A recent development is the use of solar panels as a source of energy. A disadvantage of any warning system that is triggered off by the vehicle itself is its relatively high cost. The simplest design costs about 5,000 Dutch guilders and an improved version around 10,000 Dutch guilders.

On the basis of extensive traffic information obtained with the aid of the detection and recording facilities of motorway signalling systems, the feasibility of using no more than (double) loop detectors on the relevant lanes as a reliable means of detecting wrong-way drivers is being considered. If this is possible, other road-users can in theory be automatically warned of wrong-way drivers on signal-controlled sections of the road. Special thought should be given in this context to the wrong-way driver who, having reached the carriageway, then changes lanes.

5.2.3 Physical devices

BARRIERS

To prevent or at least reduce the incidence of wrong-way driving, various physical devices can be used. Firstly, there are devices which bring the vehicle to a halt without causing right-way drivers major problems (Figure 38). A variation of this design also punctures the tyres of the wrong-way vehicle (Figure 39).

Obstacles of this kind seem very effective, but they also have obvious disadvantages:

- Bumps would also jolt right-way vehicles, which might harm the vehicle, its passengers and its load. This is not acceptable. Another factor to be considered in this connection is that the number of wrong-way drivers bears no comparison to the number of right-way drivers.
Figure 38 Example of a movable barrier
- Bumps would be seen as obstacles even by right-way drivers and might lead to unexpected braking. In theory, this problem would arise only in the initial stages.
- They would also stop the emergency services, which sometimes use exit roads to reach the scene of an accident against the flow of traffic.
- The cost of both installation and maintenance would be not insignificant.

As regards the first two objections it can be argued that a detector device could be installed to raise the barrier above the surface of the road only when a wrong-way driver approaches. This design would be even more expensive, of course. In principle, the use of barriers (whether or not equipped with spikes) seems justified in view of the purpose they are intended to serve, the prevention of wrong-way driving. Their use should, however, be subject to the criterion that they are so designed that right-way vehicles suffer no damage or as little damage as possible. The presence of the barrier must also be sufficiently obvious to right-way traffic. All these limitations stem from the law relating to highway authorities for obstacles on the highway.

Reference must also be made to a letter dated 18 February 1983 from the Director-General of Public Works, which says, among other things, that ‘the use of spikes on motorway exit roads is not being considered at present’... ‘We have estimated the cost at 15 to 20 million guilders. I do not consider such expenditure to be in proportion to the magnitude of the problem, particularly in view of the measures
I have already initiated and also in relation to the overall problem of road safety. From this it is clear that there is no chance of such barriers being installed.

**ESCAPE ROADS**

Also included under the heading of physical devices are the various types of ‘escape roads’, designed either to get the wrong-way driver back on to the right road or to bring him to a halt without harm to himself, in a ‘sand pit’, for example. Such solutions have been used sporadically and are not recommended. As already mentioned, a solution that has received a great deal of publicity in the Netherlands was suggested by A. Thysse of Alphen a/d Rijn (see Figure 34). Adequate care should be taken over the design of this gravel pit or possible variations to ensure that admissible rates of deceleration are not exceeded. The cost is not inconsiderable, amounting to around 100,000 Dutch guilders in the case of a diamond interchange where the motorway passes over the local road. Where the local road passes over the motorway and is thus at an incline, the cost may be as high as 400,000 Dutch guilders. At partial cloverleaf interchanges A. Thysse proposes a link between exit and access roads to enable the wrong-way driver to return to the access road. The question is whether a wrong-way driver, having chosen the wrong opening at an intersection by passing the central division on his left, is then likely to choose the right opening on the escape road. Escape roads could also be taken by road-users who, although proceeding along the access road in the right direction, have second thoughts about joining the motorway. It should also be noted that the wrong-way driver, who cannot always be expected to give way to traffic on the access road, may come as a considerable surprise to road-users on the access road, possibly with disastrous consequences. Exit roads should also be as narrow as possible. The cost of an escape road per exit is estimated at between 30,000 and 35,000 Dutch guilders. It appears to be a very effective measure. (See also 5.5, Selection of supplementary measures.)

5.2.4 *Design and highway devices*

The effect that any measure likely to limit wrong-way driving has on traffic as a whole should always be considered. No measure may, of course, adversely affect other traffic.

**THE DESIGN OF ACCESS AND EXIT ROADS**

When motorway interchanges are being reconstructed (and naturally when new ones are being built), a number of measures can be taken to increase the visual attraction of access roads and to keep exit roads as narrow as possible. The
following options are available in this respect:
- unless there are obvious reasons for not so doing, exit roads should be limited to one lane and hard shoulders should end as specified in the Dutch Standards for the Design of Motorways (Figure 40);
- the access road should be visually widened with the aid of markings (Figure 40);

To make it absolutely clear which intersections form part of the motorway system and to avoid confusion, no other junctions should be sited near such intersections.

THE DESIGN OF INTERSECTIONS AT PARTIAL CLOVERLEAF INTERCHANGES
At diamond interchanges the exit and access roads are on opposite sides of the local road. The access road can consequently be clearly defined. At partial cloverleaf interchanges the exit and access roads run parallel. Great care should therefore be taken over design, devices and their combination.

The following concentrates mainly on the design of roads linking partial cloverleaves and local roads. It is assumed that the access and exit roads are physically separated from the outset, in compliance with the Standards. The debate on the subject in West Germany indicates that special priority should not be given to the installation of a physical barrier where one does not already exist and that this problem should be studied in greater depth.

When a partial cloverleaf is being designed, it is particularly important to ensure
that the access roads are sufficiently eye-catching, especially where vehicles turning left are concerned. Of particular importance in this connection are the height of the central reserve and the distance between its nose and the local road. This distance is limited by the need to place an illuminated directional sign on the central reserve to direct traffic turning right. The presence or absence of a deceleration lane for traffic turning right also has a bearing on this distance.

In view of the considerable number of variables, it was decided to consider this question with the aid of models. This was done by the Aesthetic Design section of the Transport and Traffic Engineering Division.

Various basic models were used to study a local road with a left-turn lane. The beginning of the access road was also widened. Provision was made in the basic models for a number of design elements to be varied.

The following options were considered:
- a non-elevated central reserve;
- a relatively high central reserve: about 0.30 m. It should also be remembered that grass can reach this height on a non-elevated central reserve;
- elevation along the first section of the right-hand bend into the access road;
- variation of the distance from the central reserve to the edge of the carriageway of the local road, 4, 6 and 8 m being selected for this purpose;
- the introduction of a deceleration lane for traffic turning right;
- beginning the hard shoulder along the access road either at the point of intersection or some distance beyond.

Slides were made of all the relevant combinations from the equivalent of eye level for a car-driver to show:
- movement to the left at 65, 45 and 25 m before the intersection and looking into the access road;
- movement to the right at 65 and 35 m before the intersection;
- movement from the exit road.

The above views were also photographed. The many slides were inspected and discussed. This gave rise to various recommendations, which were incorporated into the models, and the results were again photographed (Figures 41 to 66).

The inspection of the slides made of the models and the variations in the lay-out of intersections linking partial cloverleaves and local roads allows the following conclusions to be drawn.
- Elevating the central reserve restricts the view traffic turning left has of the access road. This effect diminishes the further back the central reserve begins.
- On the other hand, such elevation makes it easier for through traffic and traffic turning right to distinguish the intersection. Again, this effect diminishes the further back the central reserve begins.
Figures 41 to 66: Models of intersections giving access to a partial cloverleaf. The central reserve is elevated in the 'a' series, non-elevated in the 'b' series.

Figures 41 to 55: The various alternatives.

Figures 42, 43 and 44 (a and b): The left turn on the local road as seen by traffic some 45 m before the turn, the central reserve being set back 4, 6 and 8 m respectively.
Figures 45, 46 and 47 (a and b); The left turn on the local road with a deceleration lane for right-turning traffic.
Figures 48, 49 and 50 (a and b): The right turning movement on the local road; the central reserve being set back 4, 6 and 8 m respectively
Figures 51, 52 and 53 (a and b): The right turning movement on the local road with a deceleration lane for right-turning traffic
Figure 54  The access road on the left; the central reserve set back 6 m and the first part of the right-hand bend into the access road elevated

Figure 55  The access road on the right; the central reserve set back 6 m and the first part of the right-hand bend into the access road elevated

Figures 56 to 64  The ideal design of an intersection leading into a partial cloverleaf

Figures 56 and 57  Plan view of the intersection with and without a deceleration lane for right-turning traffic

Figures 58 and 59  The access road as seen by left-turning traffic
Figures 60 and 61  The access road as seen by left-turning traffic with a deceleration lane for right-turning traffic

Figure 62  The access road as seen by right-turning traffic
Figure 63  The access road as seen by right-turning traffic with a deceleration lane for such traffic

Figure 64  The view from the exit lane
Figures 65 and 66  Examples of models with some traffic and vegetation.
Where specific situations (construction of a new intersection, reconstruction) are to be studied, all the various features can be incorporated in the model.

As turning left is the most critical movement and as through and right-turning traffic obtain also other information of the location of the intersection, moving the nose of the central reserve back by 8 m might seem advisable, but it is then too far back to be easily recognized and the illuminated directional sign is too far away from the local road. It might therefore be better not to elevate the central reserve.

Then grass can be used. But growing grass on the central reserve has two disadvantages. Firstly, high grass may restrict the view of the access road. (This can be countered by keeping the grass short.) Secondly, there is no visual contrast between the central reserve and the background. Preference should therefore be given to colliery shale or a similar material.

For maintenance reasons and to prevent vehicles driving over the central reserve, a slight elevation – by about 7 cm – is advisable.

If the access and/or exit road drains to the side of the central reserve, this solution will entail the laying of sewers, which will require considerable maintenance. Growing grass on the central reserve thus has also its advantages.

In all cases, the nose of the central reserve is moved back 6 m from the edge of the local road, with an area painted white approximately 2 m deep in front of it.

- Again with the aim of improving the view left-turning traffic has of the access road, the first part of the bend leading into this road can be elevated somewhat and made a light colour. Although the bend is then more easily seen by traffic turning left, the view right-turning traffic has of the access road is obscured. The black marks left on the light-coloured elevation by tyres, especially of heavy
vehicles, will reduce the effect this measure has on traffic turning left. In view of these objections, this measure cannot be generally recommended.

- A hard shoulder from the edge of the local road was not very effective, so there would be no objection to its beginning further along the access road. Beginning at the edge of the local road does have practical advantages, however: one width of hard shoulder can be laid, and it can be used by traffic when work is done on the access road proper. For the first 50 m the marked edges of the access road are further apart.

The design recommended above is shown in Figure 67.

It was not possible when using the models to take account of buildings, vegetation, etc. because they vary too widely in form.

The use of models is recommended where new partial cloverleaves are constructed or existing ones undergo major reconstruction.

![Figure 67 Plan of an intersection giving access to a partial cloverleaf](image)

**THE DESIGN OF THE CENTRAL RESERVE ON LOCAL ROADS**

The central reserve of roads, whether or not they have occasional sections of dual carriageway, can be so designed as to reduce the risk of traffic entering exit roads. This is done with a minimum curve design (Figures 68 and 69). It may be possible to achieve this effect sooner with painted areas and/or reflectors. Care should be taken over the installation of three-dimensional devices since they will reduce
visibility on the other carriageway. This will necessitate a careful inspection of the locality.
The radius of the curve on the left side of the exit road where it joins the local road can be modified to suit the circumstances, again with a minimum curve design. The wider the local road, the greater the effect (Figures 68 and 69).

Figures 68 and 69  Examples of changes in the form of the central reserve using flares

DIRECTION SIGNS AT THE INTERSECTIONS OF MOTORWAY INTERCHANGES
Direction signs provide the road-user with the information he needs to choose his route. At the intersections of motorway interchanges they must be of a very high standard. They should give adequate information on destinations to be reached by taking the motorway in either direction and should also help to guide the road-user to the access road. This last point in particular means that direction signs are a factor to be considered in the context of wrong-way driving.
Partly as a result of the interest that wrong-way driving has attracted, various
suggestions have been made for modifications to the present system of direction signs at the intersections of motorway interchanges. The present system is shown in Figures 70 to 78. The suggestions for modifications concerned the inscriptions on approach signs and the siting of direction signs on partial cloverleaves. These subjects are discussed separately below.

Figure 70  Siting of approach direction signs at a motorway interchange (diamond)
Figures 71 to 73  Siting of illuminated direction signs and public lighting near an access road leading to a motorway (diamond interchange)
• = inscribed side
•× = lighting column (different siting possible)
* = inscribed side
\(\bullet\times\) = lighting column (different siting possible)
Figure 74  Siting of approach direction signs before a motorway interchange (partial cloverleaf)
Figures 75 to 78  Siting of illuminated direction signs and public lighting near an access road leading to a motorway (partial cloverleaf)
* = inscribed side
- ● = lighting column (different siting possible)
• = inscribed side
→X: lighting column (different siting possible)
* = inscribed side

EX = lighting column (different siting possible)
APPROACH SIGNS
The present policy is that there should always be three appropriately placed approach signs on roads for motor vehicles.

At a distance of 900 m before the first access road is an approach sign for through traffic, at 600 m an approach sign indicating the first access road and at 300 m plus the distance between the two access roads an approach sign indicating the second access road.
On other roads a single approach sign showing the direction straight ahead and the first and second access roads is generally placed 200 m before the first access road.
If more than seven messages need to be shown, this being the maximum number considered permissible, two such signs are erected.
The first approach sign than at 400 m shows the direction straight ahead and the first access road. The second, at 200 m plus the distance between the two access roads, shows the direction straight ahead and the second access road. If the maximum number of messages on each sign – seven – is exceeded, three are used.
This is illustrated in Figures 70 and 74.

The suggested modifications to approach signs principally concerned the directions to be shown on each sign. These suggestions have been discussed by the Committee on Uniform Signposting, which believes that the clearest description of the situa-
tion is provided if the two turn-offs to the motorway are shown on one approach sign. This may also help to reduce wrong-way driving. The following policy has therefore been adopted. On roads for motor vehicles two approach signs are placed at 600 and 300 m, the first showing the direction straight ahead and the second both turn-offs. This means the omission of the distance to either of the turn-offs, which need not be regarded as a disadvantage. There must also be some restriction on the number of references to the motorway. The following information should always be provided:

- the layout of the intersection;
- the number of the motorway in both directions;
- the first large town reached by the motorway in both directions;
- any bayonet links on a section of the motorway network.

The last large town on the motorway may also be shown. If this would result in more than six messages (on roads for motor vehicles) being shown on a sign, however, it should be asked whether the last large town needs to be named. As a rule, this will not be the case, provided that the first town shown is sufficient an indication of the direction in which the road-user will be travelling.

If the last large town on the motorway has to be shown, exceeding the maximum number of messages by one may occasionally be acceptable. A further increase in the number of messages must result in the splitting of signs.

On other roads one approach sign should generally be placed at 200 m showing the direction straight ahead and the first and second access roads. If the maximum permissible number of messages, seven, is exceeded, two approach signs are installed, one at 400 m and the other at 200 m, the first showing the direction straight ahead, the second the two access roads to the motorway. Here again, the distances to the access roads are omitted, and the restrictions as regards inscriptions apply as on roads for motor vehicles. If there is no room on the verge, the signs are raised and attached to a mast for example. It was also recommended that the possibility of making the structure symbol clearer should be considered, by enlarging and/or strengthening it, for example. The above measures are illustrated in Figures 79 and 80. They will all be included in the Standards.

It is also pointed out that the layout of messages on approach signs and the symbols used should be consistent in every respect with the present situation. Particular reference is made in this connection to indications of nearby intersections, structures and bends.

**DIRECTION SIGNS AT THE INTERSECTION (DECISION-POINT SIGNS)**

Wrong-way driving has prompted a proposal for the alternative siting of direction signs on the at-grade junctions of partial cloverleaves. The principle is shown in Figures 81 and 82. This alternative has advantage with regard to the prevention of wrong-way driving.
Figure 79 Alternative siting of approach direction signs before a motorway interchange (diamond)
Figure 80. Alternative siting of approach direction signs before a motorway interchange (partial cloverleaf)
Figures 81 and 82: Alternative siting of illuminated direction signs and public lighting near an access road leading to a motorway (partial cloverleaf)
* = inscribed side
●* = lighting column (different siting possible)
since it makes for better guidance into the ‘right gap’. The alternative siting of illuminated direction signs differs from the present system. Discussion in the Committee on Uniform Signposting have revealed a preference for retaining the present system due to a desire not to separate information for through traffic and left-turning traffic and because of cost considerations. The illuminated direction sign for traffic turning left should be placed in line with the right side of the access road or possibly even beyond that line. Great care should be given to finding the correct position.

To overcome the objections to the present system, the Committee decided that the plain blue opaque disc on the central reserves of partial cloverleaves should be replaced with a disc which is similarly plain and opaque but in the same grey as the frame of the arm of the illuminated signs and that the number of the motorway should be larger, with the type height 20/15 rather than 16/12. To reduce the incidence of wrong-way driving, the emphasis will provisionally be placed on other – more direct – means.

**TRAFFIC SIGNS**

The ideal siting of traffic signs at intersections leading to motorways is shown in Figures 83 and 84. It should also be noted that two ‘no entry’ signs are placed on exit roads from diamond interchanges. These can usually be attached to the back of the ‘give way’ signs. Although one sign may be enough for some single-lane exit roads, two are obviously preferable to minimize the chances of this information being overlooked.

On partial cloverleaves a ‘keep right’ sign is always placed on the nose of the central reserve. On dual-carriageway roads this sign not only points to the ‘right gap’ but also indicates that the two carriageways form part of one road and that consequently there will be no on-coming traffic on the carriageway that should be taken. Where the central reserve is too narrow, this sign is often attached to the back of the ‘give way’ sign.

To prevent wrong-way driving, a ‘no entry’ sign is also placed on the left side of the exit road. It may be attached to the back of the ‘give way’ sign on the verge of the exit road. Where the central reserve is wider, the ‘keep right’ sign is further away from the exit road. A ‘no entry’ sign should then be placed on the right side of the exit road, possibly attached to the back of the ‘give way’ sign, thus leaving no room for the ‘keep right’ sign.

If pedestrians are permitted to use the road joined by the exit road, the ‘no entry’ sign is combined with the ‘no pedestrians’ sign. Great care should be exercised when signs are being installed to ensure that they can be seen by the road-users for whom they are important, but the effect they
Figures 83 and 84  Ideal siting of signs at motorway intersections
have on other road-users should also be considered.
Various studies by the Institute for Perception TNO indicate that the major traffic signs at illuminated intersections should be coated with high-quality retroreflecting material. See also section 5.2.6, Inspection.
LIGHTING
The at-grade intersections of motorway interchanges are generally illuminated. Examples of the siting of lights are shown in Figures 71, 72, 73, 75, 76, 77 and 78. The lighting also extends to the exit road from the motorway, the main aim being to make stationary and braking vehicles more clearly visible.

Lighting can also help to make access roads more conspicuous. On partial cloverleaf interchanges, the following three options are available:
- lighting columns on the central reserve (a);
- lighting columns on the verges of both the access and the exit road (b);
- a combination of columns on the central reserve and verges (c).

There is a slight preference for option (b) which is, however, the most expensive. The object of lighting both the access road and the exit road is also achieved—more cheaply—if option (a) is chosen. As a column is often located on the central reserve for another purpose (combined with an illuminated direction sign, for example), alternative (c) can also be considered.

As the above remarks show, none of the three options has any significant advantages over the others. Which of the three is chosen will be partly determined by other factors, such as the geometry of the intersection and the location of other lighting columns.

Low-pressure sodium lights are generally used at a luminous point height of 10 m.

In certain circumstances, a departure from the above may be permissible. For example, one or more lighting columns may be placed along inconspicuous access roads on diamond interchanges. Tests in America did not indicate that lights on exit roads should be switched off.

Figure 85  Example of a service area shown in the Standards for the Design of Motorways (ROA)
5.2.5 Areas of concern in the motorway network

On the whole, it is far more difficult to take measures on motorways than at the at-grade intersections. A smooth design seems to go some way towards preventing wrong-way driving. It is, however, to be recommended that the smooth design of convergence and divergence points comply as closely as possible with the standards. Painted noses should also be kept in the best possible condition.

Another aspect of motorways to be considered are such road-side facilities as parking areas, petrol stations, restaurants and combinations of these. Particularly where such facilities are combined, every attempt should be made to achieve a clear and logical design (Figure 85). To prevent wrong-way driving, parking spaces should generally be so arranged that road-users automatically drive off in the right direction. This means either nose-to-tail parking or parking at an angle well below 90°.

In addition to traffic signs it is recommended that additional guidance should be provided through the installation of low-level retroreflecting direction signs. Special arrows painted on the road surface may be effective.

5.2.6 Inspection

An inspection of the less obvious aspects of all interchanges is to be recommended, with particular reference to direction and other signs, delineation and markings. Inspection is something that has been done in the past and continues to be done elsewhere. Evaluations have shown that it has a positive effect.

For the inspection, reference can be made to a general check list (Annex III) and the Standards for signposting direction signs and lighting. (See also 5.2.4, Design and highway devices).

The standard equipment should always be optimal for the given circumstances. Above all, it should be visible to and aimed at road-users and give them guidance. It may be decided to depart from the above when an inspection is made. The effects of these departures on the overall traffic situation should then be carefully considered, since it is quite possible to take action which is effective in preventing wrong-way driving but is misleading for the rest of the traffic on the local road. Two alternatives are described below.

As access roads are usually entered by two streams of traffic, one turning right, the other left, it may sometimes be useful to duplicate some signs by having one face vehicles turning right and the other face those turning left. As the resulting
angle of the signs to the centre line of the through road may give rise to an unclear and confusing situation on this road. Great care is required. In some cases, it may be an advantage for signs to be lower than the standard height to improve their visibility in headlights. The problem then is that the signs are more likely to become dirty and to fall foul of vandals. This measure can be considered in exceptional cases.

Figure 86  Inadvisable siting of an illuminated direction sign at a partial cloverleaf (a). Incorrect inscription on a sign, which points to an exit road (b)

Figure 87  Intersection combined with a motel exit
Various studies by the Institute for Perception TNO indicate that the major traffic signs at illuminated intersections should be coated with high-quality retroreflective material (provided that the wide-angle effect is not objectionable). Special attention should be paid to:

- older intersections, which are not always uniform;
- temporary situations, where road work is in progress, for example;
- unnecessary stretches of pavement, which may invite incorrect use;
- exceptionally complicated situations, such as:
  - intersections combined with exits from restaurants, motels, etc. (Figure 87);
  - intersections with nearby junctions, parallel roads, structures, etc., where thought must also be given to the design of direction signs;
  - intersections that create optical illusions, perhaps by giving the impression that a motorway exit is an ordinary road or an exit from some other facility. For example, the entrance to a Californian road-side restaurant located next to a motorway exit road was so inconspicuous that many road-users mistook the exit road for the entrance.

5.3 Reporting wrong-way drivers

Wrong-way drivers should be detected as soon as possible so that the police can intervene. Road-users should be encouraged to use the road-side emergency telephones (Figure 88) to report wrong-way drivers, so that the police can take action quickly. Records of such reports at the road-patrol centre would provide an insight into the number of wrong-way drivers. The police should also keep records of wrong-way drivers. More detailed information on the wrong-way drivers encountered or stopped by the police would also be helpful in a closer study of wrong-way driving. In addition, the following possibilities might be considered:

- wrong-way drivers might be interviewed by a team of experts;
- incidents might be reconstructed using a specially equipped car.

5.4 Information and publicity

Information for road-users will have a positive effect. Experts in this area could decide on what is needed. Clearly worded information, backed by diagrams, on interchanges, intersections and direction signs might be provided, for example. It should be noted in this context that many people still have difficulty when confronted with a partial cloverleaf, their initial feeling being that they are going in the wrong direction.

It is also very important for journeys to be well planned, preferably with the aid of good road maps which also show the layout of interchanges, road numbers, the
names of exit roads and the fact that an interchange or intersection is incomplete (Figure 89). It would also be helpful if (some) standardization of maps could be achieved, both nationally and internationally.

During their driving instruction learner drivers should also be given more instruction about the specific features of motorways (Figure 90).

Publicity can be effective by making people particularly aware of the ways in which roads can be used incorrectly. Publicity has little effect on the road-user who is convinced of his own prowess as a driver and, in such cases, may even have an adverse effect.
5.5 The selection of supplementary measures

Before any of the highway-related measures described above are implemented, the following should be considered. Although fatal accidents caused by wrong-way drivers often receive considerable publicity, it should be ensured that this type of accident is not isolated – in financial and other terms – from the road safety problem as a whole and that a disproportionate amount of the money available for tackling this problem is not spent on measures to prevent wrong-way driving. Seen objectively, the wrong-way driving problem is, relatively speaking, very insignificant (an average of just over two fatal accidents a year). It must also be remembered that any measure decided on will probably have to be taken at all interchanges and service areas and that, as there are about 1,000 exit roads as far as the Netherlands are concerned, the cost of each measure should be multiplied by about 1,000. A measure which costs, say, 20,000 Dutch guilders per exit road will thus entail expenditure of 20,000,000 Dutch guilders throughout the country. Consequently, a less costly solution producing a relatively good cost-effect ratio must be chosen. In other words, the effect per guilder spent must be considered very carefully. The cost of the various measures (and combinations of these measures in some cases) have been estimated. A global estimate of the probable effect has been made.

The cost-effectiveness of Dutch guilders invested per percentage point of effect was then calculated and the resulting figures were compared, the cost of additional ‘no entry’ signs being taken as 1. This is shown in Table XI. The last column of this table is reproduced in diagram form in Figure 91. It should again be emphasized that this is a global estimate and merely provides an indication of cost-effectiveness.

Figure 91 reveals that the painting of special arrows on the road surface is the most favourable measure in terms of cost-effectiveness. There is, however, some doubt about the effect they have, and a variation in estimated effect has a fairly substantial influence on the result.
Partly in view of the advantages and disadvantages previously described, a combination of two additional 'no entry' signs and two special arrows on the surface of exit roads from interchanges and service areas appears to be the best solution.\(^1\) The special arrows could be painted on the road surface near the 'no entry' signs, unless there are already lane arrows at this point. It would also seem advisable to install clear 'start of motorway' signs at the beginning of access roads and to paint one arrow on the surface of the road at the junction of the access and local roads.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Indication of costs* per exit road (at 1980 prices)</th>
<th>Indication of costs for motorway network (interchanges and service areas)</th>
<th>Indication of effect in %**</th>
<th>Cost-effectiveness in Dutch guilders per % (rounded off)</th>
<th>Proportional and rounded off at 6,500 = 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 3 or 4 straight-on arrows per exit road in paint</td>
<td>70</td>
<td>70,000</td>
<td>17</td>
<td>4,000</td>
<td>0.6</td>
</tr>
<tr>
<td>2. 2 additional 'no entry' signs, dia. 800 mm, in high-quality retro-reflecting material</td>
<td>400</td>
<td>400,000</td>
<td>53</td>
<td>7,500</td>
<td>1</td>
</tr>
<tr>
<td>3. Combination of 1 and 2</td>
<td>470</td>
<td>470,000</td>
<td>70</td>
<td>6,500</td>
<td>1</td>
</tr>
<tr>
<td>4. Flexible barrier per lane of exit road***</td>
<td>19,000</td>
<td>19,000,000</td>
<td>98****</td>
<td>200,000</td>
<td>30</td>
</tr>
<tr>
<td>incl. shoulder</td>
<td>38,000</td>
<td>38,000,000</td>
<td>100</td>
<td>400,000</td>
<td>60</td>
</tr>
<tr>
<td>5. Escape lane partial cloverleaf</td>
<td>30,000</td>
<td>6,300,000</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>diamond flyover</td>
<td>100,000</td>
<td>21,000,000</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>diamond flyunder</td>
<td>300,000</td>
<td>53,400,000</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>service areas</td>
<td>100,000</td>
<td>39,300,000</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>120,000,000</td>
<td>95****</td>
<td>1,265,000</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>6. Information triggered off by vehicles</td>
<td>5,000</td>
<td>5,000,000</td>
<td>89</td>
<td>56,000</td>
<td>10</td>
</tr>
<tr>
<td>by vehicles</td>
<td>10,000</td>
<td>10,000,000</td>
<td>89</td>
<td>112,000</td>
<td>20</td>
</tr>
</tbody>
</table>

* Costs concern installation only; thus measures requiring (a great deal) of maintenance will be generally less favourable; this is particularly true of arrow markings on the carriageway, which need to be repainted at regular intervals

** 100% signifies that, after the measure has been taken, no one can enter the exit road in the wrong direction

*** No account has been taken of harm to the vehicle and its passengers or of any research involved in development

**** This effect is estimated on the basis of a logical view of the matter

Table XI  Measures, costs (in Dutch guilders) and general estimate of effects

\(^1\) See also Annex I
5.6 Summary and conclusions

Numerous measures are described in the literature, and the effect that some of them have is also discussed.

In the selection of measures which will be generally implemented, the following should be borne in mind:
- the magnitude of the problem, which is very minor in relative terms;
- the fact that any measure must be taken at some 1,000 points throughout the country.

A less costly but relatively effective measure is therefore to be recommended.

It is recommended that the following supplementary measures be taken everywhere:
- The siting of 'no entry' signs a short distance from the end of the exit road entered by the wrong-way driver;
- The signs should be large, coated with a high-quality retroreflective material provided that the wide-angle effect is not objectionable, placed at a low level and have a sign reading GO BACK beneath them;¹
  A large 'start of motorway' sign near intersections.
- During reconstruction work and possibly at an earlier stage simple measures should be taken to reduce the visual attraction of exit roads, to increase that of access roads and to minimize the chance of exit roads being entered in the wrong direction.

An inspection of all intersections would be advisable, if only because of the favourable results this has had in the USA. For their inspections the highway authorities can refer to the available standards.

During the inspection particular attention should be paid to:
- older intersections;
- temporary situations, as when road work is being carried out;
- the siting of illuminated direction signs, particularly on partial cloverleaf interchanges;
- exceptionally complicated situations, such as:
  - intersections combined with service areas, etc.;
  - intersections near other junctions;
  - intersections near junctions, structures, etc. with regard to the layout of direction signs;
  - intersections with optical illusions.

¹ See also Annex I
As regards the reporting of wrong-way drivers, it is recommended that:
- road-users make use of the road-side emergency telephones to report wrong-way drivers;
- reports be recorded at the road-patrol centre;
- incidents of wrong-way driving be recorded by the police;
- accidents involving wrong-way drivers be recorded separately.

The public should be provided with information on wrong-way driving. Driving instruction should cover the features of motorways and help learner drivers to use them correctly.
6 The situation on highways other than motorways and associated problems

6.1 General

As was said at the outset, wrong-way driving can also occur on roads other than motorways, especially on dual-carriageway roads, short sections of dual-carriageway roads and one-way roads. Less is known about wrong-way driving in such cases. The literature available devotes less attention to this problem. In fact, the American literature is alone in discussing this aspect. This report will do no more than indicate a number of areas worthy of consideration.

6.2 Dual-carriageway roads and roads with short sections of dual carriageway

Of dual-carriageway roads and roads with short sections of dual carriageway it can be said that drivers approaching from a side-road must have the best possible view of the second carriageway and be given adequate prior warning, which will, of course, vary in nature with the category of the road concerned (Figures 92 and 93).

Figure 92 Example of an intersection on a section of dual-carriageway road
As it is not the intention that this report should discuss design, delineation, signposting, etc. at great length, no more than a few brief comments will be made.

The view of the second carriageway is improved by:
- keeping the central reserve as low as possible;
- not having the intersection on the brow of a hill;
- placing illuminated direction signs on the other side of the second carriageway.

Prior warning of the second carriageway may consist of:
- a depiction of the layout of the intersection on approach signs (Figure 93);
- 'hammerhead' arrows in a more urban environment (Figure 94).

'No entry' signs can also be placed on the first carriageway, and this is often advisable where the central reserve is wide.

![Figure 93 Example of an approach direction sign on side-road leading to a dual-carriageway road](image1)

![Figure 94 Examples of 'hammerhead' arrows](image2)

### 6.3 One-way roads

One-way roads are chiefly to be found in urban areas. The people most likely to drive along such roads in the wrong direction are cyclists, usually intent on using as little energy as possible. Cyclists are often permitted to use one-way roads in both directions (Figure 95). Hardly anything is known about wrong-way drivers on such roads. 

*Volbeda* does, however, refer to road-users less familiar with the area losing their way in one-way systems. Speed on urban roads are generally relatively low and the chances of correcting mistakes relatively high, especially when compared with motorways. The signposting of one-way roads could be improved by making it positive rather than negative, as is done in West Germany, for example.
6.4 ‘The imaginary wrong-way driver’

Situations may arise in which road-users mistakenly believe that they are driving the wrong way. This is particularly the case where another or even two other roads run parallel to the main road (Figure 96). It is therefore very important to design parallel roads in such a way that they are far less striking in appearance than the main road (Figure 97).

A specific problem arises on motorways where other, separate lanes run parallel to the main carriageway, as is the case on cloverleaf interchanges (Figure 98). The road-user on the main carriageway sees an auxiliary lane with direction signs indicating various destinations. On these signs he may read his own destination,
whereas there are no direction signs on the carriageway he is using. Is this why the reserve between the main carriageway and an auxiliary lane is sometimes crossed? The possibility of changing the appearance of auxiliary-lane direction signs is being considered. The greatest difficulty in this connection will be trying to explain to the road-user who has not faced this particular situation what problem has been solved.

Figure 98  A motorway carriageway with a parallel auxiliary lane

The opposite of the 'imaginary wrong-way driver' is also possible, the 'imaginary right-way driver'. He wrongly believes he is on a motorway and may try to overtake in situations where it is not safe to do so. This is another reason for ensuring that parallel roads look secondary. A survey by the Royal Dutch Touring Club revealed that some 40% of the drivers interviewed had made this mistake at some time. Frequent changes from single- to dual-carriageway road can also be very confusing. The danger here is that at a given moment the driver no longer knows what kind of road he is on. He may make a mistake. As an exception, a specific example will be quoted, the Zeelandroute (Figure 99).*

One of the most difficult situations in this connection arises during the phased construction of a motorway. To begin with, many structures already have two 'gaps' to drive through, and as the construction work proceeds, the more difficult the situation becomes. A second carriageway is added, (construction) vehicles use

* Situated in the province of Zeeland in the Netherlands
it and the safety barriers are installed. These are very complicated situations, especially if, due to construction problems, for example, traffic has to be diverted from a single-carriageway road to a motorway and vice versa. Apart from carefully considering the timing of the whole project, it is extremely important to give road-users very clear warnings by frequently reminding them of the situation, particularly where they are driving along a single-carriageway road with on-coming traffic.

Figure 99 Plan of the Zeelandroute (Netherlands) from km 13.85 to km 35.8
7 Conclusions and recommendations

- Little is known about wrong-way driving in the Netherlands. Fatal accidents involving wrong-way drivers on motorways are a relatively minor problem, averaging just over two a year or slightly more than 0.02% of all motorway accidents. The situation in the Netherlands appears to be relatively favourable when compared with other countries.
- The number of fatal accidents fluctuates, although within certain limits.
- Human beings and roads both play a part.
- A global analysis of cost-effectiveness indicates that the following supplementary measures are most appropriate:
  - 'no entry' signs above signs reading GO BACK\(^1\) on exit roads;
  - positive measures on access roads.
- During reconstruction work measures can be taken to increase the visual attraction of access roads and decrease that of exit roads at junctions with local roads.
- Regular inspections should be made.
- The recording of reports can provide a better insight into the nature of the problem. The police should also keep records of incidents reported to them, and more information should be obtained on these incidents with a view to reducing the problem of wrong-way driving. There is much to be said for keeping records of all accidents caused by wrong-way drivers.
- Apart from accidents involving wrong-way drivers, which usually take the form of head-on collisions, the chances of other head-on collisions occurring on motorways should be considered. They are most likely to occur where certain types of road work are in progress and where carriageways are not separated by a central reserve and/or some kind of physical barrier.
- Thought should be given not only to motorways but also to dual-carriageway roads, roads with adjacent, parallel roads and single-carriageway roads where a motorway is being constructed.
- Roads with frequent changes from dual to single-carriageway should also receive some attention.

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\(^1\) See Annex 1
Most supplementary measures designed to prevent wrong-way driving, viz. the erection of repeat 'no entry' signs and the inspection of all motorway intersections, were taken in the Netherlands in the last quarter of 1980. The inspection has also resulted in a number of adjustments being made.

A satisfactory evaluation cannot be made of the supplementary measures owing to the absence of complete information on accidents occurring three years before and three years after the measures were taken.

The only data on the number of accidents occurring before the supplementary measures were taken relate to 1980. They allow the conclusion that about 20 accidents involving wrong-way driving occur each year. The findings of research in other countries and other sources indicate that this figure of about 20 corresponds to the number of accidents involving wrong-way drivers which occurred before supplementary measures were taken. Since 1981 information on accidents involving wrong-way drivers has been collected on a nationwide basis. The number of accidents has since varied between 2 and 5 per year.

Although the available figures are incomplete, there appears to be some justification in the claim that since November 1980 there has been a significant reduction in the number of accidents involving wrong-way drivers. Having regard to the period in which the supplementary measures to combat wrong-way driving were taken, it seems more likely that the decline has been due to the supplementary measures rather than to mere chance. It can also be assumed that publicity has played a part in increasing road-users' awareness of the problem.

Fatal accidents involving wrong-way drivers must be considered separately. The trend shown in Figure 5 - a fluctuation between one and three fatal accidents a year - appears to have continued until 1984. It is difficult to find an explanation for this. The wrong-way drivers concerned may be so inattentive and so unaware of their mistake that they continue driving the wrong way for a relatively long time, thus increasing the likelihood of a head-on collision and of the accident therefore having fatal consequences. At all events, the impression is that it is difficult to take effective action with highway devices against some wrong-way drivers who ignore repeat 'no entry' signs.

Incidents (reports of wrong-way drivers) should be reported separately. After December 1980 the number of incidents initially rose. In some cases, the radio traffic information programmes included announcements of wrong-way driving, mainly to warn other road-users. After 8 March 1982 (following a very serious accident) reports of all cases of wrong-way driving were broadcast. The number of cases of wrong-way driving reported to the authorities then increased, as did
the ratio of such reports to the number of wrong-way drivers stopped. The impres­sion was that some reports were spurious. For various reasons, reports of wrong­way drivers can clearly not be used for an evaluation of the measures taken. A more restrictive policy now applies to the reporting of such incidents on the radio. It can be said that radio reports are a useful way of warning road-users. They can move to the right-hand lane in good time. On the other hand, the safety image which the motorway rightly has may suffer unjustifiably as a result of such reports. Between one and two minutes elapse between the report of a wrong-way driver and a radio announcement. In two minutes a wrong-way driver can cover a good 3 km. According to Table VIII, by that time some 75% of wrong-way drivers have corrected their mistake. Consequently, it seems advisable for radio announcements to be used in cases where reports have been received from reliable sources (such as the police, service patrols or the highway authorities) and where the wrong-way driving incident is likely to continue for more than just a few minutes.
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Considerable interest has recently been shown in the problem known as 'wrong-way driving'. As far as is known, this phenomenon is more common in some other countries than in our own. However, many questions relating to the problem of wrong-way driving have yet to be answered.

I have asked the Transport and Traffic Engineering Division for its advice on this problem. I do not believe that supplementary measures should be postponed pending the appearance of the report which the Transport and Traffic Engineering Division will shortly be producing, provided that such measures can be kept within reasonable limits. In this context, I would request you to proceed to the erection of 'no entry' signs with signs reading 'GO BACK' mounted beneath them on the exit roads of motorways as 'repeat signs' at a distance of at least 100 m from the end of exit roads by which such roads are entered by traffic proceeding in the right direction.

The signs should be placed on both sides of the carriageway in such a way that, where possible, the front is visible only to wrong-way drivers. They should be coated with high-quality retroreflecting material, and the lowest point of the lower sign should preferably be 0.50 m above the road surface (see diagram attached).

Where the signs are not only visible to wrong-way drivers, the high-quality retroreflecting material may be replaced with normal retroreflecting material. The correct siting of the signs will partly depend on local circumstances.

I would also request you to undertake a further critical examination of the intersections for which your directorate is responsible with a view to improving direction signs, delineation, markings, lighting, safety barriers, vegetation, etc. I look forward to receiving any proposals you have to make in this respect.

If necessary, assistance can be obtained from your directorate's road safety inspector, who has been briefed by me in this matter.
‘no entry’ sign, 800 mm in diameter

ga terug

≥ 210

700

500

annex to the letter on page 117

red retroreflecting
white retroreflecting
black

type style: Ovink series E

type size: 95/70

call dimensions in mm

* ga terug = go back
Annex II
Note: What to do when confronted with a wrong-way driver

It is difficult to lay down general rules for this situation. There are two factors which have an adverse effect on the action that needs to be taken. Firstly, the right-way driver will generally be startled by the very unusual situation, which may seriously affect the action he must take. Secondly, the whole process takes place quickly: if a right-way and a wrong-way driver are both travelling 100 kph, they approach each other at a speed of 200 kph, or 56 m/s.

The best course of action is to move to the right as far away from the wrong-way driver’s path as possible and to leave room for others to do the same, i.e. move from the right-hand lane on to the hard shoulder and from the left-hand lane to the right. Drivers of heavy goods vehicles (from their high vantage point they have a better view of the situation) need to act particularly quickly because such vehicles may obstruct the view of car-drivers, especially on right-hand bends.

Having removed himself from the path of the on-coming wrong-way driver, the right-way driver should flash his lights to
- indicate his own presence and
- warn the wrong-way driver.

Once a wrong-way driver has been detected, the police should be warned (by road-side emergency telephone). No attempt should be made to catch the wrong-way driver, since this may lead to a serious multiple accident. The attempt may possibly be made to drive parallel to the wrong-way driver on the correct carriageway and to warn him, but in practice even the police find this difficult.

The most difficult question is how to act at the point where the wrong-way driver begins, when the wrong-way driver is not yet in the ‘left-hand’ lane.
Annex III
Global checklist for preventing wrong-way driving at intersections

- Is the information shown on approach signs clear and is the depiction they give of the layout a true reflection of the actual situation?
- Is positive guidance to access roads in the form of
  - direction signs
  - markings
  - traffic signs
  - lighting
  clear and easily seen?
- Is the access road visually sufficiently attractive to both right-turning and left-turning traffic?
- Is the exit road visually less attractive than the access road? Is the information on traffic signs designed to prevent traffic entering the exit road adequate and easily seen?
- Is the lighting on? Are direction signs illuminated?
- Are the direction and other signs and the lighting of standard design? Are any departures from the norm effective in the given situation?
Annex IV
List of measures to prevent wrong-way driving proposed in letters to the Ministry of Transport and Public Works, The Hague, Netherlands

<table>
<thead>
<tr>
<th>Proposal</th>
<th>Location</th>
<th>Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – Paint small arrows in the middle of the lane to indicate the right direction</td>
<td>roundabouts</td>
<td><img src="" alt="Diagram" /></td>
</tr>
<tr>
<td>2 – Install a flap system to act as a barrier for wrong-way drivers</td>
<td>dual-carriageway roads, slip roads, access and exit roads, one-way roads</td>
<td><img src="" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td>exit roads</td>
<td><img src="" alt="Diagram" /></td>
</tr>
<tr>
<td></td>
<td>Install collapsible kerbs in the exit roads of partial cloverleaf and diamond interchanges</td>
<td><img src="" alt="Diagram" /></td>
</tr>
<tr>
<td>3 – Curved yellow stripes</td>
<td>intersections</td>
<td><img src="" alt="Diagram" /></td>
</tr>
<tr>
<td>4 – Paint arrows pointing in the correct direction on dual-carriageway roads</td>
<td>dual-carriageway roads</td>
<td><img src="" alt="Diagram" /></td>
</tr>
<tr>
<td>5 – Place a warning sign reading WRONG CARRIAGEWAY on the left carriageway</td>
<td></td>
<td><img src="" alt="Diagram" /></td>
</tr>
<tr>
<td>Proposal</td>
<td>Location</td>
<td>Diagram</td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
<td>---------</td>
</tr>
<tr>
<td>6 - Place on the verges of single-carriageway roads reflectors showing green on the right and red on the left. On dual-carriageway roads place green reflectors on both sides of the right-hand carriageway and red reflectors on both sides of the wrong carriageway</td>
<td>all roads</td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>7 - On all exit roads:</td>
<td>exit roads</td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>- Rumble strips on the left</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Signs reading:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 'This is an exit road'</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 'You are in the left-hand lane'</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 'You are in the wrong lane'</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Place signs reading NO ENTRY and IN under the 'keep right' sign at the end of exit roads</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 - Install escape lanes at partial cloverleaf interchanges to guide wrong-way drivers off the exit road and on to the access road</td>
<td>partial cloverleaf interchanges</td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>- Alternative: the escape lane leads to a gravel pit</td>
<td>partial cloverleaf and diamond interchanges</td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>9 - Place cats' eyes at the end of exit roads at partial cloverleaf and diamond interchanges</td>
<td>exit roads</td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>10 - As in the USA place signs reading DO NOT ENTER along exit roads</td>
<td>exit roads</td>
<td><img src="image" alt="Diagram" /></td>
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