

Wrong-way driving

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SWOV



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Summary

In this fact sheet, we define wrong-way driving as ‘a car driving in the wrong lane and thus against traffic on a road with separate lanes.’ This mainly refers to motorways. Wrong-way driving crashes are infrequent, but their outcome is often serious. Most wrong-way driving crashes occur when drivers inadvertently enter a motorway exit or when drivers turn around on a motorway. Intentional wrong-way driving also occurs. Some typical aspects of wrong-way driving crashes and wrong-way drivers: wrong-way driving crashes often occur in the evening and at night; wrong-way drivers are often under the influence of alcohol and/or drugs; wrong-way drivers are often older drivers or, to a slightly lesser extent, young drivers.

Road design, markings and signage, in particular, are used to attempt to reduce the number of wrong-way drivers and ensure that wrong-way driving does not result in crashes. Most reports of wrong-way driving come from fellow road users, but cameras and speed detection systems can also detect wrong-way drivers. In either case, fellow road users are alerted as soon as possible via radio and navigation systems. In addition, in-vehicle systems are now available to warn drivers who are in danger of going against traffic. In a more general sense, wrong-way driving and crashes will be reduced by measures that ensure that people do not drive when they are under the influence.

1 What do we mean by wrong-way driving?

In this fact sheet, we understand wrong-way driving, following the definition in the Dutch [wegenwiki](#) (road Wikipedia) to mean: ‘a car driving in the wrong lane and thus against traffic on a road with separate lanes.’ The separateness of the lanes is essential. Without separate lanes we speak of ‘getting into the opposite lane’; which can easily be modified by returning to one’s own lane.

2 How often does wrong-way driving occur?

It is not known exactly how often wrong-way driving occurs in the Netherlands. Presumably the average annual number of wrong-way driving incidents involving police presence is about 375. The real number of wrong-way driving incidents will be higher; after all, the police will by no means receive reports of all wrong-way driving incidents or register their efforts at a wrong-way driving incident.

The annual number of 375 recorded wrong-way driving incidents is an estimate, based on a police analysis of its incident registration system for a SWOV study [1]. To this end, the police searched for registrations of traffic cases in 2015-2019 in which the term 'wrong-way dri*' occurred, in combination with terms indicating a motorway or other national road (search terms included an "A" road number, motorway, exit, entry ramp, national road). A total of 1944 police records during the aforementioned five-year period were identified in this way. The actual number of wrong-way drives is probably higher. The police file obviously includes only those incidents in which police were present, either because of a crash or in the capacity of law enforcement or emergency responders.

3 How many casualties are caused by wrong-way driving?

Information about the Netherlands

It is not known how many casualties are caused by wrong-way driving crashes in the Netherlands. In fact, since 2004, wrong-way driving crashes and casualties are no longer registered as such.

Older figures [2] show that the number of wrong-way driving crashes is low, but the consequences are often serious. Between 1991 and 1997, an annual average of 22 road crashes due to wrong-way driving were recorded on motorways in the Netherlands. That is 0.1% of all registered road crashes. On average, these 22 wrong-way driving crashes resulted in six minor injuries, six serious injuries and five road deaths. This amounts to about 3.7% of all road deaths on motorways.

Between 1998 and 2003, an annual average of seven injury crashes and two road deaths were due to wrong-way driving. This shows a downward trend, but according to an analysis of newspaper reports from 2006, after the relatively good years of 1998-2001, the number of road deaths due to wrong-way driving increased again [3].

Information from other countries

Data from other countries also show that wrong-way driving crashes are infrequent. They also show that the consequences of such crashes are relatively serious.

On Belgian motorways, 122 injury crashes involving a wrong-way driver were recorded between 2010 and 2019; this is an average of about 12 per year [4]. Almost one in five (19%) involved a fatal crash, compared to 3% of all crashes on motorways.

In Germany [5], about 0.05% of all crashes on motorways and 0.2% of crashes on motorways resulting in road deaths or injuries are wrong-way driving crashes. These wrong-way driving crashes involve one or more injuries in about half of the cases and one or more road deaths in more than 15% of the cases. The data cover the 2006-2011 period.

Swiss crash data [6] show that, between 2000 and 2004, a total of 106 wrong-way driving crashes occurred in Switzerland, resulting in 114 casualties. Of those casualties, about 29% were seriously injured and 13% fatally injured. In the crashes, significantly more casualties occurred among the occupants of the oncoming vehicle (about 70%) than among the occupants of the 'wrong-way car' (about 30%). In about 90% of the cases, multiple vehicles were involved in a wrong-way crash.

French data for 1999-2003 [7] show that 0.2% of injury crashes and 4.4% of fatal crashes on French motorways are wrong-way driving crashes.

In the United States, 3% of all crashes on highways with separate lanes were wrong-way driving crashes [8]. A study in the state of Michigan shows that 32% of wrong-way driving crashes between 2005 and 2009 were fatal, or resulted in permanent disability. This was also true for 2% of all crashes on those same roads, during that same period [9]. In the state of Illinois [10], wrong-way driving crashes (in 2004-2009) involved multi-vehicle crashes in over three-quarters of the cases, and over half of these involved head-on collisions. These head-on collisions almost always resulted in fatal injuries.

4 Who are the wrong-way drivers?

Wrong-way drivers primarily involve drivers of passenger cars. Wrong-way driving crashes occur in all age groups, but older drivers are overrepresented. To a slightly lesser extent, the same is true of young drivers. Among wrong-way drivers there are relatively many people with mental health issues and those who intentionally drive the wrong-way as a suicide attempt. Studies from several countries show a similar picture [2] [5] [6] [7] [8] [11] [12].

Gender

The effect of gender is unclear [13]. In the United States, some researchers found that men are overrepresented in wrong-way driving crashes (e.g.: [12] [14]), but other researchers did not (e.g., Lathrop et al., 2010 in [13]). Kemel [11] and Blokpoel & De Niet [2] saw no differences between men and women in France and the Netherlands, respectively, but Vias institute [4]

again reports an overrepresentation of men for Belgium. Men were also strongly overrepresented in the recent study of wrong-way drivers in the Netherlands [1], although possibly not representative of all wrong-way driving crashes: 56 out of 68 wrong-way drivers were men. Since men drive more kilometres than women, these figures do not say anything about the risk of a wrong-way crash. A Swiss study [6] did look at this and found that the risk of a wrong-way crash was 1.5 times higher if the driver was a woman.

Older drivers

According to Scaramuzza & Cavegn [6] (Switzerland), the risk of a wrong-way crash is more than 7.5 times higher if the driver is older than 65. Kemel [11] (France) reports that drivers aged 65 or older are 15 times more likely to have a wrong-way crash than those aged 25 or younger. Zhou et al. [12] (United States) found that, on highways, drivers aged 65 or older were three times more likely to be involved in a wrong-way crash than in other crashes. Vias Institute [4] reports that in all injury crashes in Belgium between 2011 and 2020, 5% were older than 65, but in injury crashes due to wrong-way driving this amounted to 21%. Dutch figures from the 1990s show that in about 33% of wrong-way drives that resulted in a fatal crash or injury crash, the wrong-way driver was aged 70 or older [2]. In the 68 Dutch wrong-way driving crashes and incidents between 2015 and 2019 analysed for the SWOV police file study [1], in about 25% of the cases the driver was aged 70 or older. It should be noted, however, that the investigated wrong-way drives need not be representative of all wrong-way drives.

5 Where and when do wrong-way driving crashes occur?

Where?

Most wrong-way driving crashes occur on motorways, but this is inherent in the definition that indicates separate lanes are an essential criterion. Entering the motorway via the exit ramp and turning on the motorway are the two most common scenarios that lead to wrong-way driving [2] [5] [15]. Xing [16] also mentions taking a wrong turn-off from a parking area: 12% of wrong-way driving crashes in Japan. In Germany, however, this percentage is much lower (1.5% [5]).

A recent study of police files on Dutch wrong-way driving crashes and incidents [1], although probably not entirely representative, shows that most wrong-way driving crashes and incidents occur on the main carriageway. Of the 68 incidents analysed, 45 occurred on the main carriageway (of which 34 occurred in the leftmost lane, or the rightmost lane for the wrong-way driver), 6 on an entry or exit ramp, and 3 in the emergency lane). For 14 incidents, the location was unknown. Wrong-way driving crashes on the main carriageway result in significantly more serious injuries than crashes occurring on the entry/exit ramp. For example, Doctor [15] reports that in the United States, 42% of wrong-way driving crashes on the main carriageway result in fatal or serious injuries; for wrong-way driving crashes on the entry/exit ramp this is 6%.

When?

Most wrong-way driving crashes occur in the evening, at night and in the early morning. In the Netherlands, between 1983 and 1998, this was the case in over 65% of wrong-way driving crashes [2]. Partly related to this: most wrong-way driving crashes/incidents take place in the dark. In the study of the police files on 68 wrong-way driving crashes/incidents in the period 2015-2019 [1], it was dark or dusky, either with or without street lights, in 51 cases, and only in 17 cases it was light.

International research also shows that relatively many crashes occur in the evening and at night, and particularly on weekend nights. On French motorways, 50 to 60% of wrong-way driving crashes occur at night [7]. In the United States, over 75% of crashes occur between 6 pm and 6 am [8]. Zhou et al. [10] report that in the state of Illinois, 51% of wrong-way driving crashes occur between midnight and 5 a.m. and 43% occur on weekend nights. Also based on data from the United States, Doctor [15] indicates that 31% of wrong-way driving crashes occur between midnight and 3 a.m. and 57% occur on weekend nights. On the basis of Swiss data, Scaramuzza and Cavegn [6] report that the risk of a wrong-way driving crash is almost twice as high when it is dark.

6 What are possible reasons for wrong-way driving?

Wrong-way driving can either be intentional or unintentional.

Intentional wrong-way driving

The following reasons/motives often underlie intentional wrong-way driving [1] [4]:

- > The driver turns, to avoid a traffic jam (via the emergency lane) or to reach a missed exit.
- > The driver attempts to turn/reverse or otherwise correct after taking a wrong entrance or exit ramp.
- > The driver does it for kicks or a bet.
- > The driver tries to escape a police check or pursuit.
- > The driver tries to commit suicide.

Deliberate, intentional wrong-way driving is more common among younger wrong-way drivers [1] [2] [6].

Unintentional wrong-way driving

Unintentional wrong-way driving is often the result of absent-mindedness, inattention and/or orientation problems [4]. For example, drivers do not realise that they are entering a motorway exit instead of the entry ramp, or they think they are taking an 'ordinary' turn and do not realise at all that they are entering a motorway. The specific design of entry and exit ramps plays an important role here [1] [2]. This form of unintentional wrong-way driving is relatively common among older wrong-way drivers [1] [16] [17]. General confusion, for example due to mental issues, dementia or alcohol and drugs, can also be the cause of unintentional wrong-way driving [1].

Effect of alcohol, drugs and medication

Both Dutch and international research shows that alcohol, drugs or a combination of both are involved in many wrong-way driving crashes. Medication also plays a role.

In 18 of the 68 Dutch wrong-way driving crashes and incidents between 2015 and 2019 [1], the wrong-way driver had an alcohol level above the legal limit; in 5 of the 68 analysed crashes, the wrong-way driver was under the influence of drugs, and 1 was under the influence of both alcohol and drugs. Thus, a total of over 33% wrong-way drivers were under the influence of alcohol or drugs. Medication that can affect driving ability also plays a role. In the study mentioned above, 5 out of 68 wrong-way driving crashes and incidents involved medication. In reality, the numbers will be higher; for the police do not check all wrong-way drivers for alcohol and drugs, nor is asking about medication part of standard procedure.

In Belgium [4], 43% of the wrong-way driving crashes involved alcohol; in all crashes this is 8%. In Germany, the percentage is lower: there, 14% of wrong-way driving crashes were reported to involve alcohol [5]. These two studies do not discuss drugs and medications. US estimates of substance use among wrong-way drivers are much higher. They range from around 50% to more than 60% [8] [10] and even as high as 70% [15]. On the basis of Swiss data, the risk of a wrong-way driving crash has been calculated to be over 3.5 times higher when alcohol, drugs or medication are involved [6]. For example, drivers under the influence of alcohol have been found to have different search and viewing patterns when turning onto a motorway and to perceive certain colour contrasts on road signs less well than sober drivers [18].

Summary overview

Arranged in a slightly different way, the following overview offers a summary of the most common factors that contribute to the occurrence of wrong-way driving crashes, based on an international literature review [19].

Table 1. Summary of factors contributing to the occurrence of wrong-way driving crashes, based on an international literature review. Source: [19].

Categories	Description
Traffic violation	Driving under the influence (DUI)
	Intentional reckless driving
	Suicide
	Test of courage
	Escaping from a crime scene
	Avoiding traffic congestion
Inattention	Falling asleep at the wheel
	Carelessness , absent-mindedness, distraction
	Inattention to informational signposts
Impaired judgement	Physical illness
	Elderly driver
	Drivers with psychiatric problems
Insufficient knowledge	Lack of understanding of how to use the highway
	Unfamiliar with the infrastructure
	Loss of bearings
Infrastructure deficiency	Insufficient lighting
	Insufficient field view
	Heavy vegetation
Others	Inclement weather

7 How can infrastructure help prevent wrong-way driving crashes?

There are several infrastructure options for reducing the risk of unintentional wrong-way drives in particular, and for ensuring that once wrong-way drives begin, they can be ended as quickly and safely as possible.

Preventing unintentional wrong-way drives

In the Netherlands, the currently most common infrastructural measure to prevent the risk of, especially unintentional, wrong-way driving is putting up C2 'Verboden in te rijden' (No Entry) signs with the sub-sign 'ga terug' (go back). The signs were introduced in the Netherlands in the early 1980s. In the late 1990s, the signs were put on a fluorescent background (see *Figure 1*) and

Rijkswaterstaat placed arrows on the road surface of entry and exit ramps to indicate the driving direction.



Figure 1. The C2 sign 'Verboden in te rijden' (No Entry) with the sub-sign 'ga terug' (go back).

These and several other design elements that can reduce the risk of wrong-way driving are included in the Dutch guidelines for the design of motorways and the lower-order roads that connect to them: the CROW Manual for road design for distributor roads [20]; the 2015 CROW Guideline on beaconing and marking [21], and Rijkswaterstaat's 2019 Motorway Design Guideline, updated in 2021 [22]. These include:

- Realising connections via a signalised intersection or, from a road safety perspective, preferably a (turbo) roundabout.
- Using arrows on traffic lights instead of full circles.
- Indicating the mandatory direction of travel with signs and arrow markings on the secondary road network near exit ramps.
- Applying wrong-way driving road markings on exit ramps that do not have arrows for getting in lane.
- Providing channelising and median islands at intersections with highway off-ramps making entry to the off ramp impossible or at least difficult..
- Providing combined entry and exit ramps at semi-cloverleaf junctions with a median barrier.

An analysis of 68 wrong-way driving crashes and incidents in 2015-2019 [1] showed that, at the location of the start of the wrong-way drive, as far as this could be determined, one or more of the design elements listed in the guidelines were often missing. An inspection of motorway connections by Goudappel [23] showed a similar picture.

Following and complementing recommendations by Brevoord [24] in the late 1990s, the SWOV study [1] contains a number of further recommendations for infrastructure measures to prevent wrong-way driving:

- Demarcating the driving lines on the underlying road, for example by using basalt blocks, if a roundabout is not possible. This keeps the through-maneuvre possible for emergency

vehicles, but does not make it comfortable for other traffic driving toward the exit ramp (see *Figure 2*).

- > Where on and off ramps are close to each other (as is the case with a partial cloverleaf) and physically separated by a barrier, an escape road can be provided to link the two.
- > The installation of a safety barrier in wide medians of motorways. In the case of a median wider than 25 metres without obstacles, this is not now prescribed in the Netherlands, but in the event of driver incapacitation, for example, the 25-metre median proves insufficient, possibly causing the vehicle to reach the other lane and continue against traffic.

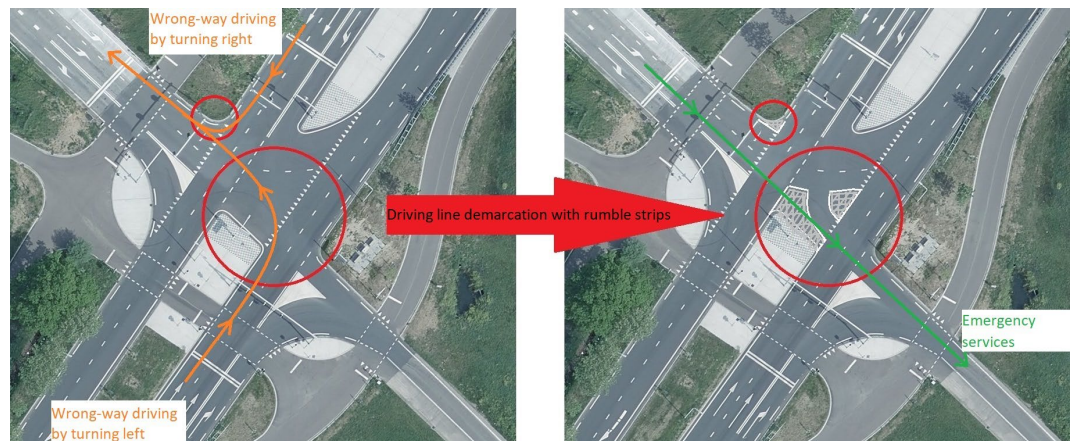


Figure 2. Example of driving line delineation (source: Cyclomedia).

In the United States in particular, not only these types of static design elements are used, but also dynamic signs and beacons that light up as soon as a vehicle is detected entering the exit ramp of a highway. Various configurations have been tested and found to be effective [25].

Quick and safe termination of wrong-way drives

Wrong-way driving must be prevented, but it is also important that once a wrong-way drive has started, the wrong-way driver leaves the carriageway as soon as possible. Rijkswaterstaat advises wrong-way drivers to [26]: *'try and find a gap in the oncoming traffic flow to reach the emergency lane safely. For you as a wrong-way driver, this is on the left. If there is a wide median where you can safely go, you can also swerve there.'* Of course, swerving to the median is safer. However, a wide median is often missing and the so-called recovery zone on motorways often turns out to be narrower than the prescribed 2.5 metres; often even narrower than the width of a car [1]. Widening recovery zones on motorways to at least 2.5 metres enables earlier termination of wrong-way driving via the median.

8 What other measures may help prevent wrong-way driving crashes?

Other measures that can help prevent wrong-way driving crashes include warning other traffic, general traffic management measures, driver-focused measures and in-vehicle technology.

Warning other traffic

In the Netherlands, when a wrong-way driver is reported, usually via the emergency number 112, all radio stations are broken into and road users are advised to ‘keep to the right, not to overtake and to warn the wrong-way driver by flashing the headlights.’ The information is also disseminated via navigation systems and traffic apps. Where matrix signs are present, lanes may be closed off with red crosses. Tunnels can generally be closed off with barriers.

This process obviously takes time. The Dutch Safety Board [27] estimates that it takes at least 2.5 minutes, but in practice 3 to 5 minutes, for a sighting of a wrong-way driver by another road user to be broadcast on radio (see *Table 1*). In that time, the wrong-way drive has usually already ended, whether or not in a crash, and if not, the wrong-way driver (at a speed of 120 km/h) is already some 6 kilometres away.

Table 2. Estimation of time from sighting to warning of a wrong-way driver (Source: [27])

Process step	Duration
Sighting	
Calling police	30 seconds minimum
Processing notification by National Police dispatch centre	60-90 seconds
Processing notification by Traffic Centre Netherlands	60 seconds minimum
Broadcasting on radio	As soon as possible
Total	Minimum: 2.5 minutes In practice: 3 to 5 minutes

Traffic management

In the late 1990s, there were also concrete proposals to completely clear the leftmost lane (where the wrong-way driver generally drives) when a wrong-way driver is reported, or to stop everyone at bridges or tunnels [28]. The (cost) effectiveness of these measures was never investigated and the measures were not introduced at the time. Meanwhile, new techniques have brought more possibilities. For example, many locations on the motorway network have cameras that can detect wrong-way drivers. In and near tunnels, a speed discrimination system (SDS) is sometimes installed that warns of stalled and slow-moving traffic, as well as wrong-way drivers. The question is, however, to what extent these methods can be used to react with sufficient reliability and speed to prevent a crash, for example by cordoning off a road section or tunnel (tube) (see, for example, [1] [29]).

Driver-focused measures

Relatively many wrong-way incidents and crashes occur because a driver is under the influence of alcohol, drugs or medication, or has mental health problems (see the question [What are possible reasons for wrong-way driving?](#)). Preventing people from driving under such circumstances will help reduce the number of wrong-way driving crashes [1]. In more general terms, this could include tackling alcohol and drug abuse and reducing the increasing pressure on mental health services. In addition, more specific measures in the field of medical fitness to drive and enforcement on alcohol and drug use in traffic can be considered.

In-vehicle technology

For years, the car industry has been working on technological solutions to the wrong-way driving problem: in-vehicle 'Wrong-Way Alert' or 'Wrong-Way Assistant'. Such systems aim to warn drivers (visually and aurally) if they are in danger of wrong-way driving, for example when entering an exit ramp. A number of car brands/types now have such systems operational, although sometimes only in a limited number of countries. These systems are usually based on GPS data combined with a navigation system. They also use built-in cameras that 'read' traffic signs. Research on the effectiveness of the systems is not known to us. There are also developments to use 'vehicle-to-vehicle' (V2V) communication to warn other drivers of an approaching wrong-way driver.

Publications and sources

Below you will find the list of references that are used in this fact sheet; all sources can be consulted or retrieved. Via [Publications](#) you can find more literature on the subject of road safety.

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