



Accidents caused by wrong-way driving on motorways

Accident patterns and measures



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1. Introduction

In Germany, approximately 1,950 incidents of wrong-way driving occur on motorways every year.¹ By contrast, accidents resulting from wrong-way driving are rare. However, the very high proportion of fatalities resulting from such accidents highlights their particular relevance. It is necessary to distinguish between three different aspects when discussing the frequency of wrong-way driving: the wrong-way driving incident, the incident report and the accident resulting from it. Naturally, the wrong-way driving incident itself lies at the origin of all this, but not every incident is reported and not every incident leads to an accident.

In Germany, it is common to talk of “ghost drivers” because this term accurately reflects the feelings aroused in such scenarios: a sudden situation arising from nowhere that is characterized by an aura of helplessness and fear. By contrast, the term “wrong-way driver” is a much more factual description that indicates the presence of a driving error under the road traffic regulations. In Germany, accidents involving wrong-way drivers have been explicitly recorded in this category since 2016. From the legal perspective, wrong-way driving is considered to constitute a road traffic hazard as set out in § 315c of the German penal code and is therefore a criminal offence.

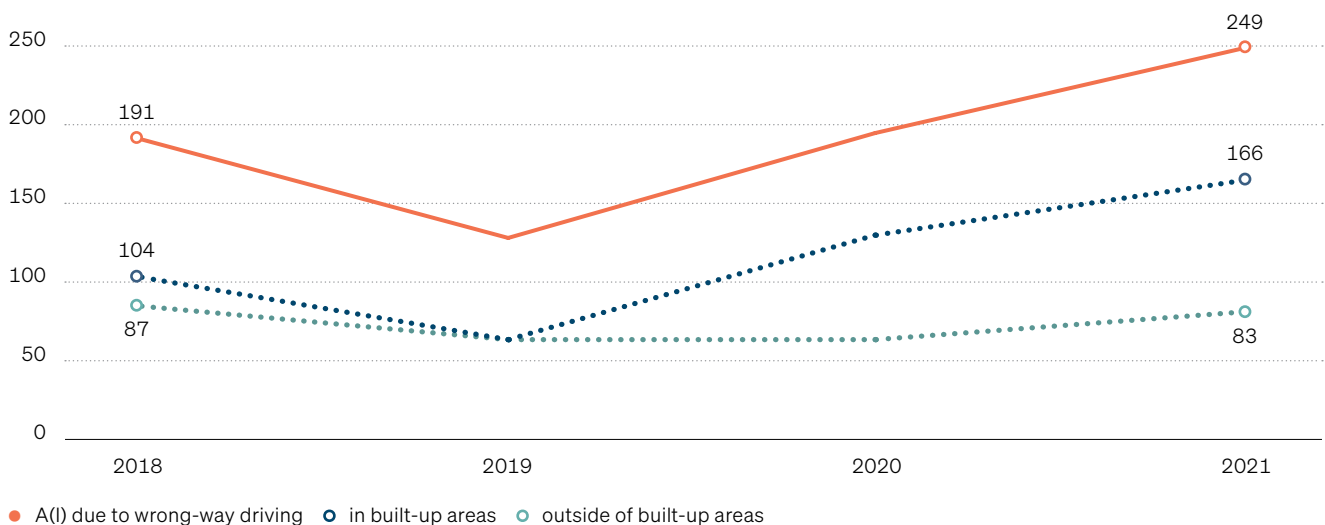
The purpose of the present study is to use accident data relating to wrong-way driving incidents on motorways in order to identify patterns, assess possible countermeasures and compare their effectiveness. The results presented here are taken from the research report issuing from a project undertaken in cooperation with RLS Unfallforschung Service GmbH.²

2. German traffic accident statistics

Data on wrong-way driving has been collected centrally by the German Federal Statistical Office in Wiesbaden (DESTATIS) since 2016, meaning that it is now possible to provide quite detailed information: see Figure 1.

Accidents due to wrong-way driving are rare

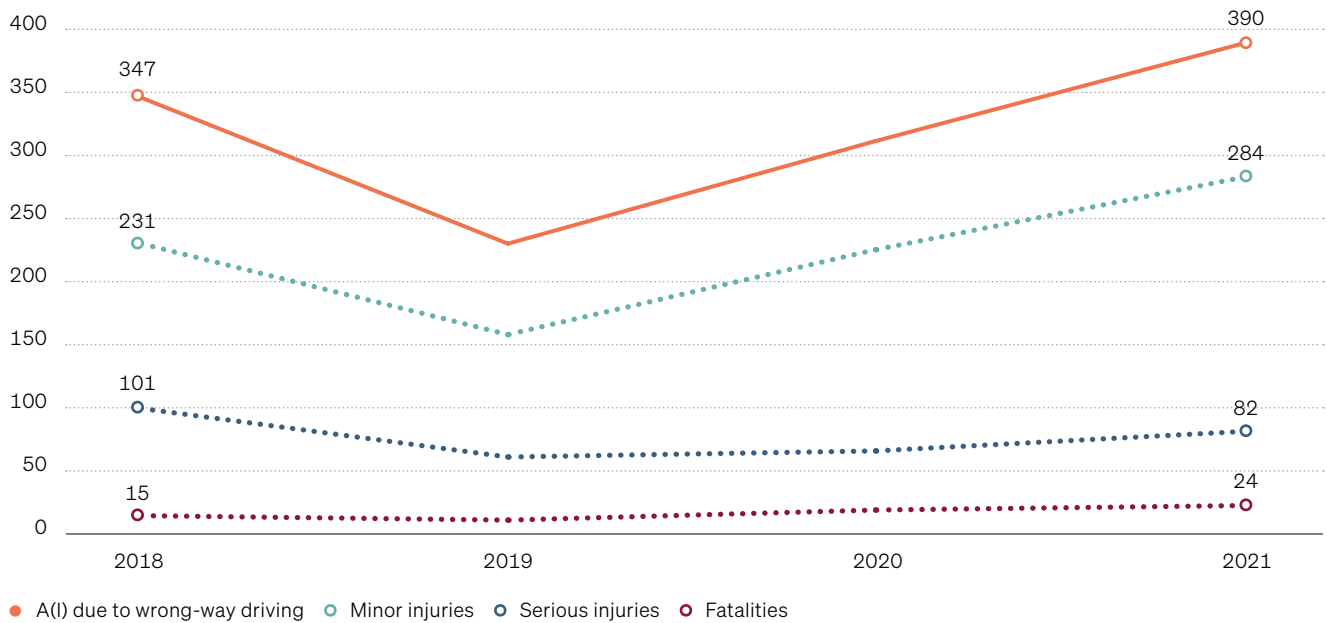
Figure 1 · Accidents with injuries A(I) resulting from wrong-way driving in Germany as a function of location^{3, 4, 5, 6}



Despite this, accidents on German motorways characterised as involving “wrong-way driving on roads with carriageways separated by driving direction (wrong-way drivers)” are addressed only imprecisely in the documents published by DESTATIS because these take account not only of all the possible locations – i.e. not just motorways – but also all types of road use (including cyclists, for example). In built-up areas, in particular, cyclists are involved in a high proportion of so-called “wrong-way driving incidents” because the roads in question are not motorways but typical main roads with structurally separated traffic lanes and at-grade intersections, as well as cycling and pedestrian facilities. The information on accidents due to wrong-way driving outside of built-up areas (83 accidents with injury, 24 fatalities) gives us the best insight into the problem of accidents caused by wrong-way driving on motorways (see Figures 1 and 2). This indicates that only 0.5 % of all the accidents that occur on motorways are due to wrong-way driving. However, they account for 6 % of all fatal accidents and 7 % of all motorway fatalities. It is therefore important to remember that accidents caused by wrong-way driving are rare occurrences that have serious consequences.

Accidents caused by wrong-way driving have serious consequences

Figure 2 · Casualties due to wrong-way driving in Germany ^{3,4,5,6}



3. What is known about accidents caused by wrong-way driving and about wrong-way drivers

The analysis of the literature that was conducted as part of the current project revealed the following picture of motorway wrong-way driving and the circumstances surrounding it: Wrong-way driving tends to occur at weekends, during the night and when the traffic density is low. The vehicles are usually driven by unaccompanied older men. Among other things, the drivers in question have been found to be emotionally unstable and to have a low level of self-control, a slightly below-average level of safety consciousness and inadequate risk awareness. Alcohol and drugs also play a role.^{7, 8, 9}

Possible measures to overcome the problem of wrong-way driving can be identified in the fields of infrastructure, vehicle technology and the familiarization of road users with the issues involved.

The examination of the literature thus made it possible to identify a number of risk factors for the occurrence of wrong-way driving, as well as some possible ways of preventing such incidents.² However, this data comes from a variety of countries with differing infrastructural arrangements and was collected during different periods. It is therefore almost impossible to draw any reliable conclusions about wrong-way driving in Germany on the basis of this data. The analysis described below, which is based on data from the German Insurers Accident Research, does nevertheless make it possible to draw such conclusions concerning accidents resulting from wrong-way driving on motorways.

4. Database

The following analyses and assessments are based on data for a total of 224 accidents resulting from wrong-way driving incidents between 2002 and 2022. The information comes from various sources and varies in the specific items reported:

- Insurers' claim files
- Cases recorded in the EUSka database
- Insurers' questionnaires
- Media reports

The details given in the claim files of selected insurance companies provide the highest information content of all these sources. They contain, among other things, road accident reports, loss reports, accident reconstructions, medical appraisals as well as the minutes of court proceedings and photographic material. The information on the cases in the EUSka database is based on police road accident reports. The information they contain corresponds to that available in media accident reports. The accidents analysed for the considered period constitute only a subset of all accidents due to wrong-way driving in Germany.

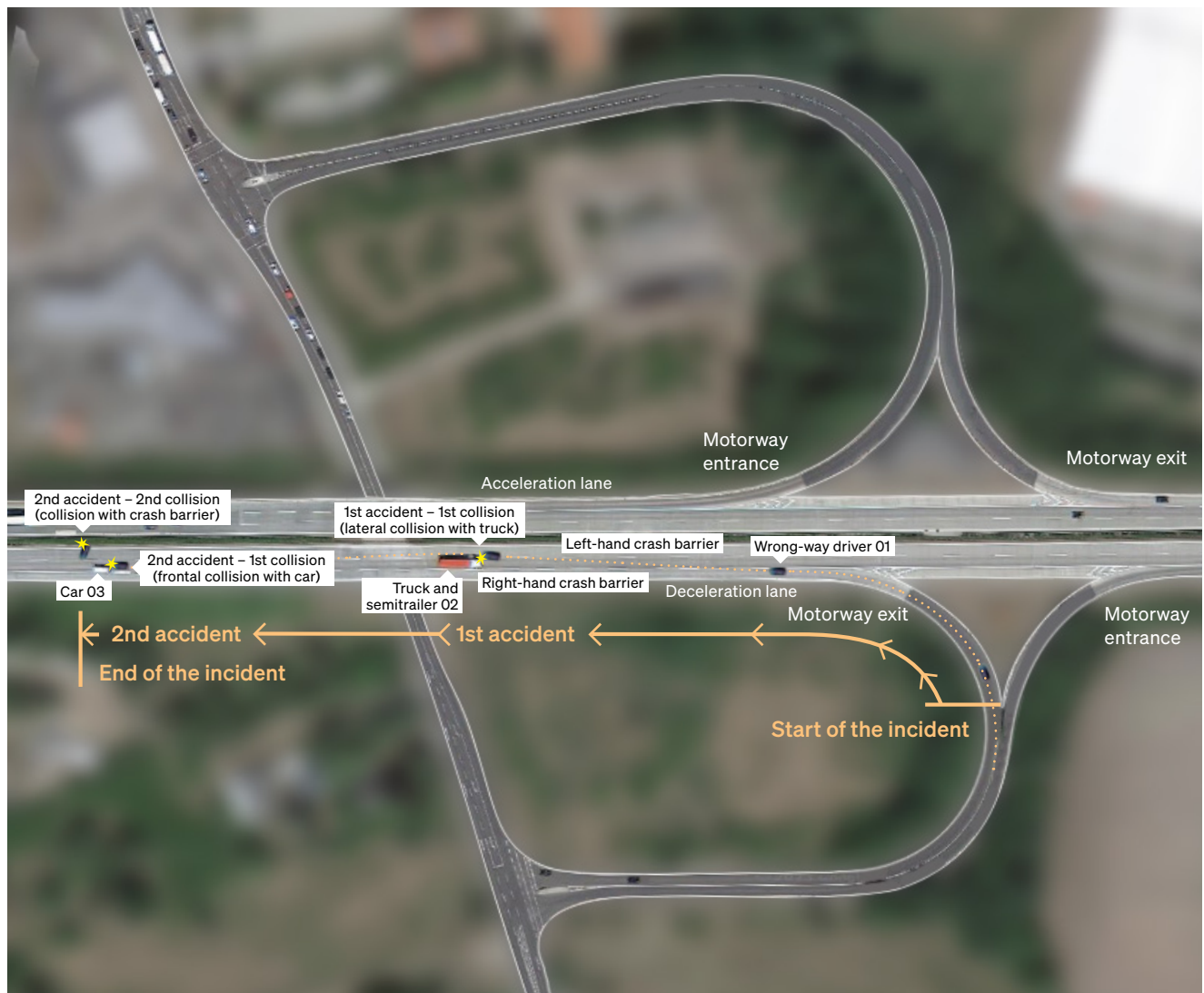
For the purposes of the present analyses, an incident in which the driver drove against the predefined direction of travel on a motorway constituted a prerequisite for considering the accident to result from wrong-way driving. The accident also had to occur after the start of the structural separation between the carriageways.

Figure 3 illustrates the general course of a wrong-way driving incident as an aid to understanding. It is also conceivable for one such incident to lead to multiple accidents involving multiple collisions.

To permit a subsequent analysis and assessment of the accidents, all the available information was entered in the insurers' accident database (UDB). To this end, additional attributes were set up in the UDB in order to permit the structured recording and evaluation of specific information relating to wrong-way driving accidents.

Definitions for the description of wrong-way driving

Figure 3 · Definitions used when describing the course of a wrong-way driving incident



5. Analysis

Figure 4 clearly illustrates the very serious consequences resulting from these accidents. At 28.1 %, the high proportion of accidents involving fatalities is particularly striking. If we consider this number only as a proportion of the accidents with injury (n=169), then the corresponding value reaches as much as 37.3 %. Overall, in the 169 accidents with injury, 99 people were killed, 207 suffered serious injuries and 210 minor injuries.

In 81.1 % of wrong-way driving incidents, the incident did not result in multiple accidents but did lead to multiple collisions. One of the reasons for this is that such accidents are often extremely serious and consequently prevent the driver from continuing after the first accident. On average, there were 2.9 parties involved in each accident.

Accidents caused by wrong-way driving end with serious consequences

Figure 4 · Consequences of the examined accidents due to wrong-way driving (n=224)



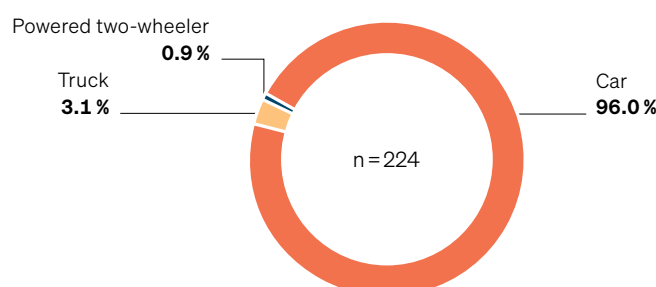
5.1 Analyses of wrong-way driving

The analyses also show that somewhat more than half of the wrong-way driving incidents occurred during the hours of darkness and only a very small number at dawn/dusk. At 46.4 %, wrong-way driving incidents in daylight were only slightly less common than at night time. These proportions are very similar to those reported in the literature.¹⁰ It is also clear that accidents resulting from wrong-way driving occur frequently in the evening and at night.

If we consider the number of incidents occurring on the different days of the week, we find that weekends and Fridays account for more than half of all accidents. If Monday is also included, then this proportion rises to 68.7 % of all accidents.

Wrong-way driving incidents are caused almost exclusively by car drivers

Figure 5 · Type of road user (n=224)

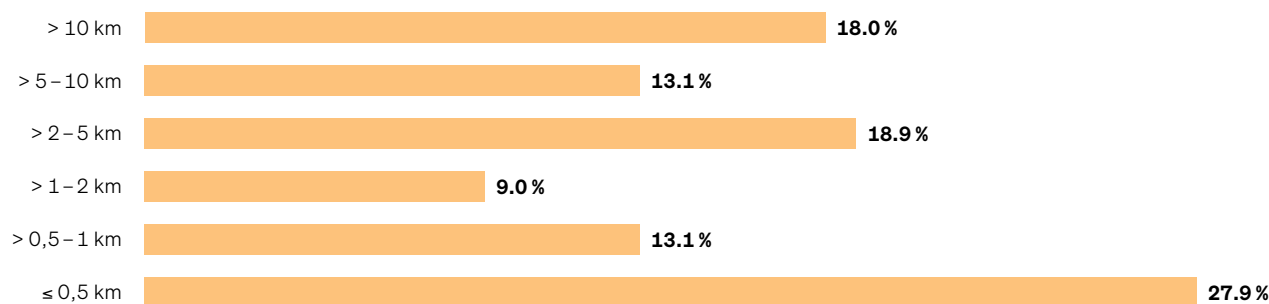


If we consider the type of road user responsible for the wrong-way driving incident, we find that 96 % of such incidents are caused by car drivers (see Figure 5).

With regard to the distance driven by wrong-way drivers in incidents that ended with accidents, we find that more than 50 % of the instances of wrong-way driving ended after less than 2 km. However, at 18 %, a high proportion of these incidents only ended after more than 10 km (see Figure 6).

More than 50 % of wrong-way driving incidents ended with an accident after less than 2 km

Figure 6 · Breakdown of wrong-way driving incidents leading to an accident by distance travelled (n = 122)



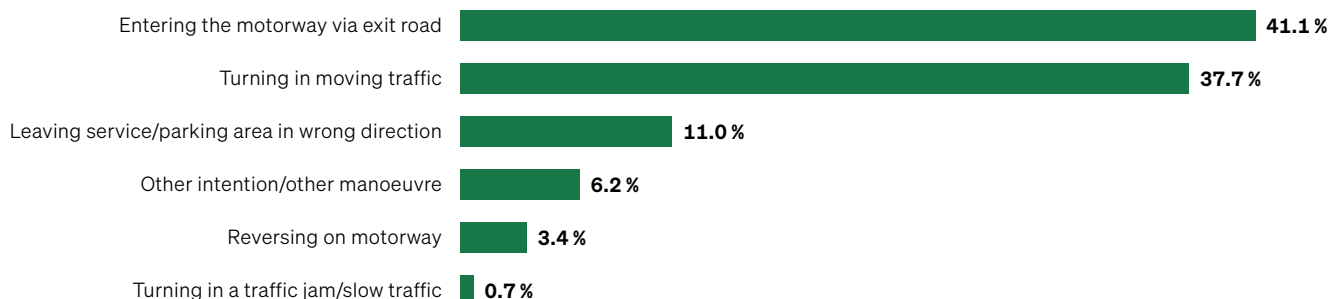
If we assume that wrong-way drivers drive at a speed of 100 km/h, then the time taken to drive 2 km in the wrong direction is only 72 s. A large proportion of the considered incidents therefore lasted only seconds or just a few minutes. The longest of the analysed incidents lasted as much as approximately 43 minutes, during which time the driver travelled 100 km.

An examination of the relationship between the length of wrong-way travel and the prevailing lighting conditions clearly shows that the distances travelled during daylight are often shorter and that increasingly long distances are observed as darkness falls.

It is particularly important to examine the manoeuvres that lead to wrong-way driving, since they form the basis for the subsequent evaluation of measures intended to prevent such incidents. It was possible to identify the manoeuvre at the origin of the wrong-way driving incident in 146 of the 224 accidents (see Figure 7). At 41.1 %, entering the motorway via the exit road and/or deceleration

More than half of wrong-way driving incidents start at junctions and service areas

Figure 7 · Manoeuvre at the origin of the wrong-way driving incident (n = 146)



lane was the manoeuvre that most frequently led to wrong-way driving. At 37.7 %, turning manoeuvres were almost equally as often the cause of the incident. Of the total of 55 such turning manoeuvres, 36 occurred on open stretches (24.7 %) and 17 directly after entering the motorway and/or on the acceleration lane (11.6 %). In 11 % of cases, the driver left a service or parking area in the wrong direction. The remaining incidents were distributed across other manoeuvres, reversing on the motorway and turning in a traffic jam.

It is also particularly important to know about how other road users are warned of the presence of wrong-way drivers and informed about possible ways to react. To this end, it is necessary to know where the wrong-way driver is located on the carriageway (see Figure 8). These specifications refer to the situation as seen by normal drivers travelling in the right direction. In over two thirds of the wrong-way driving incidents, the wrong-way driver used the left-hand lane. This means that seen from the the wrong-way driver's perspective, they were using the right-hand lane. To lend further support to this assertion, the position of the most serious collision on the carriageway as seen from the normal driver's perspective was also examined. In nearly 60 % of cases, the most serious collisions during the incident also occurred in the left-hand lane. In approximately 20 % of cases, it occurred in the right-hand lane.

From the normal driver's perspective, the wrong-way driver was driving in the left-hand lane

Figure 8 · Lane used by the wrong-way driver as seen from the normal driver's perspective (n = 140)

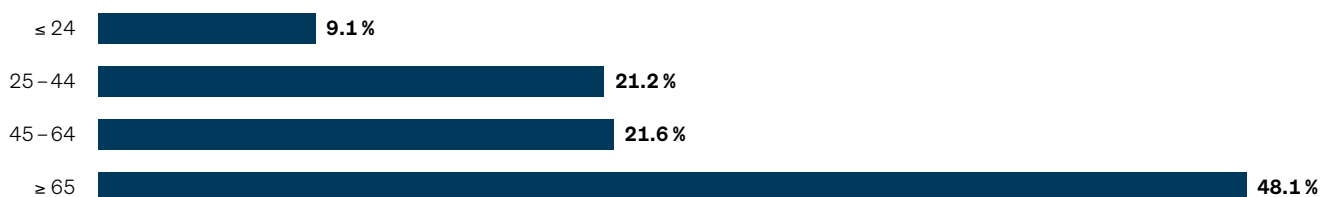


5.2 Analyses of wrong-way drivers

The analyses show that, at 79.3 %, men were significantly more often responsible than women for a wrong-way driving incident that resulted in an accident. It is particularly striking that almost half (48.1 %) of all the wrong-way drivers were aged 65 years or older (see Figure 9).

Almost half of all wrong-way drivers are aged 65 or older

Figure 9 · Breakdown of wrong-way drivers by age (n = 208)



Given that persons aged 65 years or more accounted for so many incidents, this group was subdivided in more detail and it was found that, at 64 %, the 75- to 84-year-old age group was responsible for by far the greatest proportion of cases. As a proportion of all accidents due to wrong-way driving, 30.8 % of the wrong-way drivers were aged between 75 and 84 years and 40.9 % were aged 75 or more. The breakdown by gender in the 65+ year age group was the same as in the overall sample, with 21 % women and 79 % men.

The proportion of incidents due to the 75- to 84-year-old age group is particularly high

Figure 10 · Proportion of wrong-way drivers aged 65 years or more in the different age (n = 100)

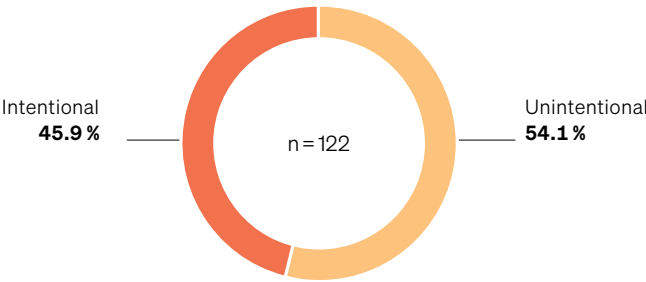


Further analyses showed that it tended to be rare for passengers to be present during these accidents. In the 12.5 % of accidents in which another person was present in the vehicle together with the driver, this person was aged 65 years or more in nearly 60 % of cases.

Intentional wrong-way driving was frighteningly prevalent, accounting for 45.9 % of the analysed accidents.

Intentional wrong-way driving is frighteningly prevalent

Figure 11 · Breakdown of intentionally and unintentionally initiated wrong-way driving (n = 122)

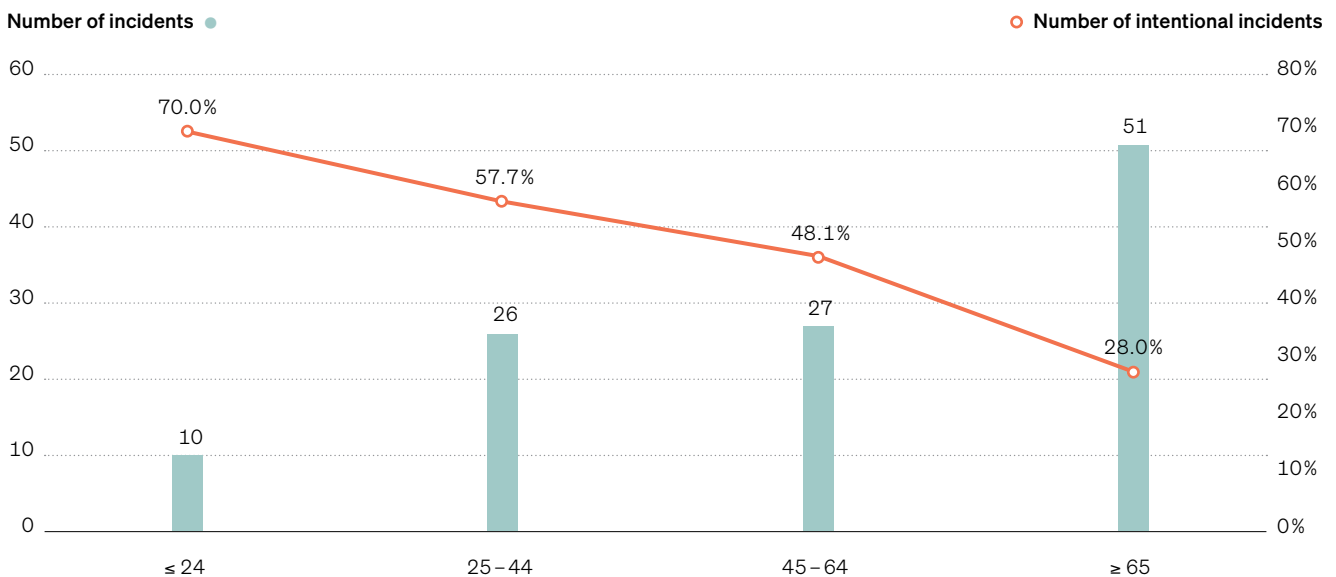


The high proportion of intentional wrong-way driving incidents is due, on the one hand, to suicidal intent or drivers fleeing the police although, on the other, a failure to appreciate the potential risks of wrong-way driving may also be a possible explanation.

It is also striking that the younger the wrong-way drivers were, the more likely it was for their behaviour to be intentional (see Figure 12).

Intentional wrong-way driving tends to occur among younger drivers

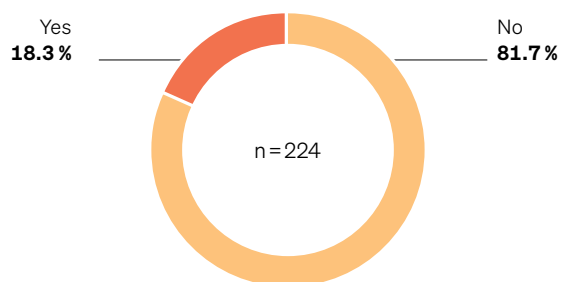
Figure 12 · Breakdown of intentional wrong-way driving incidents by age group (n = 114)



In 18.3 % of the 224 cases, the wrong-way driver was under the influence of alcohol; alcohol played no role in the remaining cases. According to the German Federal Statistical Office, alcohol played a causal role in between 3.0 and 3.3 % of accidents in the years 2017 to 2021.^{3, 4, 5, 6, 11} This means that alcohol is involved in approximately six times more wrong-way driving accidents than it is in other road accidents. This very high proportion of wrong-way drivers under the influence of alcohol is consistent with the high number of incidents observed in the evening, at night time and at weekends.

Alcohol as accident cause is six times more frequent than in other accidents

Figure 13 · Wrong-way drivers under the influence of alcohol (n = 224)



The analysis of the proportion of wrong-way drivers under the influence of alcohol revealed a clear trend for younger wrong-way drivers to be under the influence of alcohol more frequently than older drivers. 42.1 % of the wrong-way drivers in the under-24 age group were under the influence of alcohol. Among the drivers aged 65 years or more, by contrast, the corresponding level was only 4 %.

The younger the wrong-way drivers are, the more frequently alcohol is involved

Figure 14 · Breakdown of wrong-way drivers under the influence of alcohol by age group (n=208)

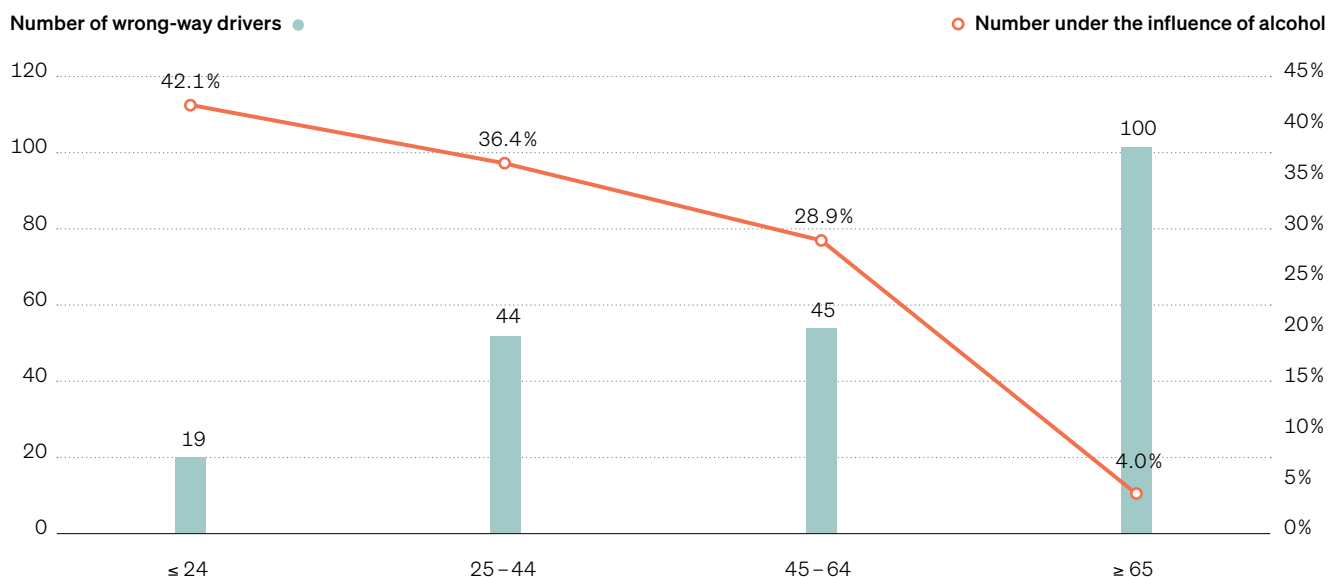
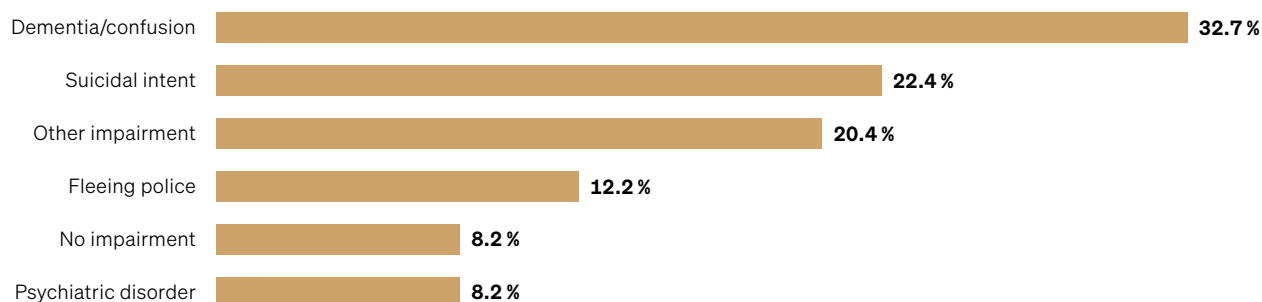


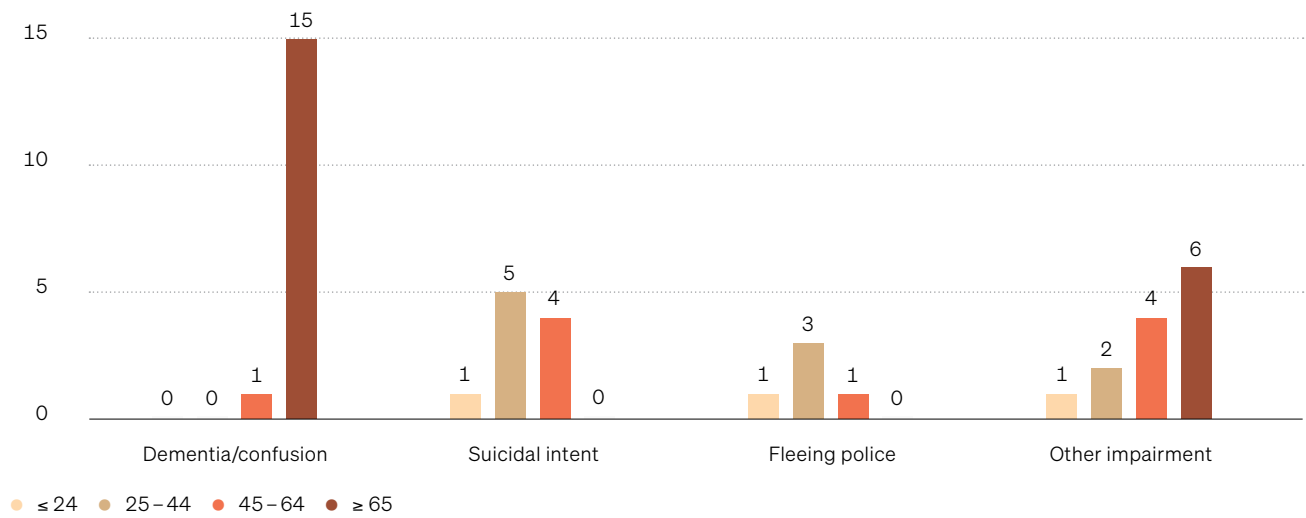
Figure 15 presents the proportions of wrong-way drivers with physical and mental impairments.

Dementia and confusion are the main causes of wrong-way driving

Figure 15 · Physical and mental impairment of wrong-way drivers as accident cause (n=49, 2x multiple categories)



It was only possible to determine whether the wrong-way driver was suffering from such an impairment in 49 of the 224 cases. If, nevertheless, anything can be said on the basis of these figures, then dementia and/or confusion were the most frequently observed impairments, being present in almost a third of cases. At 22.4 %, suicidal intent was also frequent. The high proportion of dementia and confusion can be explained in part by the high average age of the wrong-way drivers (see Figure 16). It is, above all, those aged over 75 years who are prone to such conditions. Suicidal intent is particularly often a trigger of wrong-way driving in the 25- to 64-year-old age group.

Among drivers aged over 65, dementia and confusion are the main causes**Figure 16** · Physical and mental impairment as a function of the age of the wrong-way drivers (n=44)

6. Measures for avoiding wrong-way driving

The table of possible measures below presents technical solutions from various areas. It also presents an estimate of the proportion of wrong-way driving accidents that can be addressed by the measure. However, these values should not be considered to equate to the number of accidents that could be prevented.

Measures in the field of vehicle technology address the majority of cases of wrong-way driving

Table 1 · Overview of measures and their effectiveness based on addressed accidents due to wrong-way driving

	Maßnahme	adressierte Falschfahrten	Anmerkungen (FF: Falschfahrer:in)
Infrastructure	Clear design of motorway junctions: Signage/signals, road markings, lane guidance	36%	Unintentional entrance to motorway via exit in the area of junctions is addressed, only WWD addressed
	Clear design of service areas: Signage/signals, road marking, lane guidance	5%	Unintentional entrance to motorway via exit in the vicinity
	Equip motorway exits with flip-type blockers ("lane claws")	52 %	Prevents entry in the wrong direction, Problems: Rescue vehicles, follow-up accidents, only WWD addressed
Organisat. measures (detection & warning)	Radio notifications	31 %	Wrong-way driving incidents that last for sufficiently long are addressed. E.g. > 5 km (3 min at 100 km/h), other road users present are addressed
Vehicle technology (detection & warning)	App-Lösung Ghosthunter	95 %	Intentional and unintentional wrong-way driving incidents in the vicinity of motorway entrances exits are addressed, WWD & other road users are addressed
	Bosch app solution	52 %	Bewusste und unbewusste Falschfahrten im Bereich von BAB-Einfahrten und -Ausfahrten werden adressiert, FF & Umfeld werden adressiert
	Detection of wrong-way driving incidents via traffic sign recognition (e.g. camera), warning issued to WWD	33 %	Unintentional wrong-way driving in the vicinity of junctions and service areas is addressed, confusion has been deducted, only WWD addressed
Vehicle technology (detection, warning & intervention)	Detection of wrong-way driving incidents via traffic sign recognition (e.g. camera) & in-vehicle intervention	52 %	Intentional and unintentional wrong-way driving incidents in the vicinity of junctions and service areas are addressed, only WWD addressed
	Detection of wrong-way driving, intervention & car-to-X communication	95 %	Potentially addresses all wrong-way driving incidents that do not initially immediately lead to a collision, will presumably experience slower market penetration than app, WWD and other road users addressed

¹ All percentage specifications are based on the assumption of nationwide implementation (100 %)

6.1 Infrastructure

Infrastructural measures have no effect on the great majority of intentional wrong-way driving incidents and can have no influence on the resulting accidents. They address only wrong-way drivers who are unintentionally responsible for such incidents. Such measures therefore have a limited impact and they can only be implemented in the long term and at considerable expense. One possible infrastructural measure that has already been implemented in some cases consists in the clear design of motorway junctions. Among other things, this comprises appropriate signage and signalling as well as road markings and lane guidance. This measure addresses unintentional wrong-way driving in the vicinity of motorway junctions.

Such incidents account for 36 % of all accidents due to wrong-way driving. The clear design of service and parking areas extends the area of effectiveness of this measure by the 5 % of addressed unintentional wrong-way driving incidents that start in these areas.

Equipping all exits at motorway junctions and service areas with so-called claws (flip-type blockers) would prevent drivers from entering the motorway against the direction of travel. This could address 52 % of all wrong-way driving incidents. Although this is a high proportion of total incidents, the need for rescue vehicles to be able to enter motorways opposite to the prescribed direction of travel, the intensity of maintenance and the negative cost-benefit ratio argue against this measure.

6.2 Vehicle technology

Technological app-based, in-vehicle measures address both the wrong-way drivers themselves and other road users. In cases where the technology intervenes actively in the wrong-way driver's car, such measures are very effective because intentional wrong-way drivers are also addressed. Otherwise, only unintentional wrong-way drivers are addressed. The app solutions are enjoying faster market penetration than purely vehicle-based solutions because road users are informed, for example via smart phone updates and consequently also via CarPlay/Android Auto on the car's dashboard.

The examined app solutions ascertain the direction of travel of vehicles and compare this with the prescribed direction of travel via GPS. If a wrong-way driving incident is identified, both the wrong-way driver and other affected road users are informed/warned.^{12, 13, 14} If the app solution is restricted to entrances and exits at motorway junctions then 52 % of wrong-way driving incidents are addressed. By contrast, if there is no such restriction then 95 % of incidents are addressed. Only those incidents that immediately lead to a collision are not addressed.

Conventional technological in-vehicle measures, such as traffic sign recognition without active braking intervention, address only the unintentional wrong-way driving incidents (33 %). In this context, systems that actively intervene in the vehicle and also prevent the initiation of intentional wrong-way driving by stopping the vehicle are more effective (52 %). If this system is also extended by car-to-X communication, then the proportion of addressed wrong-way driving incidents can be increased to 95 % because the other affected road users are also reliably warned. Incidents that immediately lead to a collision or accident at the start of the wrong-way driving episode cannot be addressed.

6.3 Organisational measures and recommended behaviour

The radio notifications that already exist inform road users in a wide area about the presence of a wrong-way driver. Due to the complex notification channels, approximately three-and-a-half to four minutes elapse between the reception of the notification and the broadcasting of the warning relating to the wrong-way driver. In order to determine the wrong-way driving incidents that are addressed by this measure it is necessary to make assumptions regarding the minimum duration that an incident has to last for a radio notification to be able to provide an effective

warning. A vehicle travelling at 100 km/h would cover 5.8 km in three-and-a-half minutes. To take account of wrong-way driving incidents at slightly lower speeds, a minimum distance of 5 km has been defined. As a result, this approach will ideally provide a warning of all wrong-way driving events that continue for a distance of 5 km or more; this corresponds to 31 % of accidents due to one-way driving.

The recommended actions broadcast via these radio messages or app solutions are important for the other affected motorway traffic. As analyses have shown, the recommendations that have been given in the past, namely to drive as far on the right as possible and not to overtake, are correct. However, these recommendations should be extended by also telling drivers not to exceed a speed of 80 km/h and to turn on their warning lights. A precondition for this recommendation to be effective is timely information about the precise location of the incident so that all drivers possess the same information and their driving behaviour does not bring about any hazardous traffic situations.

People who accidentally enter a motorway in the wrong direction and quickly recognise their mistake should stop on the hard shoulder if they possibly can, turn on their warning lights and call for help. In this way, they no longer have any kinetic energy and are no more dangerous than a breakdown van parked on the hard shoulder.

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