ANALYSIS OF CAR ACCIDENTS CAUSED BY UNINTENTIONAL RUN OFF ROAD

Matthias Kuehn
Thomas Hummel
Jenö Bende
German Insurers Accident Research
Germany

Paper Number 15-0245

ABSTRACT

Car accidents caused by unintentional run off road (in this paper the term "inadvertent lane departure" is used) have become an important topic within world wide accident research activities. These accidents can be addressed by lateral support systems (e.g. Lane Departure Warning) which are considered by experts to be the second most important active safety countermeasures after forward collision intervention systems.

There is no common understanding for "run off road" yet. This term is being used both for the event of a departure from the own driving lane and for the event of a departure from the road. But it is known that when a driver leaves its driving lane unintentionally, it mostly results in a severe crash involving an oncoming vehicle or an obstacle (e.g. tree).

The importance of this topic is also visible as efforts have already been made in order to adopt this issue in current and future testing procedures (eg. NHTSA, IIHS, Euro NCAP).

In Germany, the relevance of unintentional run off road accidents can hardly be estimated when using only official numbers. Official statistics categorize accidents by the parameter "leaving the carriageway" without any differentiation between intentional or unintentional lane departure. However, in the year 2013, these accidents made up 14% of all accidents with personal injury involving all kinds of road users but 30% of all fatalities and 23% seriously injured persons. A more accurate view on the accidents that match the definition "unintentional run off road" was given by UDV in an earlier study (paper-09-0317).

This paper presents now the results of a second more detailed analysis which was carried out with up-to-date accident data. For the analysis, the In-depth database of the German Insurers (UDB) was used. It contains a representative cross section of all third party insurance claims reported between 2002 and 2011. The group of car accidents analyzed was defined as "unintentional run off road accidents" and implies only cases where a car had left his driving lane unintentionally. The aim of the analysis was to get a better understanding of the circumstances at which these incidents occur and to derive key accident scenarios.

From a total of 118 relevant cases in the database, which account for 5% of all accidents caused by a car, five accident scenarios were deduced. These make up 68% of the accidents and 66% of the fatalities in the datapool. Some of the main results were: A lane departure to the left occurred more frequently than a lane departure to the right. Generally, the lane departure was followed by a collision with an oncoming vehicle (in 70% passenger car) rather than by a run off from the road. Regarding behavioral issues, health problems of the driver were found to be twice as frequent as distractions of any kind.

INTRODUCTION

Car accidents caused by inadvertent lane departure now feature significantly in accident research around the world. Systems for lateral support (or lane departure warning systems) can have a positive effect on these accidents and are seen by experts as being the second most important active safety measure that can be taken, right after advanced emergency braking systems. Accidents caused by inadvertent lane departure are generally very serious because they often result in collisions with oncoming traffic or roadside obstacles such as trees at relatively high speeds. The significance of these accidents is also evident from the level of attention now being given to them by international

test institutes (e.g. NHTSA, IIHS, Euro NCAP). At the European level, Euro NCAP has already made progress toward including systems for lateral support in its test program in future. Euro NCAP's current roadmap [1] includes the objective of providing a test procedure for lane departure warning systems from 2016. From 2018, a procedure will also be available for active lane keeping systems, which constitute a further development of lane departure warning systems.

The relevance of accidents caused by inadvertent lane departure has not yet been extensively investigated in Germany. The official accident statistics do not allow concrete statements to be made about these kinds of accidents. The reason for this is that the road accident reports on which the official statistics [2] are based do not contain any information on inadvertent lane departure because this is not recorded in police accident records.

A previous UDV study [3] provided an initial overview of car accidents caused by inadvertent lane departure. The aim of the present study is to describe these accidents in more detail and identify the main accident scenarios in order to assist with the development of realistic future test procedures. The study also describes the complex methodology that is required for the identification of the relevant accidents and underlines the priority and challenge of this important part of the analyses.

CASE MATERIAL

The accident material on which the study is based covers the years 2002 to 2011 and comprises 4,245 car accidents, in which 339 people were killed, 2,756 sustained serious injuries, and 4,592 sustained minor injuries. A total of 6,822 cars (not including vans) were involved in these accidents, and 41% of them were the main causer of the accident. All types of road users were taken into account as the other parties in the collisions (cars, vans, trucks, buses, two-wheel motor vehicles, bicycles and pedestrians). Single-vehicle accidents were also included. However, single-vehicle accidents are underrepresented in this case material because, for methodological reasons, cases not involving injury or damage to a third party are not included in the UDV's accident database (UDB).

TERMINOLOGY AND FORMULATIONS

It is best to begin by explaining some of the terminology and formulations used in this study:

- **Accident type**: Designated by a code of up to three digits. Describes the initial conflict between two road users that led to the accident [4].
- **Kind of accident**: Designated by a single-digit code. Indicates the position of the parties to the collision in relation to each other immediately before the impact [2].
- **Person-related misbehavior** (cause 01-69): This term is taken from the translation of the official accident statistics and essentially refers to a personal error. It is assessed and assigned to the relevant road user by the police officer recording the accident on the basis of a list of accident causes [2].
- **Lane and carriageway**: The carriageway (roadway) consists of at least two lanes, which separate it into two directions of travel; the borders of a lane are generally indicated by markings (Figure 1).
- **Case car**: This is the car that leaves its lane, without the driver intending to do so, and thus causes the accident. In this study, the case car is always the main causer of the accident. In the course of the accident, other road users may leave their lanes either intentionally (to get out of the way) or inadvertently (following a collision), but they are not considered to be the case car.
- **Lane departure**: This is when at least one wheel of the case car leaves its lane. This can be either to the left, which means it crosses the center line, or to the right, in which case it crosses over the border of the carriageway.
- **Leaving the carriageway**: This happens when the case car leaves not just its lane but the entire carriageway (roadway). Leaving the carriageway thus always involves lane departure.

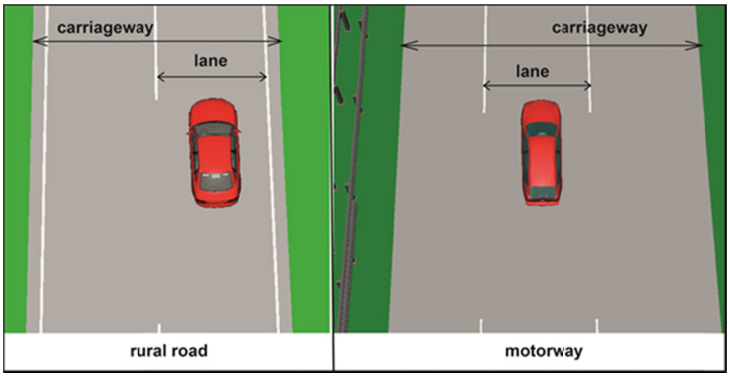


Figure 1. Illustration of the terms "lane" and "carriageway"

METHODOLOGICAL APPROACH

The methodology used in the study involves the following steps:

a. Pre-analysis of a random sample of cases in order to ascertain the defining factors for identifying accidents caused by inadvertent lane departure
b. Selection of factors that indicate inadvertent lane departure and identification of the relevant case material by means of a database query
c. Case-by-case analysis of the relevant case material with descriptions of the accidents and identification of the main accident scenarios.

a: Pre-analysis

Information on inadvertent lane departure is not recorded in police accident records and thus does not exist in this form in the accident database. It was possible to obtain this information subsequently by utilizing expert knowledge and by taking into account relevant factors that made it possible to conclude from the course of an accident that inadvertent lane departure had occurred. To begin with, the defining factors were ascertained by means of a brief analysis of a random sample of cases. The ten kinds of accident were selected here as the filter criterion, and ten cases were then randomly selected for each kind of accident. The kind of accident [2] has the advantage that it describes the collision position of the vehicles at the time of the accident and thus reveals a key aspect of the accident. In addition, by taking into account all kinds of accident, we ensured that the random sample covered all the accident constellations contained in the database. In the pre-analysis of individual cases, we investigated whether any cases of each kind of accident were caused by inadvertent lane departure, and we examined which factors indicated this.

The pre- analysis resulted in two important findings: Firstly, a combination of different factors and their refinements was required in order to properly identify the cases we were looking for. Secondly, it became clear that a vehicle that causes an accident as a result of inadvertent lane departure is almost always the main causer of an accident. It was thus possible to clearly identify the case car in the subsequent analyses.

b: Selection of factors that indicate inadvertent lane departure

The relevant cases were selected by using expert knowledge on the basis of the following factors:

- Kind of accident
- Accident type (three-digit code)
- General accident cause
- Person-related misbehavior (cause per road user involved)
- Location

- Soft shoulder
- Single-vehicle accident (yes/no)
- Party with which the car collides.

Taking into account the above factors, the methodology involved combining the ten kinds of accident with the following three-digit accident types [4]:

- "Other accident" (761-763; 771-775; 799)
- All "driving accidents" (in which the driver loses control over the vehicle), filtered by the criteria "rural road" and "soft shoulder".

After preselecting the accidents with the car as the main causer of the accident (n=2,475), a new set of case material was formed by means of a database query using the factors specified above (n=118 cases). This contained only cases that could be attributed to the inadvertent departure of the car from the lane. In other words, it was the case material we were looking for.

Description of the methodology by means of an example

In the following example the methodology is explained with respect to the identification of the relevant cases:

The case material involving accidents in which the car was the main causer of the accident was filtered on the basis of the fourth kind of accident, "collision with another oncoming vehicle". This kind of accident provides important information on the accident, such as that it was not a single-vehicle accident and that it was a collision with oncoming traffic in which none of the road users involved intended to turn off across the lane of the oncoming traffic. In order to establish the relevance of the case material conclusively, the following questions also had to be answered:

- Which of the road users left their lane?
- Was this road user a car (case car)?
- Did the driver of the car leave the lane intentionally (e.g. in order to overtake) or inadvertently?

In addition to the kind of accident, accident type 7 ("other accident") was included as a further factor. For this accident type, the refinement "sudden physical incapacity" (two-digit code 76) was set as the filter criterion, for example, together with the additional refinement "asleep at the wheel" (three-digit code 761). This three-digit accident type indicates that the accident was caused by a driver who lost control of his or her vehicle as a result of falling asleep. Together with the information "collision with another oncoming vehicle" and the pre-selected criteria "car driver was the main causer of the accident", it was possible to conclude that the accident occurred because the driver left his or her lane inadvertently as a result of falling asleep. Further factors such as "person-related accident cause" (with the refinement "overfatigue") and "location" (with the refinement "rural road without motorway") confirmed this picture.

RESULTS OF THE ANALYSES

The following chapters give a first general description of accidents caused by inadvertent lane departure and they then present the results of the analyses with respect to the main accident scenarios.

Relevance of accidents caused by inadvertent lane departure

From the case material of n=2,475 accidents in which the car was the main causer, a total of n=118 relevant cases were identified by means of the methodology described. In these cases, 33 people were killed, 153 people sustained serious injuries, and 148 sustained minor injuries. Accidents caused by inadvertent lane departure thus made up only 3% of all car accidents and 5% of all accidents caused by cars. However, they accounted for almost 10% of the total of 339 fatalities involved in all car accidents, and are thus highly relevant in terms of accident severity.

Causes of the lane departure

In order to obtain a better understanding of the course of these accidents, the causes of the departure from the lane were examined in relation to the case car.

It was possible to clearly identify the causes in half of the cases (n=50). In descending order of importance, these were:

a. Physical problems and health problems such as overfatigue and faintness or loss of consciousness (66%)
b. Distraction/inattentiveness, e.g. caused by adjusting the navigation system or radio or engaging in some other activity in the car (26%)
c. Alcohol/drugs (6%)
d. Weather conditions, such as heavy rain or fog (2%).

The causes were almost exclusively driver related. The comparatively low number of usable cases was due to the fact that a rather conservative approach was taken to analyzing them. In other words, only cases in which at least one clear cause was ascertained were included. These accident causes were ascertained on the basis of police inquiries, witness statements and medical reports (of low blood sugar or pre-existing medical conditions, for example).

The analyses revealed that physical and health problems were the cause of the inadvertent lane departure in two-thirds of the cases. This cause was twice as common as inattentiveness/distraction (26%). Drugs and/or alcohol (three cases) and severe weather conditions (one case) were found to be the cause far less often.

The distractions involved in the inattentiveness/distraction category originated almost exclusively in the vehicle itself. Examples included adjusting the navigation system, conversations with passengers and searching for things. In a few cases, nothing more was known than that the driver of the case car left the lane due to inattention. These cases were also included in the subsequent analyses.

a: Collision events caused by "physical and health problems": For the above mentioned "physical and health related causes", the collisions that occurred after the lane departure were investigated. The results were as follows:

a. Collision with oncoming traffic on a rural road (n=19)
b. Subsequent collisions on the motorway (n=6)
c. Single-vehicle accident including a collision with an obstacle such as a tree (n=3)
d. "Other", such as a collision with a pedestrian at the side of the road (n=2)

In over half of the cases caused by physical problems, the case car collided with oncoming traffic on a rural road (n=19 cases). It is worth noting here that the underlying case material originated from third-party claims, which means that collisions with oncoming traffic (i.e. with third parties) may be overrepresented, just as single-vehicle accidents are underrepresented, as already mentioned.

The second most common collisions were motorway accidents in which the case car and/or further road users collided with each other (n=6 cases). The accidents often took the following course: The case car left its lane, hit the crash barrier and came to a standstill on the carriageway. Subsequent collisions then occurred between the case car and other road users or between other vehicles without any direct involvement of the case car.

b: Collision events caused by "distraction/inattentiveness": Collisions with oncoming traffic on rural roads were also clearly the most common accidents caused by "distraction/inattentiveness" (nine out of twelve cases).

It was noticeable in five of the nine cases that the case car first went onto the soft shoulder at the side of the road before ending up in the lane for oncoming traffic as a result of the driver overcorrecting. Despite the low number of cases, this result is worthy of note in that the soft shoulder did not play a role in any of the accidents caused by the driver experiencing physical or health problems. One possible explanation for the high proportion of cases in which the car departed from its lane on the right-hand side is that the distracting activities described above generally took

place on the driver's right-hand side. In consequence, the driver unintentionally moved the steering wheel to the right while moving to the right.

Main accident scenarios

In the subsequent analyses, the 118 accidents were subdivided into predefined categories in order to identify the main accident scenarios. For these analyses, vehicle-specific and infrastructure-related aspects were taken into account in order to form these categories. The following factors and their refinements were taken into account and applied in terms of an "analysis path":

- State of the road surface (dry, wet/damp)
- Course of the road (straight road, bend)
- Radius of the bend (greater or less than 200 m)
- Light conditions (daylight, dawn/darkness)
- Severe weather conditions (heavy rain, fog)

Due to a lack of information, 18 cases could not be allocated to any category. This reduced the case material to be analyzed to n=100 cases with n=32 fatalities.

Relevance of the main accident scenarios: A total of five scenarios were identified. These are shown in figure 2 together with the factors described. The five main accident scenarios together account for 68% of the accidents and 66% of the fatalities in the case material of 100 cases.

It has to be mentioned that other combinations of these "analysis paths", resulting in other scenarios, are also possible. Against the background of the planned test procedures for lateral support systems and the use of accident data to support them, this approach was considered to be reasonable. This ensures that the scenarios also address those aspects that describe the characteristics of the sensors of lateral support systems and can also be tested in future.

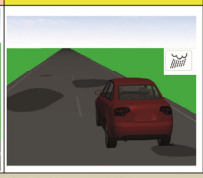
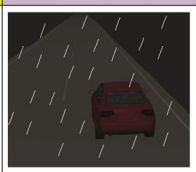
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Relevance and brief description						
Filter criteria for assignment to a scenario						
Road surface		Dry	Dry	Damp/wet	Damp/wet	Damp/wet
Course of the road		Bend	Straight	Straight	Straight	Bend
Radius of the bend		≥ 200 m	-		-	≥ 200 m
Light conditions		Daylight	Daylight	Daylight	Dawn/darkness	Daylight
Severe weather conditions		None	None	None	Heavy rain	None
Additional information						
Relevance in relation to all accidents (n=100)	n	27	23	7	6	5
	%	**27**	**23**	**7**	**6**	**5**
Relevance in relation to all fatalities (n=32)	n	12	2	3	3	1
	%	**38**	**6**	**9**	**9**	**3**
Average speed of the case car		85 km/h	90 km/h	75 km/h	Unknown	70 km/h

Figure 2. Main accident scenarios for accidents caused by inadvertent lane departure

For example, according to figure 2 all accidents that met the following criteria were allocated to Scenario 1:

- Dry road surface
- Daylight
- Accident in the vicinity of a bend with a radius of at least 200 m
- No severe weather conditions such as heavy rain or fog.

In-depth analysis of the main accident scenarios

In the course of a more in-depth analysis, the following aspects were examined more closely, allowing the scenarios to be described in greater detail in relation to the test procedures mentioned:

- Location
- Lane width
- Type and location of the road markings
- Speed of the case car
- Typical collision opponent of the case car
- Direction of the lane change before the collision
- Driver-related causes
- Age of the driver.

The results are shown in Table 1.

Scenario	Percentage (n=100)	Location	Typical lane width	Typical speeds	Lowest speed	Highest speed	Type and location of the road markings		Typical collision opponent and direction of the lane change before the collision		Average age of the drivers (only cases with a known cause)	Typical driver-related causes for inadvertent lane departure	Average age of drivers with health problems
S1	27	Rural roads	2-3 m	86 km/h	45 km/h	160 km/h	Left	Broken	Car	To the left	59	Health problems (45%), distraction/inattention (36%), overfatigue (9%), drugs (9%)	72
							Right	Continuous					
S2	23	Rural roads	2-3 m	91 km/h	50 km/h	140 km/h	Left	Broken			51	Health problems (38%), overfatigue (23%), distraction/inattention (38%)	61
							Right	Continuous					
S3	7	Rural roads	3-4 m	68 km/h	40 km/h	90 km/h	Left	Both			55	Health problems (50%), overfatigue (25%), alcohol/drugs (25%)	52
							Right	Both					
S4	6	Both urban and rural roads	2-3 m	100 km/h (one case)			Left	Broken			22	Overfatigue (75%), alcohol/drugs (25%)	-
							Right	Continuous					
S5	5	Rural roads	2-3 m	67 km/h	50 km/h	90 km/h	Left	Broken			48	Health problems (25%), overfatigue (25%), distraction/inattention (25%), severe weather conditions (25%)	25
							Right	Continuous					

Table 1. Descriptive details of the five main accident scenarios

The in-depth analysis revealed following results:

- With only a few exceptions, all accidents took place on rural roads with typical lane widths of 2 to 3 meters.
- There was at least one road marking present in all cases.
- The most frequent collision opponent of the case car was another car (in 70% of the cases). The case car always departed from its lane on the left-hand side before colliding with the other car.
- The average age of the drivers who had inadvertently left their lane due to health problems was 67 in the two most common scenarios (S1 and S2, which accounted for 50% of the case material).
- The most common health-related cause was faintness (as a result of low blood sugar, for example).
- Falling asleep at the wheel was specified most often in connection with the cause “overfatigue”.

- The following ranking was obtained for driver-related causes:

  - Health problems: e.g. faitness (36%)
  - Distraction/inattention (27%)
  - Physical problems: e.g. overfatigue (25%)
  - Alcohol/drugs (8%).

Main accident scenarios under the consideration of test procedures

As a result of the finding that over a third of the cases were attributable to health problems of the driver, and that these were thus cases in which the driver's reaction and acting were significantly impaired, the scenarios had to be adjusted. In the cases described, it is highly unlikely that the accidents could have been prevented by lateral support systems, and the scenarios would thus not be suitable for the planned test procedures.

Figure 3 therefore shows what the structure of the scenarios would look like if only cases with known causes were used, and cases caused by health problems were excluded. For this new structure the analysis revealed that the five scenarios would remain the same but their ranking would change. Within the individual scenarios marginal changes in the average driven speeds of the case car could be observed.

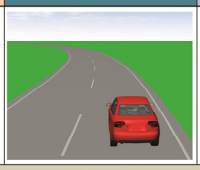
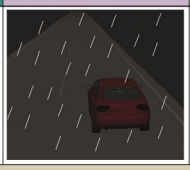
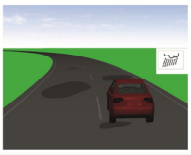
Relevance and brief description (only cases with a known cause, excluding the cause "health problems") n=23 accidents; n=4 fatalities		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
						
Filter criteria for assignment to a scenario						
Road surface		Dry	Dry	Damp/wet	Damp/wet	Damp/wet
Course of the road		Straight	Bend	Straight	Bend	Straight
Radius of the bend		-	≥ 200 m	-	≥ 200 m	-
Light conditions		Daylight	Daylight	Dawn/darnkess	Daylight	Daylight
Severe weather conditions		None	None	Heavy rain	None	None
Additional information						
Number of accidents	n	8	6	4	3	2
Number of fatalities	n	1	2	0	0	1
Average speed of the case car		71 km/h	77 km/h	Unknown	70 km/h	80 km/h

Figure 3. Rearrangement of the main accident scenarios with the following constraint: only cases with a known cause of the inadvertent lane departure and excluding cases caused by health problems

CONCLUSIONS

The analysis of car accidents caused by inadvertent lane departure showed that, although these accidents only occur rarely (accounting for 3% of all car accidents), they have serious consequences (accounting for 10% of all fatalities in car accidents). The most common reasons for inadvertent lane departure were physical and health problems and distraction/inattention. The main accident scenarios that were deduced from the analyses account together for 68% of the accidents and 66% of the fatalities in the case material (n=100 cases).

It was found that, in the main accident scenarios, most drivers inadvertently left their lane on a straight road, in daylight and on a dry road surface (i.e. in nearly ideal driving conditions). However, it was also found that over a third of these cases could be attributed to health problems of the driver and that over half of the drivers affected were over 60 years old. In view of the high percentage of accidents caused by health problems (36%), it is clear that there are limits on how effective current lateral support systems can be. The systems are not capable of preventing these

accidents. For the future there is a need to consider systems that are effective regardless of the location (on rural roads or on motorways) and that bring the vehicle to a standstill safely when the driver is no longer in a fit state to drive. Consequently, for the scenarios identified for the purpose of testing the features of lateral support systems, only those cases that are not attributable to health problems should be taken into account.

The following findings were also obtained in relation to these scenarios:

- 75% of the accidents occurred on a dry road surface, with 25% thus taking place on a wet road surface.
- Most case cars initially left their lane on the left-hand side.
- They then collided with an oncoming vehicle.
- At the point at which they left their lane, the case cars were generally traveling at over 70 km/h.
- At least one road marking was present in all cases. In cases where the case car left the lane on the left-hand side, there were both broken and continuous markings (to indicate that overtaking was prohibited, for example).
- Dawn/darkness and severe weather conditions (heavy rain, fog) were not significant factors in lane departure.

REFERENCES

[1] Euro NCAP: Euro NCAP`s Road map 2020, June 2014.
[2] German Federal Statistical Office (2013): Road traffic accident statistics, Wiesbaden.
[3] Kuehn, M., Hummel, Th. and Bende, J. (2009): Benefit Estimation of Advanced Driver Assistance Systems for Cars Derived from Real-Life Accidents. 21st ESV Conference, Paper No 09-0317, Stuttgart, June 15-18, 2009.
[4] GDV (1998): Accident type catalogue - A guide to determine the accident type, Köln.