

## ACCIDENT RISKS OF CYCLISTS USING THE BICYCLE PATH DEPENDING ON THE SIDE OF THE ROAD

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### ABSTRACT

Two way cycle lanes are common in Germany especially in rural areas. However, sometimes they are also used within city limits. There are special accident risks connected with two way cycle paths. These are in towns at crossings where especially the drivers of motorised vehicles often do not consider cyclists using the left side cycle path and in rural areas at points where the cyclists need to cross the main road in order to get to the cycle path. For this study data from GIDAS (German In Depths Accident Study) is analysed which is based on a representative accident sample that is collected in the cities and surrounding areas of Dresden and Hannover. It is important to know that in the town of Hannover cycle paths are considerably often designed as two way cycle paths while this is not the case in Dresden. There are about 1,500 cyclists in the GIDAS sample that were involved in an accident using the left cycle path inside city limits and about 50 outside city limits. Both groups are almost similar in size compared to the cyclists that are using the cycle path on the right side. This paper analyses accident risks for cyclists using the left cycle path compared to those using the right one. There is also a comparison between those that used the left cycle path where it was allowed to those that used the left cycle path where it was not allowed. The analysis is conducted also by comparing the Dresden data to the Hannover data in order to analyse whether or not there are differences for the two cities with different cycle path design policies. In the scope of this study scenarios were created for conflicts of vehicles with cyclists at junctions in towns, while accidents in rural areas where the cyclists need to cross the main road due to only one available cycle path could not be identified efficiently enough from the database. In general for the accidents at junctions in towns the analysis revealed that accidents with cyclists travelling on the left bicycle path (allowed or not) are not prone to a higher accident risk where a road user turns off the main road. There is however a higher risk at junctions where a road user crosses the bicycle path to enter the priority road which is influenced by the observation strategy of the entering vehicle. The comparison of the accident situations of the cities Dresden and Hannover also revealed that seemingly there is no "training effect" in Hannover meaning that the road users there could be more used to bicyclists on the left cycle path.

## INTRODUCTION

The cycle path design has an important influence on cycling safety [1] - [4]. One of the design factors potentially influencing the accident risk is whether or not the cycle path is promoted as a bi-directional bicycle path. While it is common to use bi-directional cycle paths in rural areas mainly to save infrastructure costs there is a trend in some regions to promote also bi-directional cycle path designs in urban areas. The speciality of bi-directional cycle paths in urban areas is that there are normally cycle paths on both sides of the road and both sides can be used in both directions. The authors believe that this design is chosen in order to facilitate and thus promote cycling in urban areas.

The main safety implication that may result from bi-directional cycle paths in rural areas are at points where the cyclists need to cross the main road (e.g., at the city limits where there is a change from uni-directional cycle path design at both sides of the road to bi-directional cycle path design at one side only) and conflicts with motorists at intersections within city limits where the motor-vehicle driver does not consider cyclists using the left cycle path.

The objective of this paper is to analyse safety implications resulting from the use of the left bicycle path. In order to achieve this objective in-depth accident data of cyclists using a bicycle path is analysed with a special focus on the side of the road on which the bicycle path is located and whether or not it was allowed to use the left bicycle path in cases it was used.

## METHOD

The study is based on GIDAS in-depth accident data. GIDAS (German In-Depth Accident Study) is the largest and most comprehensive in-depth road accident study in Germany. Since mid-1999, the GIDAS project investigates about 2,000 accidents per year in the areas of Hannover and Dresden and records up to 3,000 variables per crash. The project is supported by the Federal Highway Research Institute (BAST) and the German Association for Research in Automobile Technology (FAT) [6]. The sponsors and the investigation teams have access to the data.

In GIDAS, road traffic accidents involving personal injury are investigated according to a statistical sampling process using the "on-the-scene"

approach. This means that teams are called promptly after the occurrence of any kind of road traffic accident with at least one injured person occurring in determined time shifts. In addition, the investigation areas were chosen in accordance with the national road network characteristics and the share between built-up areas and non-built-up areas.

The detailed documentation of the accidents is performed by survey teams consisting of technical and medical staff supported by specially trained students. The data scope includes technical vehicle data, crash information, road design, active and passive safety systems, accident scene details and causes of the accidents.

In the GIDAS data set, the injury severity is described following the national statistics metrics but also using the AIS (Abbreviated Injury Scale describing the mortality risk in an ordinal scale ranging from AIS 0 – uninjured to AIS 6 – no medical treatment possible, i.e. 100% mortality risk [7]) code for every individual injury. In order to summarise the whole body injury severity, especially for victims with multiple injuries, the Maximum AIS (MAIS) is used. Because of the more detailed nature of the AIS scale, this scale is used as metrics for the analysis in this paper.

The causes of the accident are mainly analysed using the Type of Accident and ACAS (Accident Causation Analysis System).

For this study it is important to know that in the city of Hannover a large number of cycle paths are promoted for bi-directional use while there are very few in Dresden.

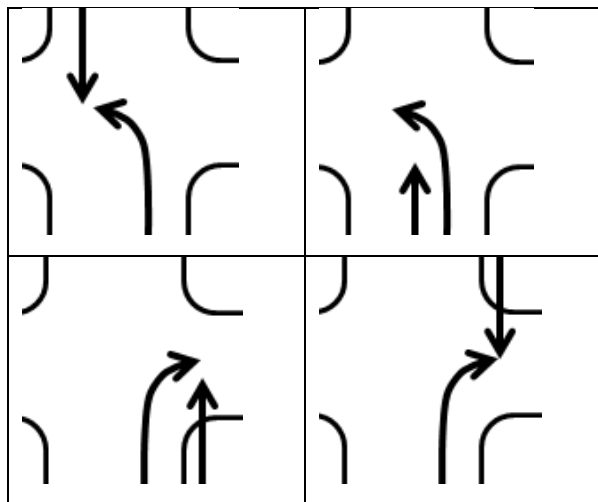
Furthermore it is important to have at least an idea about the exposure of cyclists using the right and the left bicycle path. In order to get an insight into the distribution of the usage of the left and the right bicycle path a field observational study was conducted in Hannover.

## Type of Accident

The type of accident provides valuable information concerning the conflict situation that resulted in the accident, i.e. a phase in the traffic situation where the further course of events could no longer be controlled because of improper actions or some other cause. The Type of Accident does not describe the actual collision but indicates how the conflict was touched off before the possible collision.. The

following seven main types of accidents are distinguished [8]:

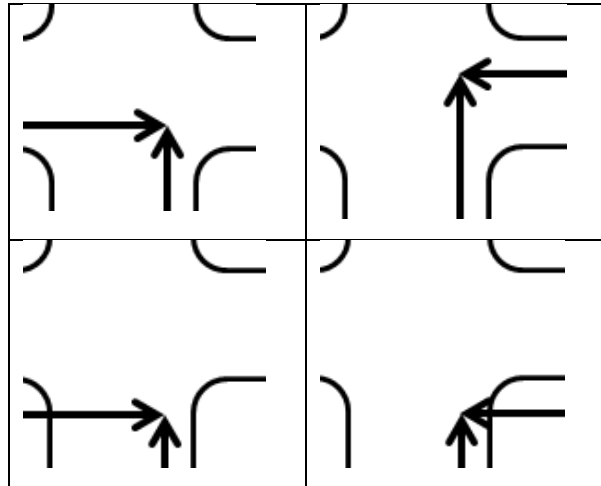
1. Driving accident: The accident was caused by the driver's losing control of his vehicle (due to unadapted speed or misjudgement of the course or condition of the road, etc.), without other road users having contributed to this. As a result of uncontrolled vehicle movements, however, a collision with other road users may have happened. A driving accident does not include accidents in which the driver lost control of his vehicle due to a conflict with another road user, an animal, or an obstacle on the carriageway, or because of a sudden physical incapacity or a sudden defect of the vehicle. In the course of the driving accident, the vehicle may collide with other road users, so that it is not necessarily a single vehicle accident. For this study, the loss of control may be caused by either of the two opponents (bicycle or motor-vehicle).
2. Accident caused by turning off the road: The accident was caused by a conflict between a vehicle turning off the main road and another road user approaching from the same or opposite direction (incl. pedestrians) at crossings, junctions and drive ways or car parks. A road user following the priority turn of a main road is not considered as turning off, examples see Figure 1



**Figure 1. Example cases of turning-off accidents.**

3. Accident caused by turning into a road or by crossing it: The accident was caused by a conflict between a road user turning into a priority road or crossing it and a vehicle on the priority road (with the right of way) at crossings,

junctions, or drive ways and car parks. In contrast to turning-off the road accidents where the participants are using the same road in this type of accident the participants are coming from crossing roads. Examples are shown in Figure 2.



**Figure 2. Example cases of turning into a road or crossing it accidents (similar for vehicles that are entering the crossing and turning).**

4. Accident caused by a pedestrian crossing the road: The accident was caused by a conflict between a vehicle and a pedestrian on the carriageway, unless the pedestrian walked along the carriageway and unless the vehicle turned off the road.. Even if the pedestrian who caused the accident was not hit, the accident is classified as caused by a pedestrian crossing the road. A collision with a pedestrian walking along the carriageway is recorded as an accident type no. 6.
5. Accident involving stationary vehicles: The accident was caused by a conflict between a moving vehicle and a parked/stopping vehicle or a vehicle manoeuvring in connection with parking/stopping. Accidents with vehicles only waiting because of the traffic situation are not included.
6. Accident between vehicles moving along on the carriageway: The accident was caused by a conflict between road users moving in the same or opposite direction, unless this conflict belongs to a different type of accident.
7. Other accident: This includes all accidents that cannot be allocated to any other type of accident. Examples: U-turning, reversing,

accidents between parked vehicles, obstacle or animal on the carriageway, sudden failure of the vehicle (brake failure, defective tyre, etc.).

In addition to the main accident types the Type of Accident is coded more in detail in the three digit Type of Accident. Here further information is given w.r.t. the direction of travel of the accident participants and the intended manoeuvre, e.g., right turning vehicle in conflict with a bicycle in opposite direction using the cycle path on the cyclist's left side.

### **ACAS**

The causes of the accidents are described by using the methodology of the Accident Causation Analysis System developed by Hannover Medical School [9]. The identification of the accident causes is done by means of a structured interview with the accident participants or witnesses on scene or at hospital. If no interview is possible in some cases the information is collected from police reports or expert opinion of the accident researchers.

ACAS collects accident causation factors with a focus on the human causes, which are identified and classified in 5 categories.

The 5 categories of human factors are:

- information access
- information admission
- information evaluation
- planning
- operation

Except for the first category (information access) the following four categories refer to a chronological sequence of human basic functions, which were active during the pre-crash phase in the situation of the accident emergence and in which failures of the road users are identified that had contributed to the causation of the accident.

Besides the human factors also accident causation factors that are vehicle based or environmental based are considered. According to the ACAS methodology especially for the environmental based factors only sudden changes of the environment are considered so that e.g. precipitation per se is not a causal factor.

It has to be noted that, if relevant, multiple causation factors can be assigned to one accident participant. In addition accident participants who are

not the main causers of the accident also may not have been assigned with a causation factor. ACAS codes are only available from the cases of the Hannover Accident Research Unit for cases from 2008 or later. In this study only cases from 2011 and later are used.

### **Evaluation of Exposure**

In order to have an insight concerning the exposure of cyclists at the right vs. the left cycle path a field observational study was conducted at 7 locations with cycle paths in the city of Hannover. The locations were selected to represent sections with and without allowed use of the left cycle path. At 5 locations the use of the left cycle path was allowed while it was not allowed at 2 locations. At each location 72 cyclists were observed.

### **DATA ANALYSIS**

The enquiry of the GIDAS database from the years 1999 to 2016 included 33,731 accidents of which 30,533 were available for analysis. These cases included 59,037 accident participants with 9,626 cyclists. Of these cyclists 9,352 had a known injury severity and were used for this study. These cases consist of 4,143 involved cyclists from the city of Dresden and 5,209 cyclists from the city of Hannover. The majority of these cyclists were involved in accidents that occurred inside city limits so in Dresden only 137 cyclists (3.3%) had an accident outside city limits and in Hannover only 200 cyclists (3.8%) had an accident outside city limits, respectively.

As a base for the comparison of different accident scenarios with cyclists travelling on cycle paths the availability of accident cases with a cyclist travelling on a cycle path is displayed in Table 1.

**Table 1.**  
**Distribution of bicycle path usage for cyclist-accidents in Dresden and Hannover**

	Dresden	Hannover
Cyclist on bicycle path on the left side of the road and usage allowed in this direction	85 (6.5%)	670 (24.3%)
Cyclist on bicycle path on the left side of the road and usage <b>not</b> allowed in this direction	419 (31.9%)	651 (23.7%)
Cyclist on bicycle path on the right side of the road.	809 (61.6%)	1431 (52.0%)

Considerably more accidents of cyclists using a bicycle path occurred in Hannover than in Dresden. The distribution of the cycle path used by the cyclist at the time of the accident shows that in Hannover many more accidents happened when the cyclist had used the left cycle path and was allowed to do so. This is obviously a result of the fact that in Hannover the use of the left cycle path is often allowed while this is not the case in Dresden. The higher share of bicycle accidents in Hannover could be the result of special actions in the region of Hannover to promote cycling which results in a higher share of bicycle use in Hannover (19% in 2011 [10]) compared to Dresden (12% in 2013 [10]). Both cities show increasing trends.

The analysis of the data obtained from the field study revealed that 26% of the observed cyclists used the left cycle path. Interestingly the share was almost similar independent of the legal situation (27% where it was not allowed to use the left cycle path and 26% where it was allowed).

#### Accident Scenarios

There are two main categories of accident scenarios which arise from two way cycle paths. The first, most common category includes scenarios where there is a conflict between a non-priority vehicle turning at a crossing or entering a crossing and a cyclist that is travelling on the cycle path. These accident scenarios are mainly found inside urban areas. The second category of scenarios includes accidents where there

is a conflict between cyclists having to cross the road because of the availability of only one bi-directional bicycle path on the left side of the road. The accidents of this scenario are mostly found outside urban areas. This paper studies the first category only.

For this study the accident scenarios are identified from the GIDAS database by using the type of accident and the information on the usage of the bicycle path (bicycle path on the right side, bicycle path on the left side and usage allowed in this direction or bicycle path on the left side and usage not allowed in this direction).

The relevant types of accident which describe the conflict of a road user with a cyclist travelling on the cycle path at junctions and crossing are combined in scenarios. As bi-directional cycle paths are less common in the city of Dresden than in the city of Hannover the case numbers are divided into cases from the Dresden team and into cases from the Hannover team to identify differences in the incidence of the different scenario types. In general the analysis revealed that less accidents of road users with cyclists on cycle paths occurred in Dresden (1,051 cases) than in Hannover (2,042).

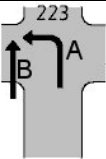
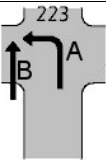
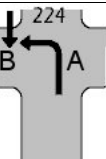
**Scenario 1.1:** At a junction a road user turns to the left and has a conflict with a cyclist travelling on the parallel cycle path.

When comparing the accident situation of this scenario (Table 2) to all accidents with cyclists on cycle paths (Table 1) it can be noticed that in both cities accidents of this scenario occur particularly often with cyclists travelling on the right side of the road (Dresden: 76% at this scenario vs 61% at all other accidents; Hannover: 73% at this scenario vs. 51% at all accidents). This deviation is statistically significant in Dresden ( $\chi^2=6.96$ ,  $p<0.01$ ) and in Hannover ( $\chi^2 = 31.42$ ,  $p < 0.0001$ ). Note that for the calculation of the significance the cases shown in Table 1 were reduced by the number of cases of the scenario in order to compare the cases of the scenario with the other cases. This is also true for the following scenarios.

Compared to the exposure data obtained from the field observational study the accident risk for cyclists at the left side appears to be similar to those using the right cycle path (approx. 26% of the involved cyclists in this scenario used the left cycle path compared to 26% of cyclists using the left cycle path in the field study).

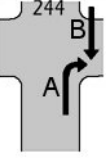
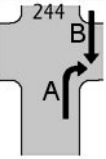
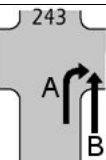
**Table 2.**

**Accident case numbers for the scenario 1.1 where at a junction a road user turns to the left and has a conflict with a cyclist travelling on the parallel cycle path**

Accident type	Usage of bicycle path from the perspective of the cyclist	GIDAS accident cases		
		Dresden	Hannover	Total
	Bicycle path on the left side of the road and usage allowed in this direction.	4 (5%)	24 (14%)	<b>28 (11%)</b>
	Bicycle path on the left side of the road and usage <b>not</b> allowed in this direction.	14 (19%)	23 (13%)	<b>37 (15%)</b>
	Bicycle path on the right side of the road.	57 (76%)	125 (73%)	<b>182 (74%)</b>

**Table 3.**

**Accident case numbers for the scenario 1.2 where at a junction a road user turns to the right and has a conflict with a cyclist travelling on the parallel cycle path**

Accident type	Usage of bicycle path from the perspective of the cyclist	GIDAS accident cases		
		Dresden	Hannover	Total
	Bicycle path on the left side of the road and usage allowed in this direction.	14 (7%)	83 (22%)	<b>97 (17%)</b>
	Bicycle path on the left side of the road and usage <b>not</b> allowed in this direction.	28 (14%)	68 (18%)	<b>96 (17%)</b>
	Bicycle path on the right side of the road.	161 (79%)	225 (60%)	<b>386 (67%)</b>

**Scenario 1.2:** At a junction a road user turns to the right and has a conflict with a cyclist travelling on the parallel cycle path.

As with the previous scenario in this scenario (where a vehicle turns to the right) the most frequent conflicts with cyclists travelling on cycle paths are when the cyclist was travelling on the right cycle path (79% of cases in Dresden, 60% of cases in Hannover), see Table 3. The remaining cases, where a cyclist was travelling on the left cycle path, have a lower share of cases, where the cyclists was not allowed to do so, in Dresden than in Hannover (Dresden 7%; Hannover 22%). Interestingly in Dresden the share of accidents where the cyclists that used the left cycle path and were not allowed doing so (14%) is also lower than in Hannover (18%).

The comparison with all accidents with cyclists on cycle paths again reveals that in Dresden the probability of a cyclist being in an accident when travelling on the right cycle path in this scenario is particularly high at 79% compared to all accident cases on bicycle paths (Table 1, 62%). The situation in Hannover is similar; however the difference is less distinctive: 60% in this scenario vs. 52% in all accidents on cycle paths.

When comparing the accidents with the field study results, using the left cycle path appears to be slightly more dangerous than using the right one (34% of the involved cyclists used the left cycle path while the share of left cycle path use in the field study was 26%).

**Scenario 1.3:** A non-priority vehicle enters a crossing and has a conflict with a cyclist travelling on the cycle path before entering/crossing the main road.

When crossing a priority road there are two situations where a conflict with a cyclist travelling on a cycle path of the priority road can occur: Once just before entering the main road (scenario 1.3) and once just after the main road (scenario 1.4). Most accidents of road users that have a conflict with a cyclist on a bicycle path are accidents from the scenario 1.3 (when entering the main road, Table 4). Here the analysis of the accidents reveals that most accidents (more than 2/3<sup>rds</sup>) in Hannover and also in Dresden (where cycling on the left cycle path is rarely permitted) occur when there is a cyclist travelling on the left cycle path and thus is coming from the right side of the road user which is entering the priority road. In Dresden the vast majority of these cases occurred in situations where cyclists

were illegally travelling on the left cycle path (274 cases) and only in 37 situations where they were travelling legally on the left cycle path. This deviation of the distribution of all cycle accidents on bicycle paths (Table 1) where accidents with cyclists are common when using the right bicycle path, is statistically highly significant ( $\chi^2 = 260.86$ ,  $p < 0.0001$ ).

Compared to the exposure data obtained from the field observational study the accident risk for cyclists at the left side is much larger than for those using the right cycle path (approx. 72% of the involved cyclists in this scenario used the left cycle path compared to 26% of cyclists using the left cycle path in the field study).

In Hannover the accidents from this scenario with cyclists travelling on the left cycle path are evenly split between cases where the cyclists were allowed to do so (37%) and where the cyclists were not allowed to do so (37%). And like in Dresden the frequency of accidents with cyclists travelling on the left cycle path and thus are coming from the right side of the road user which is entering the priority road is significantly higher at 74% compared to the 48.1% at all accidents of cyclists on bicycle paths (Table 1,  $\chi^2 = 465.72$   $p < 0.0001$ ). Especially in Hannover the relation between cyclists using the left cycle path correctly and the ones using it illegally is similar to all accidents; that means that the risk appears similarly high for both cyclists.

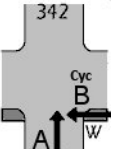
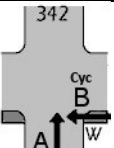
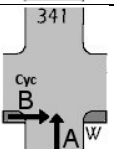
As the view and attention towards traffic on the priority road and on the bicycle path may vary depending on the intended driving manoeuvre (crossing the priority road, turning right onto the priority road or turning left onto the priority road) the frequencies of the intended driving manoeuvre for the cyclists opponent are displayed in **Table 5** for all accident types (intended manoeuvres) of this scenario.

Over 80% of the accidents where a road user enters a priority road and has a conflict with a cyclist travelling on the left bicycle path of the priority road (allowed or not allowed) occurred when the road user wanted to turn right onto the priority road. When doing so he has to mainly focus on traffic coming from the left and therefore may easily overlook cyclists coming from his right side - which is the case when the cyclist uses the cycle path on the left side of the road. However when there was a conflict with a cyclist travelling on the right side of

the road (thus coming from the left side of the entering road user) the share of accidents with a right turning road user drops to 62% amongst all accidents within this scenario. So accidents with a road user entering the main road and a cyclist on the bicycle path are most common when the road user

wants to turn to the right. Here there is no need to look for other motor-vehicles coming from the right and therefore it is likely that the right turning driver is just looking for other road users coming from the left.

**Table 4.**  
**Accident case numbers for the scenario 1.3 where a road user enters a priority road and has a conflict with a cyclist travelling on the bicycle path**

Accident type	Usage of bicycle path from the perspective of the cyclist	GIDAS accident cases		
		Dresden	Hannover	Total
	Bicycle path on the left side of the road and usage allowed in this direction.	37 (8%)	392 (37%)	<b>429 (28%)</b>
	Bicycle path on the left side of the road and usage <b>not</b> allowed in this direction.	274 (60%)	391 (37%)	<b>665 (44%)</b>
	Bicycle path on the right side of the road.	146 (32%)	275 (26%)	<b>421 (28%)</b>

**Table 5.**  
**Intended manoeuvre of road user when entering the priority road in scenario 1.3**

Scenario 1.3	Intended manoeuvre of road user when entering the priority road			
	Crossing the priority road.	Turning right onto the priority road.	Turning left onto the priority road.	Other
Bicycle path on the left side of the road and usage allowed in this direction.	27 (10%)	223 (81%)	17 (6%)	7 (3%)
Bicycle path on the left side of the road and usage <b>not</b> allowed in this direction.	39 (9%)	369 (85%)	16 (4%)	8 (2%)
Bicycle path on the right side of the road.	41 (15%)	165 (62%)	52 (20%)	8 (3%)



**Scenario 1.4:** A non-priority vehicle crosses the priority road and has a conflict with a cyclist travelling on the cycle path after having crossed the priority road.

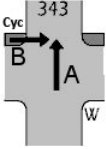
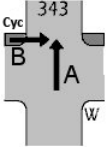
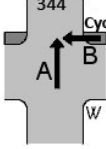
Accidents with cyclists after having crossed the main road are much less frequent than with cyclists before crossing/entering the main road. Here however Table 6 shows that the majority of accident occurred with cyclists that were travelling on the right side of the road (coming from the right). Even though a statistical significance cannot be determined due to low case numbers in this scenario it is remarkable that (as with the scenarios 1.1 and 1.2) the share of accidents with cyclists travelling on the right side of the road is higher than at all

accidents with cyclists on cycle paths. Here the distance (or better the time) that the cyclist is travelling on the road may be an important factor. It is normally easier to avoid an accident with a cyclist coming from the left – the same is true for the possibilities for the cyclist to avoid the accident.

Compared to the exposure data obtained from the field observational study the accident risk for cyclists at the left side appears to be smaller to those using the right cycle path (approx. 21% of the involved cyclists in this scenario used the left cycle path compared to 26% of cyclists using the left cycle path in the field study).

**Table 6.**

**Accident case numbers for the scenario 1.4 where a road user crosses the priority road and has a conflict with a cyclist travelling on the cycle path after having crossed the priority road**

Accident type	Usage of bicycle path from the perspective of the cyclist	GIDAS accident cases		
		Dresden	Hannover	Total
	Bicycle path on the left side of the road and usage allowed in this direction.	0 (0%)	8 (21%)	<b>8 (12%)</b>
	Bicycle path on the left side of the road and usage <b>not</b> allowed in this direction.	3 (10%)	3 (8%)	<b>6 (9%)</b>
	Bicycle path on the right side of the road.	27 (90%)	27 (71%)	<b>54 (80%)</b>

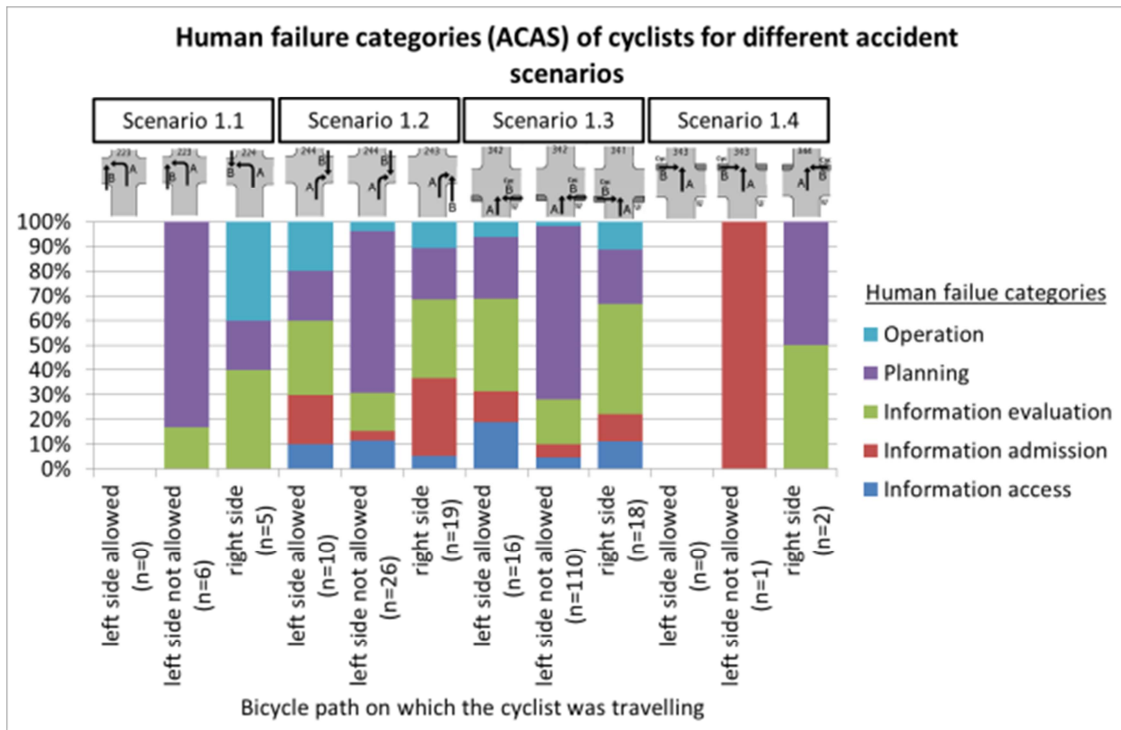


Figure 3. Distribution of human failure categories from the cyclists on a cycle path that were involved in an accident with a road user from the roadway.

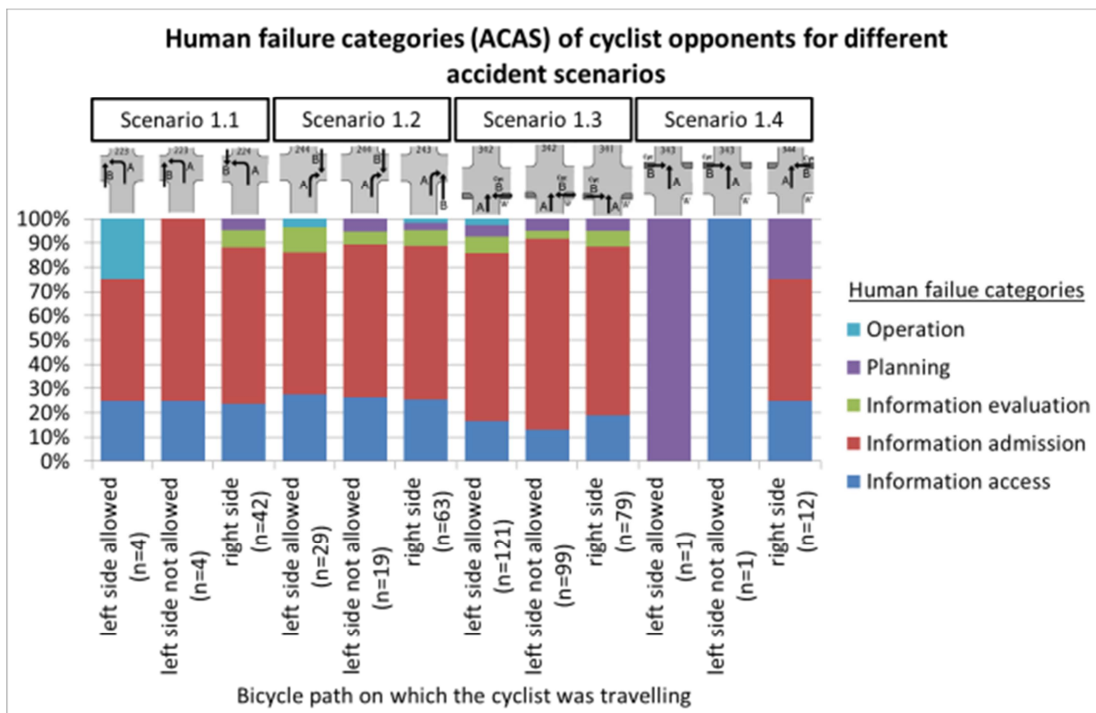


Figure 4. Distribution of human failure categories from the road users that were involved in an accident with a cyclist travelling on a cycle path.

## Accident causation factors (ACAS)

From the Hannover GIDAS data sample 626 cases correlating with the analysed accident scenarios are available with ACAS causation codes. For this study the causation analysis was divided into two groups:

- The cyclist that may also have contributed to the emergence of the accident e.g. by using the wrong bicycle path.
- The road users that had a conflict with a cyclist on the cycle path.

**Causes of cyclists on bicycle path:** A special focus here lays on the intentional breach of rules (which are included in the failure category of planning errors) of all cyclists that have used the left cycle lane and were not allowed to do so (Figure 3). For these cases the share of planning errors lays between 65% (Scenario 1.2) and 83% (scenario 1.1). The other most frequent category of human failures from the cyclists includes failures from the information evaluation. These are mostly a wrong expectation concerning the accident place.

**Causes of the accident opponent of the cyclist:** For the analysis of the accident opponents of the cyclists 582 opponents were available with a causation code. All of the road users had been assigned with human failures. In no case a failure of the vehicle technology or the infrastructure had contributed to the cause of the accident. The frequency distribution of the human failure categories is displayed in Figure 4 by the 4 scenarios and the direction of travel of the cyclist.

Here a special focus lays on the information admission failures which would include accidents caused by the fact that the road user did not perceive the cyclist on the cycle path e.g. due to a wrong focus of attention. For the most common type of scenario where a non-priority vehicle enters a crossing and has a conflict with a cyclist travelling on the cycle path before entering/crossing the main road (scenario 1.3) the share of causation factors from the information admission is highest at about 70% with the highest percentage for cases where the cyclist used the left cycle lane although it was not allowed (79%). At the same time causes based on a failure of the information access (e.g. cyclist could not be seen because he was hidden by parking vehicles) are lowest for this scenario at less than 20%. Failures from the field of information evaluation rarely occurred.

## Injury severity

As the different accident scenarios induce different crash constellations between the road user and the cyclists travelling on a bicycle path the injury severity of the cyclists was analysed according to the most severe injury (MAIS) of each cyclist. For this analysis no distinction was made between the cities of Dresden and Hannover. Due to the available number of cases the injury severity was only analysed for not injured or slightly injured cyclists (MAIS 0 - MAIS 2) and for severely or fatally injured cyclist (MAIS 3+).

In a first step the injury severity distribution of the cyclists is displayed in Table 7 for the different scenarios. Here the analysis reveals no major differences among the 4 accident scenarios concerning the injury severity.

**Table 7.**  
**Injury severity distribution of cyclists travelling on bicycle paths for different accident scenarios**

Scenario	Cyclist not or slightly injured (MAIS 0-2)	Cyclist severely or fatally injured (MAIS 3+)
Scenario 1.1	328 (96.8%)	11 (3.2%)
Scenario 1.2	702 (97.4%)	19 (2.6%)
Scenario 1.3	1876 (97.6%)	47 (2.4%)
Scenario 1.4	103 (93.6%)	7 (6.4%)

In a second step the injury severity of the cyclist was determined for the usage of the cycle path (**Error! Not a valid bookmark self-reference.**). Again no major differences can be identified whether the cyclist was travelling on the left or on the right bicycle path and whether or not he was allowed to do so. In about 3% of the cases the cyclist suffered severe or fatal injuries (MAIS 3+). Thus the injury severity is approximately at the same level of all bicyclists in the GIDAS database where 95.6% of the cyclists are below MAIS 3.

**Table 8.**  
**Injury severity distribution of cyclists travelling on bicycle paths for different usage of the bicycle path (direction, allowed or not)**

Scenario	Cyclist not or slightly injured (MAIS 0-2)	Cyclist severely or fatally injured (MAIS 3+)
Bicycle path on the left side of the road and usage allowed in this direction.	733 (97.1%)	22 (2.9%)
Bicycle path on the left side of the road and usage <b>not</b> allowed in this direction.	1043 (97.5%)	27 (2.5%)
Bicycle path on the right side of the road.	2169 (96.8%)	71 (3.2%)

## CONCLUSION

In the scope of this study the influence of the design of bicycle paths (whether or not they may be used as bi-directional bicycle paths) on the accident occurrence was analysed by using the GIDAS database. The analysis focussed on accidents that resulted from a conflict between a non-priority vehicle turning at a crossing or entering a crossing and a cyclist that is travelling on the cycle path.

These accidents were further divided into 4 different types of scenarios. The accident data was separately analysed for the two cities of Dresden and Hannover as in contrast to Dresden in Hannover bicycle paths are often free to be used in both directions.

The most common accident scenario includes accidents where a non-priority vehicle enters a crossing and has a conflict with a cyclist travelling on the cycle path. Here more than 2/3rd of the accidents in both cities occurred with a cyclist travelling on a cycle path on the left side of the road (in Dresden mostly illegally and in Hannover equally split between legal and illegal use of the left cycle path) and thus coming from the right from the perspective of the road user which is entering the priority road. Most road users in this accident scenario had intended to turn right onto the priority road and it can be presumed that they did not see the cyclists coming from their right side because

they were focusing on finding a gap in the traffic coming from the left. The analysis of the accident causes underlines this finding as this scenario has particularly high shares of failures from the field of information admission (mostly being a wrong focus of attention) which are present at over 69% in cases the use of the left cycle path is allowed and 79% in cases where the use of the left cycle path is not allowed.

For the accident scenarios where a road user turns off the main road at a junction and then has a conflict with a cyclist travelling on the parallel bicycle path the most common accidents are with cyclists travelling on the right bicycle path. Interestingly this is the case when the road user turns to the right (the cyclist travelling on the right cycle path comes from behind) as well as when the road user turns to the left (the cyclist travelling on the right cycle path comes from the front). Here the analyses of the accident causes on behalf of the road user having the conflict with the cyclist showed that again errors from the information admission (wrong focus of attention) are most common at around 60% of the cases. However at these scenarios failures in the information access (blocked view towards the cyclists) are more common than in the previous scenario.

The analysis of the accident causes on the part of the cyclists showed that human failures from the category of information evaluation (mostly a wrong expectation concerning the accident place) were most common except for cases where the cyclist was travelling on the wrong side of the road. Here of course human failures from the category of "planning" were most common as this category includes the deliberate traffic violations such as driving on the wrong side of the road.

In summary this study revealed that accidents with cyclists travelling on the left bicycle path (allowed or not) are not prone to a higher accident risk at scenarios where a road user turns off the main road and the cyclist is travelling in the same or opposite direction. There is however a higher risk at junctions where a road user crosses the bicycle path to enter the priority road and concentrates on finding a gap in traffic. To avoid these accidents a separation of the bicycle path from the roadway could benefit the observation strategy of the road user by first having to concentrate only on the cycle path and after that only on finding a gap in traffic on the priority road. For the remaining accident scenarios the creation of

free sight zones (e.g. no parking zones) at junctions or crossings avoids a blocked view towards cyclists travelling on bicycle paths.

From the separate analysis of Dresden and Hannover data there was no “training effect” visible, meaning that the motor-vehicle drivers in Hannover are not more used to bicyclists on the left cycle path. Furthermore it appears that not allowing bi-directional use does not effectively prevent cyclists from using the left cycle path which occurs much more often in Dresden than in Hannover.

When having an accident the injury severity appears to be independent from the used cycle path side.

All together there is a negative safety effect from allowing the use of the left cycle path within urban areas resulting in more conflicts with motor-vehicles that are crossing the path of the bicycle. This occurs more often than the less common scenario with the use of the left cycle path in conflicts with motor-vehicles that are travelling on the same road as the cyclist and are turning to the left or to the right.

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