Investigation of the accident avoidance potential of front-camera-systems with lateral field of vision in vehicle-bicycle accidents on the basis of the GIDAS accident database

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The Traffic Accident Research Institute at University of Technology Dresden investigates about 1,000 accidents annually in the area around and in Dresden. These datasets have been summarized and evaluated in the GIDAS (German Accident In-Depth Study) project for 13 years.

During the project it became apparent that the specific traffic situation of a covert exit of a passenger car and an intersecting two-wheeler involves a high risk potential. This critical situation developes in a large part due to the lack of visibility between the driver and the intersecting bike. In this work the accident avoidance potential of front camera systems with lateral field of view, which allows the driver to have an indirect sight into the crossing street area will be studied.

The following points will be discussed in the study:

• Existing systems and their functionality

In the first step, the existing systems will be presented in a short overview.

• Identification of the accident avoidance potential

On the basis of the Dresden-GIDAS accident dataset 2009/2010 relevant accident situations will be found. Furthermore, the vehicles involved will be identified. A classification of the accident locations is required.

• Investigation of the critical situation

The critical situations will be studied in more detail. In this part of the investigation the different vehicle types and their specific field of view at different accident sites will be shown. The relationship between speed and avoidance potential will be illustrated.

• Accident avoidance potential

This last step will analyze how the accident avoidance potential of front camera systems with lateral field of view could be estimated.

1 Motivation

The GIDAS accident-investigation team investigates traffic accidents with injured persons regardless of the form of the participation or injury severity. The proportion of accidents involving several vehicles and at least one cyclist has the dimension 34% of all recorded accidents in the GIDAS database.

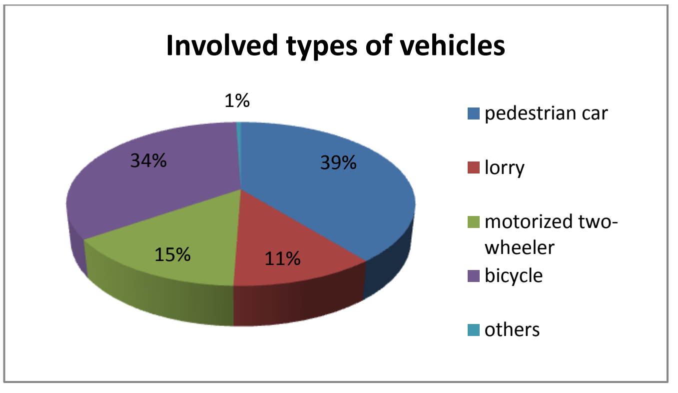

Figure 1: Involved types of vehicles
(Source: own illustration)

In nearly all cases involving a cyclist the cyclist was injured exclusively. The percentage of severely injured or killed cyclists in these accidents was 20.7% of all injured cyclists.

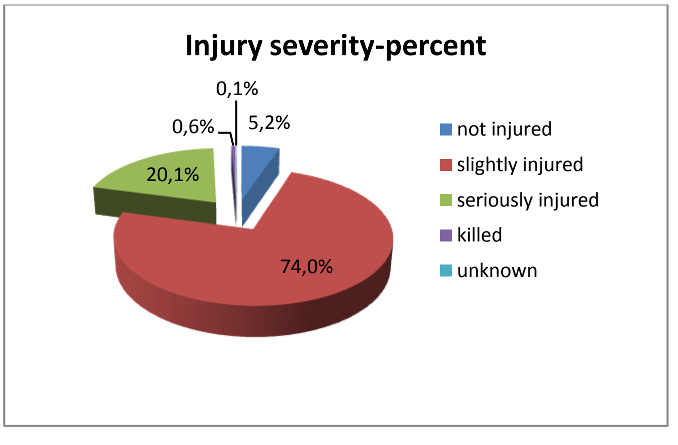

Figure 2: Injury severity in percent
(Source: own illustration)

It is therefore clear that many injuries to cyclists can be prevented by avoiding the critical situation between a motorized vehicle and a bicycle first and foremost.

Over the accident survey, a special type of accident emerged. It involves the re-occurring situation of an intersecting vehicle from a land access, driveway or a road at one site and on the other site a bicycle on a bicycle way or pavement. The view of both accident opponents to each other is strongly obscured.

This difficult conflict-situation is almost inevitable for the driver because he constructively is behind the line of sight. The equipment of cars with vision systems that produces an insight into the intersecting roadway behind the obstruction could be a solution for avoiding this accident situation. The present study investigated on the basis of two selected Dresdner-years GIDAS accident database, how the accident occurrence could be changed by the behalf of these vision systems.

2 Existing systems

In principle, two different systems are distinguished: one-or two-camera systems. Both image views are shown in different ways, depending on various systems of manufacturer and model series of the vehicles. The possibilities are wide-ranging, from simple pictorial representation on a screen in the integrated navigation system to intelligent work-up in Birds-view representation.

Figure 3: Example for a split-screen display in the vehicle
(Source: own illustration)

2.1 One-camera-system

As the name suggests, only one camera is used for detection. The camera is located in front of the vehicle, usually in the emblem or on the radiator grille of the vehicle. Thus, an undisturbed field of view is possible to the right and to the left. In order to realize the angle of deflection, a prism in front of the camera is installed.
The system is structurally relatively simple and is relatively common, therefore it is very widespread under the vision systems.

The disadvantage is the limited field of view caused by the opening angle of the prism.

Furthermore, it must be noted that in some systems, a protective hood is attached, which closes the unit at standstill or from speeds of over 15km/h. Thus, the applicability of the system is limited to the range of speeds up to 15km / h.

Figure 4: One-camera-system, integrated in the emblem of the car
(Source: http://www.adac.de/_ext/itr/tests/Autotest/AT1226_Toyota_Corolla_Verso_18_Executive/Toyota_Corolla_Verso_18_Executive.pdf)

2.2 Two-camera-systems

In this technical solution, two cameras are installed. They are located either directly behind the plate or in the front fenders or bumper covers. Thus an almost unlimited field of view allows to the side. A disadvantage is the installation in the fenders. The vehicle must move already 30 to 40cm behind the obstruction out of the crossing way to give a view-access to this road area.

Figure 5: Two-camera-system
(Source: http://www.7-forum.com/bild.php?bild=news/2010/6er_cabrio/p90068743-b.jpg&title=BMW%206er%20Cabrio%20(F12)
,%20Felge,%20Side-View-Kamera%20im%20Kotfl%FCgel&cpy=bmw)

Due the further extension of the one-camera-systems the following study refers only on these systems.

3 Identification of the accident avoidance potential

In the next step, the critical accident situations should be identified. Basis of the investigation should be two selected Dresdner years of the GIDAS database. The investigated accidents of the years 2009 and 2010 are complete and plausible available.
In the GIDAS accident database both technical as well as medical and statistical data are collected.

3.1 Type of accident

Essential information of an accident is the so-called critical situation. This critical situation is identified and categorized in the database according to the German accident type system of the General Association of German Insurers (GDV) [1]. For the identification of the type of accident the collision types or guiltyness are not interesting, only the conflict situation is shown by the type of accident.
The type of accident is categorized in different basic situations. Because of the intersecting routes of the vehicles involved, the category "bending-crosses" assigned.
In the German traffic law vehicles from driveways and intersections which cross the pavement or bicycle ways have to respect the right of way. That´s way in these situation is a privileged bicycle. The direction from which is crossed, does not matter. Walking and biking trails are also categorized as special ways.
This situation is represented by the type of accident number 341 and 342.

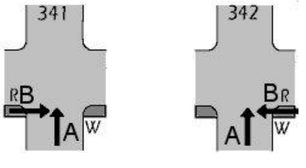

Figure 6: Type of accident 341 (left) and 342 (right)
(Source: GIDAS Codebook 2014)

The share of this critical situation of total accidents is overall in GIDAS in 7%, 1558 accidents, in the two years in Dresden at 5%, 96 cases.

3.2 Vehicle participation and visual obstruction

Furthermore, only accidents will be used, which have occurred between a vehicle (car, truck) and a bicycle. Because of a bicycle-bicycle accident 95 cases are still available for the evaluation.

Finally, the sight situation is assessed at the scene. In the database GIDAS a detailed documentation of the accident-scene and the driven roads takes place. An important detail is the evaluation of a visual obstacle that has influenced a direct view of the accident opponents to each other (or even in single vehicle accidents the view of the driver on the road).
After evaluating the situation view 60 accidents were available for evaluation.

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[1] GDV has emerged among others out of the liability insurance, personal accident and motor insurers association (HUK). The HUK created the accident-type-system originally.

4 Investigation of the critical situation

4.1 Vehicle shape

In order to assess the critical situation and the effectiveness of a camera system, the vehicle shape is included in the investigation. The main reason for this safety-increase is the distance from the front of the vehicle to the original viewing position of the driver. Suppose here is, that the driver can see now into the crossing direction with a camera system from the position of the steering wheel-the originally view position. This distance could be called as the safety-increase by using a camera system.

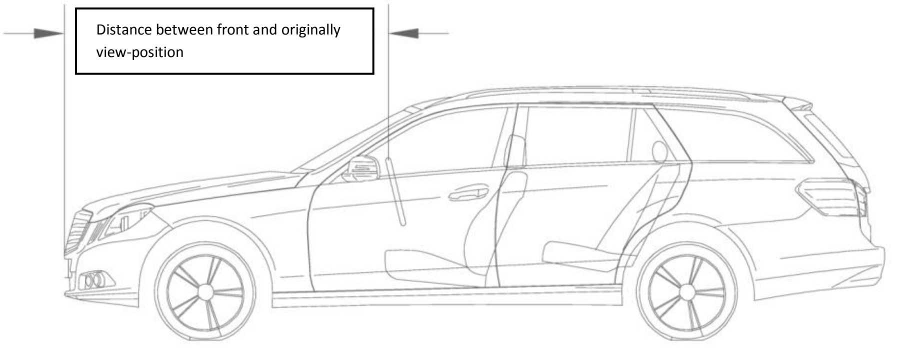

Figure 7: Distance between front an originally view-position
(Source: own illustration)

4.2 Initial velocity

In the GIDAS accident analysis, all accidents are reconstructed, i. e., the most likely progress of the accident will be presented. Important elements of reconstruction are the determination of the collision and initial speeds.
As described in "2.1 One-camera-systems", systems are currently applicable only up to a speed of 15 km/h. That´s why the initial speed of the involved pedestrian cars and heavy good vehicles (lorries, busses) have to be investigated. In the reconstruction were found 15 cars with more than 15km/h initial speed. In these cases, the camera system as described would not be effective. For these cases could not be detected a prevention-potential.

For the remaining 45 accidents the safety-potential is analyzed.

5 Accident avoidance potential

5.1 Spatially avoidable

The spatial preventability is examined whether an accident participant his vehicle in time may bring to a stand before the collision point by maintaining the required speed and reacts in the same way. Here this calculation is made only for the driver of the motor vehicle. The response of the cyclists is assumed to be the same.

"An accident is then spatially avoided if the distance between the reaction and the collision, the distance to avoid the crash, is greater than the stopping way out of permitted speed." [3, p. 293]

Basic assumption should be that all involved drivers use the camera system and react accordingly.
As a further assumption a mean braking deceleration of a mid-size car on dry pavement (asphalt) is assumed.

$$a_b = 8\frac{m}{s^2} \quad [5.1.1]$$

Adding the routes during the reaction time $\mathrm{d_r}$ and during the braking period $\mathrm{d_b}$ we obtain d_a the distance to avoid the crash.

$$d_a = d_r + d_b \quad [5.1.2]$$

If the collision speed and braking deceleration a_b are known, the initial speed v_0 could be calculated.

$$v_0 = \sqrt{{v_K}^2 + 2 * a_b * \ d_b} \quad [5.1.3]$$

If the speed during the reaction-time stays constant, the distance to avoid the crash is:

$$d_a = \frac{{v_0}^2 - {v_K}^2}{2 * a_b} + v_0 * t_r \quad [5.1.4]$$

The reaction time could be divided into seven distinct sections. The primary reaction time includes the perception time, the detection time and the decision time. Then the motoric phase, the time for the implementation, the application period and the swelling time follow.
Reaction times fluctuate between 0.4 s and 1.6 s. They will be influenced by the driver's attention, the intensity of the response prompt and view payments within peripheral events. To create comparable results a total reaction time of 0.7 seconds is assumed here in every case. This assumption is justified because the driver expects the other road users and thus has a low response time.

$$t_r = 0{,}7s \quad [5.1.5]$$

From this it follows, that the way of the reaction d_r with a constant initial speed v_0 and the assumed reaction time t_r could be calculated with:

$$s_r = \frac{v_0}{3{,}6} * 0{,}7s \quad [5.1.6]$$

After that the measured distance front-originally view d_{afs} will be added to s_a. As a result we get the distance to avoid the crash s_{a_K}, which is available with a lateral front-camera-system.

$$s_{a_K} = s_a + s_{afs} \quad [5.1.7]$$

By the help of the distance to avoid the crash s_{a_K} the maximum speed could be calculated, where the vehicle had come to a halt in front of the originally collision point. This is the maximum speed for the spatially avoidance.

$$v_{R_{max}} = -a_b * t_r + \sqrt{(a_b * t_r)^2 + 2 * a_b * s_{a_K}} \quad [5.1.8]$$

This calculation was done for all 45 vehicles. A total of 13 accidents are spatially avoidable. This means that in 13 cases the motorized vehicles with a front camera system would come to a halt with an adequate reaction of the driver before the initial collision point.

5.2 Temporally avoidable

In the following, the temporally avoidance of the relevant accidents is examined. Here it is checked whether it would have been possible to reach the point of collision due to the previous review so much later that the cyclist would have already left the collision point.
For this purpose the distance to avoid the crash is divided into several sections. First, the road is determined that the driver travels during the reaction time. Due to the requirement that the motor vehicle driver expects a forthcoming event, a response time of 0.7 seconds is assumed again.

$$t_r = 0{,}7s \quad [5.2.1]$$

The reaction distance $d_r$is calculated out of:

$$d_r = \frac{v_0}{3{,}6} * 0{,}7s \quad [5.2.2]$$

Subsequently, the path is computed which is covered in the swelling time. Here a linear increase of the brake pressure is assumed and thus determines a delay during the swelling time of 4 m/s ². This corresponds with $\frac{a_b}{2}$. It is further assumed a swelling time of 0.3 seconds.

$$a_s = \frac{a_b}{2} = 4\frac{m}{s^2} \quad [5.2.3]$$

$$t_s = 0{,}3s \quad [5.2.4]$$

The part of the distance, which belongs to the swelling time, could be calculated with:

$$d_s = a_s * t_s{}^2 \quad [5.2.5]$$

The entire distance to avoid the crash available to the driver of the passenger vehicle is calculated in the GIDAS reconstruction. It is the length of the travel time by the path of the reaction to the primary collision. This length is referred to here with d_f. In order to show the usefulness of the front camera system to the travel time by the path d_f will be added the distance front-originally view d_{afk}. The result is d_{FK}.

$$d_{FK} = d_f + d_{afk} \qquad [5.2.6]$$

By the known length of the distance to avoid the crash, the available braking distance d_b can be calculated.

$$d_b = d_{FK} - d_r - d_s \qquad [5.2.7]$$

The available time for the braking of the vehicle obtained from the following formula:

$$t_b = \sqrt{\frac{2*d_b}{a}} \qquad [5.2.8]$$

The time available for the entire maneuver time is then calculated out of

$$t_g = t_r + t_s + t_b \qquad [5.2.9]$$

To calculate the maximum speed for temporal avoidance that time has to be determine, which requires the cyclist for clearing the point of collision t_{cl}. The vehicle width of motorized vehicle d_v and the speed of the cyclist v_c affect the clearance time. Here, it is assumed that the cyclist continues its travel at a constant

$$t_{cl} = \frac{d_v}{v_c} \qquad [5.2.10]$$

The time to avoid the crash is then obtained by adding the total time it takes for the car driver to arrive at the collision point and the time it takes the cyclist for clearing the point of collision.

$$t_{avoid} = t_g + t_{cl} \qquad [5.2.11]$$

With the help of these can then the maximum speed of temporal avoidance be determined:

$$v_{Z_{max}} = \frac{2*d_{FK} + \frac{1}{2}*a*t_s{}^2 - a*(t_{avoid} - t_r - t_s)^2}{2*t_r} \qquad [5.2.12]$$

The temporal avoidance was calculated for all investigated accidents. With this method of calculation including the use of a front camera system 10 accidents could be avoided.

As already would have been spatially avoided 2 accidents could be avoided by 60 relevant accidents in total through the use of a camera system 21.

6 Summary and conclusions

The individual case analysis has shown that camera systems with lateral field of view to each other involve a high safety potential in the specific situation of a covert visual relationship of the parties. In about one third of the examined and illustrated critical situations, these systems have the driver given the opportunity to avoid the accident. As a result of an avoided accident with cyclists participation injuries could be prevented.

But this is a single case-analysis and that’s why there should be discussed the following points:

Until now, the conditions under which these camera systems are subject to high restrictions (field of view, speed), and in addition they are not yet widespread.

But an increase in the degree of distribution is expected with the increasing vehicle equipped with parking assistance systems. That means that the equipment of a car with those systems is simultaneously an advantage in traffic safety.

If one assumes that the driver is aware of the danger of the situation, it can be assumed from low speeds and thus of applicability of the systems. That means that there is a lot of work to do to improve the awareness aof the drivers for these critical situations. As a result we get a better possible application-rate of the camera systems.

The camera systems could but so far only be judged as passive assistance systems. They only transfer the image from the lateral field into the inner space of the car to any desk and there is no automatic evaluation and assessment of the situation. That means that drivers must correctly process the information and react appropriately. This has been assumed in the present case by case analysis.

Certainly current research in the field of video analysis will have an impact on the camera systems with lateral field of view. Conceivable here automated alerts and independent braking interventions in identified and defined critical situations. With such a development camera systems can make an effective contribution to accident prevention and the reduction of injuries in traffic accidents with covered lateral field of view.

Appendix

Table 1: Type of participation in vehicle-bicycle accidents in GIDAS

Participation of minimum:	Description	Number of cases	Percent
passenger car	one passenger car and no one vehicle of the following groups is involved	6662	39%
lorry	one lorry, bus or tram and no one vehicle of the following groups is involved	1928	11%
motorized two-wheeler	one motorized two-wheeler and no one vehicle of the following groups is involved	2506	15%
bicycle	one bycicle and no one vehicle of the following groups is involved	5805	34%
others	one other vehicle is involved	87	1%
unknown	unknown vehicle is involved	1	0%
sum		**16989**	**100%**

Table 2: Injury severity (official categorization) of participating bicyclists in vehicle-bicycle accidents in GIDAS

Injury severity	Number of byciclists	percent
not injured	311	5,2%
slightly injured	4417	74,0%
seriously injured	1200	20,1%
killed	36	0,6%
unknown	4	0,1%
sum	5968	100%

Table 3: Injury severity (Maximal abbreviated injury scale-MAIS) of participating bicyclists in vehicle-bicycle accidents in GIDAS

MAIS 2005	Number of byciclists	percent
0	317	5,3%
1	4464	74,8%
2	731	12,2%
3	182	3,0%
4	30	0,5%
5	20	0,3%
6	7	0,1%
9	217	3,6%
sum:	5968	100%

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