# <sup>イタルダ</sup>インフォメーション **ITARDA INFORMATION** 交通事故分析レポート No.122

# Special Crossing collision accidents involving cyclists feature and four-wheel vehicles

### ~ Drivers must be cautious of cyclists rushing out into intersections with poor visibility ~





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# 1 Introduction

The number of accidents involving cyclists in 2015 came to about 100,000. This represents a high share of the total number of traffic accidents at roughly 20%, and calls into question the importance of countermeasures against bicycle accidents.

Fig. 1 shows the composition rate of the number of casualty accidents involving cyclists by party in 2015. In 85% of the cases, a four-wheel vehicle was the other party to a collision with a cyclist, which is an overwhelmingly high percentage compared to those where the other party was a two-wheel vehicle, cyclist, or pedestrian.

Fig. 2 shows the number of casualty accidents among accidents involving cyclists and four-wheel vehicles by type of accident. Crossing collision accidents account for more than half of the total at 55%, which is a remarkably high number than the 15% for accidents while turning left and those while turning right, respectively. Therefore, countermeasures against crossing collision accidents involving cyclists and four-wheel vehicles have surfaced as an important topic.

Given such circumstances, recently an Advanced Emergency Braking System (AEBS) that detects cyclists began being equipped on some commercially-available vehicles.

The system uses cameras, radar, and other sensors to detect physical objects and automatically issues warnings and applies the brakes. It was initially developed and put on the market with the goal of reducing rear-end collisions against four-wheel vehicles in front, which is the most prevalent type of accident. But in recent years its scope has been expanded to include pedestrians and cyclists as well in order to reduce serious accidents (however, the current system primarily covers cyclists moving parallel to four-wheel vehicles).

Therefore, for this issue, we focused on crossing collision accidents involving cyclists and four-wheel vehicles, and analyzed the actual circumstances surrounding such accidents by using the road traffic accident statistics (macro data) and in-depth case studies possessed by ITARDA (micro data). In addition, we attempted to estimate the effectiveness of AEBS in response to crossing collision accidents involving cyclists and four-wheel vehicles in an effort to improve preventive safety technologies for accidents involving cyclists.



Fig. 1. Number of casualty accidents involving cyclists by party (2015)

Fig. 2. Number of casualty accidents among accidents involving cyclists and four-wheel vehicles by type of accident (2015)

# **2** Macro data analysis

### Is the direction of movement of cyclists more commonly on the right or the left?

Fig. 3 shows the composition rates for the direction of movement of cyclists moving straight versus four-wheel vehicles moving straight.

(This excludes accidents where the cyclist was emerging from somewhere other than a road, such as a parking lot.) The composition rates for the direction of movement of cyclists moving straight versus four-wheel vehicles moving straight is a roughly even breakdown of 50% each for the right and left. No unique characteristics were observed with the direction of movement of cyclists with regard to crossing collision accidents.

In Japan, vehicles travel on the left-hand side. When you consider the visibility of cyclists proceeding straight ahead from the sides, generally speaking there is poorer visibility of cyclists coming from the left as they are obscured by structures, walls, and other objects. So presumably the visibility of cyclists coming from the right would improve corresponding to the width of the oncoming lane.

Yet despite this, it is conjectured that the reason the percentage of accidents is the same for both the right and left sides is possibly due to the impact from the mental situation of the self-conceit of the driver owing to the good visibility on the right-hand side every bit as much as it is due to the bad physical situation due to obstructions on the left-hand side.



# Fig. 3. Composition rates for the direction of movement of cyclists moving straight versus four-wheel vehicles moving straight (2015)

### What age groups tend to encounter more crossing collision accidents?

Fig. 4 shows the composition rate of drivers of four-wheel vehicles by age group.

The age groups upto 35 - 44-years tend to make up a larger percentage as they get older. But after that point, the percentage gradually diminishes the older they get.

When viewed by gender, women exhibit the same tendency as mentioned above. Men upto the age group of 35 - 44 years also make up a larger percentage the older they get, while those in each of the age groups of 35 - 74 years tend to stay at roughly the same rate.

This indicates that there is presumably a strong possibility that even those drivers with a great deal of driving experience due to their advanced age may get into a crossing collision accident.

Fig. 5 shows the composition rate of cyclists by age group.

The percentage accounted for by the 10 - 19 years age group of so-called teenagers is conspicuously high at over 30% of the total, which gives an indication of the severity of crossing collision accidents involving junior high and high school student cyclists. A gradually decreasing trend is seen between the ages of 20 and 59, while a slight upward tick can be seen between the ages of 60 and 79.

Looking at this by gender reveals that among young people between the ages of 0 and 19, the composition rate of men is higher compared to that of women. Yet conversely from age 30 onward, the composition rate of women surpasses that of men.



Age of the drivers of four-wheel vehicles

Fig. 4. Composition rate of drivers of four-wheel vehicles by age group (2015)



Fig. 5. Composition rate of cyclists by age group (2015)

# 3 Micro data analysis

The micro data dealt with in this study was primarily generated from around the Tsukuba Region of Ibaraki Prefecture. From this, 200 cases related to crossing collision accidents involving cyclists and four-wheel vehicles at intersections were extracted as the subject of this analysis.

### On what sorts of roads do crossing collision accidents occur?

Fig. 6 shows the composition rate of accidents for cyclists and four-wheel vehicles by type of lanes for the accidents targeted for this analysis.

Cases where the four-wheel vehicles' lane was un-demarcated and where the cyclists' lane was a roadway accounted for the highest composition rate at just under half of the total. If you include everything up through roads with one lane in one direction in this, then this would account for over 80% of the total.

When the bicycle lane is a roadway, there is a tendency for the composition rate of accidents to increase as the number of four-wheel vehicle lanes decreases. When the bicycle lane is a sidewalk, no inverse correlation was seen in the composition rate due to the difference in the lanes for four-wheel vehicles.

Roads lacking sidewalks and where there is no demarcation between the lanes for four-wheel vehicles generally have numerous locations where the road is narrow, or where traffic signals, signs, and other safety features have not been thoroughly set in place. Moreover, such locations also feature lots of densely-packed residential areas. These roads tend to have poor visibility, which is why it is conjectured that they account for such a high composition rate.



Four-wheel vehicle lane

### Fig. 6. Composition rate of accidents for cyclists and four-wheel vehicles by type of lanes

### Are cyclists or drivers of four-wheel vehicles more likely to abide by the traffic rules?

Fig. 7 shows the composition rates for the right of way for cyclists and four-wheel vehicles for the accidents targeted for this analysis.

The four-wheel vehicle had the right of way in roughly 70% of the cases, while the cyclist had the right of way about 10% of the time. Cases in which decisions could not be reached on who had the right of way came to about 20% (the determinations on who had right of way mentioned here were primarily carried out based on the road conditions, such as whether or not traffic signals were obeyed, whether or not stop signs were present, and whether or not there was right of way on account of the road width).

Regarding the accidents targeted for this analysis, it is estimated that many of the cyclists did not obey the traffic rules. The reason for this is believed to be because in locations where stop signs are located, for example, while bicycles are vehicles and therefore obligated to stop, the young people who account for a large number of the cyclists are not fully aware of this fact. Conversely, there are also thought to be many cases in which the cyclist was aware of this but did not think it would constitute a violation if they did not stop, and so they proceeded ahead on their own interpretation of this.



Fig. 7. Composition rates for the right of way for cyclists and four-wheel vehicles

### About how fast were the four-wheel vehicles going?

Fig. 8 shows the composition rate of accidents by danger perception speed for the accidents targeted for this analysis.

Over 30km/h upto 40km/h occupied the highest composition rate at just below 30% of the total. With this as the peak, the data exhibits a distribution pattern whereby the composition rate falls off sharply for both low speeds and high speeds.

Despite the fact that bicycle accidents are accidents that occur on ordinary roads, the composition rate of the accidents targeted for this analysis involving collisions that occurred at over 60km/h came to more than 10%, indicates the high speed of some of the collisions.



Danger perception speed

### Fig. 8. Composition rate of accidents by danger perception speed

### Possibility of using AEBS to avoid accidents

In general, many of the crossing collision accidents involving cyclists and four-wheel vehicles are thought to occur at intersections where there is poor visibility. In such settings, cases in which the driver of the four-wheel vehicle applies the brakes after becoming aware of the cyclist but is unable to stop in time occur all-too frequently.

Therefore, clarifying the visibility conditions at intersections and the distance between cyclists when drivers become aware of them is important. So we conducted an analysis using the diagrams of the general road conditions from the micro data. In addition, we also attempted to predict the possibility of using AEBS to avoid accidents based on the numerical data obtained from this.

#### Analytical method –

Fig. 9 shows a schematic diagram of a hypothetical crossing collision accident involving a cyclist and a four-wheel vehicle at an intersection.

Based on the diagrams of general road conditions from the micro data, we estimated Px and Py, which are the positions of obstructions facing the collision point. Then, based on the four-wheel vehicle's speed of Vy and the cyclist's speed of Vj, we found the distance at which the driver could perceive the cyclist Ln and other data.

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## Fig. 9. Schematic diagram of a hypothetical crossing collision accident involving a cyclist and a four-wheel vehicle at an intersection

In intersections with poor visibility due to obstructions, the earliest point where the vehicle can be perceived of Y and the point where the cyclist can be perceived of J fall along a straight line with edge point P0 of obstruction P. Here, Px is taken as the distance between edge point P0 of obstruction P and collision point C in the direction of X, while Py is taken as the distance in direction Y. Moreover, when the intervening distance between C-Y is taken to be the distance the driver could become aware of the cyclist as Ln, then Ln can be found using the following equation.

$$\frac{Py}{Ln-Px} = \frac{Vj}{Vy} \dots (Equation 1)$$

- In the schematic diagram, all objects were regarded as points without giving consideration to factors like the size or shape of the four-wheel vehicle and bicycle, or the driver's position, with this including determinations of whether or not the collision could have been avoided.
- For vehicle speed Vy, the danger perception speed recorded in the micro data was used.
- For bicycle speed Vj, this was estimated in light of photos and road condition diagrams from the micro data surveys based on a road travel speed of 15km/h and a sidewalk travel speed of 12km/h from research by Akira Yamamoto, et. al.<sup>(1)</sup>
- For distances to obstructions Px and Py, we decided to read this directly from the diagrams of the general road conditions in the micro data. In addition, for distance PI between collision point C and edge point P0 of obstruction P, we calculated this by using the equation  $PI=\sqrt{Px^2 + Py^2}$ .
- The road condition diagrams from the micro data are not necessarily restricted to intersections where the roads intersect at right angles. But in order to simplify the model, the calculations were performed by considering all of these to be right-angle intersections.

As for the four-wheel vehicle's braking distance of Lb, here we envisioned the use of a bicycle detection and warning system or automatic braking system, assuming that such a system would be capable of sounding a warning or starting to brake in the instant that it detected a bicycle. Danger perception speed Vy, idle running time Ty, and deceleration a, were used to find Lb using the following equation.

$$Lb = (Vy \times Ty) + \frac{(Vy)^2}{2 \times a} \dots (Equation 2)$$

For deceleration a, in this paper we used the values 6.86m/s<sup>2</sup> (0.7G) for dry road surfaces and 4.90m/s<sup>2</sup> (0.5G) for wet road surfaces as representative values. This is from the 0.5 - 1.0G for dry and the 0.3 - 0.9G for wet asphalt road surfaces found by Onoda, et. al.<sup>(2)</sup>

Now, when Lb < Ln, it is considered that the four-wheel vehicle could stop before reaching the collision point and the collision could be avoided.

- (1) Akira Yamamoto, et. al.: Analysis on the difference in traveling speeds due to differences in the cycling space, etc., Edited lectures from the Committee of Infrastructure Planning and Management, Vol. 43, 2011
- (2) Mitsuyuki Onoda: Skid Resistance on Road Surfaces, ASPHALT, Vol. 46, No. 214, issued October 2003, p. 3 10

### Are there more accidents in intersections with poor visibility?

Fig. 10 shows the composition rate of accidents by straight distance (PI) between the collision point and the obstruction for the accidents targeted for the analysis in section 3.

Cases where this distance is over 5m and upto 10m make up the majority, and account for more than 30% of the total. In addition, cases where this is 5m or less account for 30% of the cases. When you combine these two, the results indicate that cases where the distance is 10m or less account for more than 60% of the total.

The percentage of accidents that occur when this is greater than 10m drops off precipitously. Generally speaking, the poorer the visibility of an intersection, the more likely crossing collision accidents are to occur there.

On the other hand, this also revealed that roughly 20% of the accidents occurred even in over 50m locations where there are not any obstructions and visibility is relatively good.



Straight distance between collision points and obstructions

# Fig. 10. Composition rate of accidents by straight distance (PI) between the collision point and the obstruction

### How many meters ahead can drivers of four-wheel vehicles detect cyclists?

Similarly, Fig. 11 shows the composition rate of accidents by distance the driver could perceive the cyclist (Ln) in the accidents targeted for the analysis in section 3.

Cases where this distance is over 10m and upto 20m make up the majority, and account for a little over 30% of the total. In addition, cases where this is 10m or less make up more than 20% of the total. When you combine these two, the results indicate that cases where the distance is 20m or less account for roughly 60% of the total.

In most cases where crossing collision accidents occur, there is not much distance remaining between the point where the driver of the four-wheel vehicle becomes aware of the cyclist and the collision point.

On the other hand, this also revealed that roughly 20% of the accidents occurred even in cases where the cyclist could be perceived from more than 100m and in the absence of obstructions blocking visibility.

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Fig. 11. Composition rate of accidents by distance the driver could perceive the cyclist (Ln)

### Are automatic brake (warning) systems effective against crossing collision accidents?

We used the accidents targeted for the analysis in section 3 to assess the possibility of avoiding collisions by assuming a situation in which a four-wheel vehicle is equipped with warning and automatic braking systems that use sensors such as cameras, radar, etc. This was assessed to see whether said systems could detect a cyclist the instant they emerged from behind an obstruction and sound a warning or automatically apply the brakes, thereby stopping the vehicle prior to reaching the collision point.

Fig. 12 shows the success rate for using systems to avoid collisions.

- Collision avoidance through warnings is defined as cases in which a system issues a warning the instant that it
  detects a bicycle, and where the driver was able to apply the brakes and stop before reaching the collision
  point with an idle running time Ty of one second.
- Collision avoidance through automatic brakes is defined as cases in which the brakes were applied automatically the instant that the system detected a bicycle (where idle running time Ty is taken to be zero seconds), and the vehicle was able to stop before reaching the collision point.

From this study, it was learned that collision avoidance results of over 50% can be expected from warnings, while this is greater than 80% for automatic brakes.



Fig. 12. Success rate for using systems to avoid collisions

# **6** Case examples of accidents

Lastly, we will introduce two specific case examples of accidents.

### Accident that could potentially have been avoided by adequately decelerating (Case example 1)

At around 8:00 AM on a clear day, Ms. A (30s, passenger car) was driving at roughly 30km/h on a road that she is accustomed to commuting to work. As she approached a T-shaped intersection with poor visibility to the left, she found the surrounding traffic situation to be light and so proceeded ahead without decelerating to any great extent. In doing so, she detected a bicycle ridden by Ms. B (teens), who suddenly rushed out from the left at a point about 8m ahead of her car. Ms. A braked suddenly, but not in time to avoid a collision.

This accident is primarily thought to have been caused by Ms. B failing to check to confirm the safety of the T-shaped intersection with poor visibility and rushing out into it without altering her speed. However, even though Ms. A was traveling on the road with right of way, when passing through this intersection with poor visibility she needed to respond by properly decelerating when passing through.

However, in this case, by how much would Ms. A have needed to decelerate in order to avoid a collision by braking suddenly thereafter?

Ms. A became aware of Ms. B at a point of 8m in front of the collision point.

Therefore, calculating the speed at which Ms. A could stop after becoming aware of Ms. B and before reaching the collision point by using (Equation 2) from the previous section shows that this would be approximately 20.4km/h (5.66m/s) (but this was calculated using an idle running time Ty prior to starting to brake of one second, deceleration a when braking on a dry road surface of 6.86m/s<sup>2</sup> (0.7G), and stopping distance Lb of 8m by regarding all objects as points without giving consideration to factors like the size or shape of the four-wheel vehicle and bicycle, or the driver's position).

Ms. A was traveling at 30km/h, but if she had reduced her speed to around 20km/h she could have avoided getting into the accident.

When passing through intersections with poor visibility like this one, it is important for drivers to constantly be aware that someone or something could suddenly rush out without indulging in the self-conceit that the traffic is light or that the driver has the right of way, and properly decelerate.



Fig. 13. Accident that could potentially have been avoided by adequately decelerating (Case example 1)

### Accident that could potentially have been avoided by adequately checking to confirm safety (Case example 2)

At around 6:00 AM on a slight rainy morning, Mr. A (60s, passenger car) was driving at a speed of about 45km/h on a road with one lane in one direction. Visibility was poor due to the rain, and he failed to notice a bicycle ridden by Ms. B (70s) holding up an umbrella from the right side of the intersection while his attention was focused on the left-hand side of the road. He noticed her right before the collision and braked suddenly, but not in time to avoid a collision.

To start with, this accident is mainly thought to have been caused by the fact that Ms. B failed to come to a stop despite having a stop sign. But Mr. A also needed to be looking straight ahead while he was driving, instead of solely focusing his attention to the left.

Incidentally, the visibility in Case example 2 was slightly better than it was in Case example 1.

Could the collision have been avoided if Mr. A had not been looking to the side?

Based on the diagram of the road conditions and the road structure, we would like to consider how many meters ahead of the collision point Mr. A could have become aware of Ms. B.

Going back in time with both Mr. A and Ms. B each moving at a certain speed backwards from collision point C, we hypothesized that the first time Mr. A could have become aware of Ms. B would have been when their positions were in a straight line with edge point P of the utility pole obstructing their views.

Calculating Ln using (Equation 1) from the previous section based on the diagram reveals that Mr. A could have become aware of Ms. B roughly 31.5m ahead of the collision point (but this was calculated by assuming that Mr. A's speed Vy was 12.5m/s (45km/h), Ms. B's speed Vj was 4.17m/s (15km/h), Px was 1.5m, and Py was 10m, and regarding all objects as points without giving consideration to factors like the size or shape of the four-wheel vehicle and bicycle, or the driver's position).

In addition, we found that Mr. A's stoppable distance at a speed of 45km/h would be approximately 28.4m when you apply Equation 2 from above to calculating it (but this assumes a running idle time Ty before the brakes are applied of one second and deceleration a from braking on a wet surface of 4.90m/s<sup>2</sup> (0.5G)).

Had Mr. A been driving by properly checking to confirm the safety of his surroundings, there is a good possibility that he would have been able to stop roughly 3m before the collision point after becoming aware of Ms. B, and the accident could probably have been avoided.

There are numerous cases like this in which accidents could be avoided by quickly becoming aware of one's surroundings, even in intersections with poor visibility like this one. We feel that it is important for drivers to constantly be paying attention to the surrounding traffic environment so that they have enough composure to be able to respond to changes in conditions.



Fig. 14. Accident that could potentially have been avoided by adequately checking to confirm safety (Case example 2)

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This study performed an analysis on crossing collision accidents involving cyclists and four-wheel vehicles by using macro data and micro data.

6) Conclusion

The micro data is characterized by the fact that it is from accidents in the limited region of the Tsukuba District of Ibaraki Prefecture, and it was collected with a somewhat slanted emphasis on serious accidents. As such, it does not necessarily correspond to national averages. But it was used for this study because it made it possible to get a grasp of the detailed conditions of each individual accident and allowed for a concrete examination of the possibility of avoiding collisions.

To mention a few of the emblematic findings from those brought to light through the results of this analysis, one thing it revealed is the fact that bicycle accidents involving young people in their teens are noticeably high. Moreover, it also showed that cases in which the cyclist had the right of way were low at only around 10%, and in many cases the fault lies with the cyclist. For example, in intersections with stop signs bicycles, which are a light vehicle, must come to a stop before the stop line. However, there are many junior and senior high school students (who do not possess licenses) who are unaware of this fact, which is presumably one of the reasons for why they are prone to suddenly rushing out into intersections. The number of people who commute to school by bicycle also rises among junior and senior high school students, and so for these people there is a need to reaffirm traffic rules and instill in them an awareness of danger and ways of traveling safely.

Conversely, there are presumably cases in which pedestrians or cyclists suddenly rush out from unexpected places and cause an accident because the driver was under the impression that their own lane had the right of way, and the other person should be the one to stop.

Drivers are obliged to drive while giving forethought to vulnerable road users like pedestrians and cyclists.

This is something that should be kept firmly in mind. Even when one's own lane has the right of way, when drivers pass through intersections, especially those with poor visibility, they must properly check to confirm that it is safe and slow down. They must also constantly strive to drive in a manner that gives them enough composure to respond when someone or something suddenly rushes out in front of them.

This study confirmed the great effectiveness of automatic brakes when it comes to crossing collisions involving cyclists. The majority of the automatic braking systems currently on the market are designed to prevent rear-end collisions with four-wheel vehicles up ahead. But the hope is that systems that are effective for cyclists will also begin to be equipped on vehicles in the near future.

(Akio Takahashi)

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