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Study of the Field of View (FOV) of AEB for Pedestrian When the Vehicle Turns Right
~ Targeting Pedestrians While Crossing the Road on the Crosswalk ~

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1. Background

Pedestrians were the highest number of fatalities and serious injuries in traffic accidents according to the circumstances at the time of the accident in 2020. When we focus on pedestrians' crossing places, the number of pedestrians during crossing the road on the crosswalk is the highest, and vehicles turning right recorded the highest number as vehicle action in such situations.

In Chapter 2, we analyzed the features of pedestrians' traffic accidents of fatalities and serious injuries during crossing the crosswalk caused by vehicles turning right from the perspective of traffic accident macro data (hereinafter referred to as "macro data") and studied their countermeasures. In Chapters 3 and 4, we materialized the countermeasures by using the results of the investigation into actual traffic accident examples that occurred in Ibaraki Prefecture (hereinafter referred to as "micro data").

2. Features of the accidents of pedestrians while crossing the crosswalk caused by vehicles turning right and the policy of countermeasures

To grasp the features of fatal and serious injury accidents of pedestrians who cross the crosswalk caused by vehicles turning right, we compared such accidents with general trend of pedestrian-vehicle accidents with regard to danger perception speed, driver human factors, and age groups of pedestrians. The macro data in this chapter were totalized as a total of primary parties and secondary parties for four-wheeled vehicles turning right with the road configuration being intersections.

2-1. Danger perception speed

As the danger perception speed in fatal and serious injury accidents, 30 km/h or less accounted for 98.2% in accidents of pedestrians who cross the crosswalk caused by vehicle turning right, while it accounted for 65.9% in the entire pedestrian-vehicle accidents. (Fig.1 Red-framed part) Therefore, it is understood that for vehicles turning right, countermeasures for the speed of 30 km/h or less is extremely effective against fatal and serious injury accidents of pedestrians.

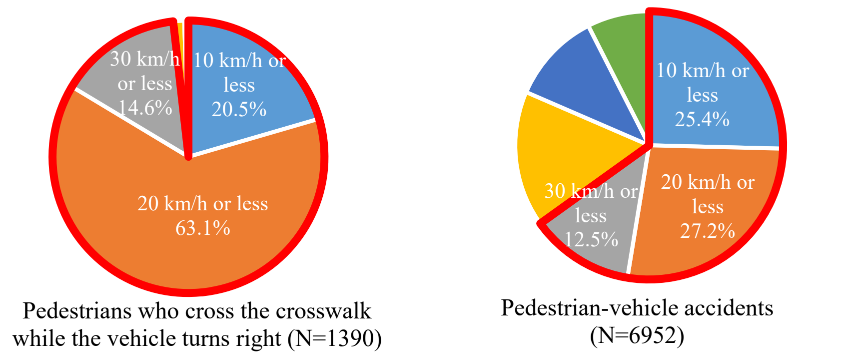


Fig.1 Ratio of the number of fatalities and seriously injured persons according to danger perception speed of drivers in each type of accident (2020)

2-2. Driver human factors

According to the ratio of human factors in accidents of pedestrians who cross the crosswalk caused by vehicle turning right, "delay in noticing", which is a sum of failure to confirm safety factors and failure to pay attention forward, accounts for 97.5%, larger than 90.0% as the ratio for the entire pedestrian-vehicle accidents. (Fig.2 Red-framed part) This shows that the ratio of accidents that could have been prevented if the driver had found the pedestrians is larger. Particularly, the ratio of failure to confirm safety accounts for 81.9% and 56.6% respectively, which means the ratio in accidents caused by vehicle turning right is larger than that of the entire pedestrian-vehicle accidents. (Fig.2 Blue part) This suggests that there are many cases where the driver had an intention of confirming safety when turning right at the intersection but the confirmation was insufficient, resulting in accidents.

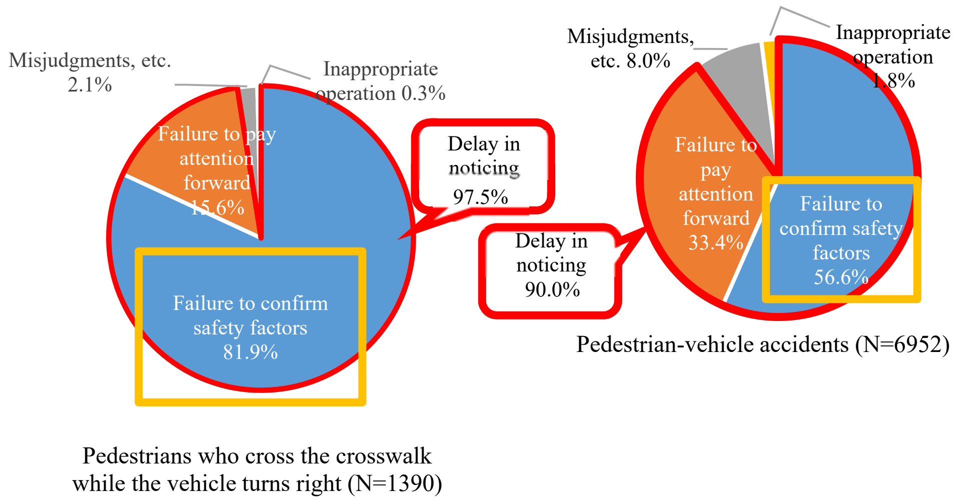


Fig.2 Ratio of the number of fatalities and seriously injured persons according to human factors of drivers in each type of accident (2020)

2-3. Age groups of pedestrians

When we focus on age group next, the ratio of persons aged 65 years old or older accounts for 63.2% in accidents of pedestrians who cross the crosswalk caused by vehicle turning right, which is higher than 60.1% as the ratio of the entire pedestrian-vehicle accidents. As indicated in 2-1, accidents caused by vehicle turning right occurred relatively at a low speed range of 30 km/h or less. Therefore, it can be considered that the ratio of persons aged 65 years old or older becomes high because their impact resistance is generally low.

2-4. Policy of countermeasures

Based on the three features mentioned above, as the policy of countermeasures, we consider the following cases effective: [1] a vehicle turning right at 30 km/h or less at the intersection [2] detects that a pedestrian is on the crosswalk (i.e., prevents oversight) and [3] stops to prevent it contacting with the pedestrian.

We will advance this study by focusing on the prevention of accidents caused by vehicle turning right at intersections by the Autonomous Emergency Braking System (AEB) for pedestrians, which is considered to meet such requirements.

3. Study of the the field of view (FOV) of AEB using micro data

3-1. Development of study items

In this section, using micro data, we aim to specify the FOV required for the operation of AEB in accidents caused by vehicle turning right. Also, after Chapter 4, we define the travelling directions of crossing pedestrians as the same direction (when the direction of a vehicle turning right is same as the crossing direction of pedestrian) and the opposite direction (when the direction of a vehicle turning right is opposite to the crossing direction of pedestrian), and study the cases by classifying them into two categories.

3-2. Specify the FOV using micro data

(1) Preconditions for accident reconstruction

In this study, we assume that a vehicle equipped with AEB for pedestrians is running at intersection and there is no oncoming vehicle. Also, we reconstructed accidents using micro data under the following conditions.

Table 1 Preconditions for accident reconstruction

<table>
<tr><td rowspan="2">Speed of pedestrians</td><td>Under 65 years old</td><td>65 years old or older</td><td>Jogging</td></tr>
<tr><td>5 km/h(1.39 m/s)</td><td>3.5 km/h(0.97 m/s)</td><td>6 km/h(1.68 m/s)</td></tr>
<tr><td>Vehicle speed</td><td colspan="3">Assume that a vehicle runs at danger perception speed at intersection</td></tr>
<tr><td>Others</td><td colspan="3">・Casualty accidents that occurred from 2009 to 2020 are targeted (opposite direction: 7 cases, the same direction: 13 cases)
・The position of starting turning right is identified from the travel track of vehicle and defined as the point for entering the intersection.
・There are no other crossing people and obstacles which can become noise during detection.
・Even if FOV becomes large, the performance of AEB sensor does not change.</td></tr>
</table>

Casualty accidents are used as accident data to secure a certain number of data. Also, the extracted data include T-junction and five-street intersection and cover various intersections from the perspective of the number of lanes.

(2) Method of specifying FOV

The procedure for specifying FOV using micro data is as follows and the example is shown in Fig.3.

[1] Specify the collision site, estimate vehicle travel track and pedestrians travel track, and create their models. In such case, define the coordinate system by setting the travelling direction of pedestrian as X axis and the collision site as X = 0.

[2] Calculate the sum of the AEB's detection reaction time and braking time at danger perception speed as the total braking time, and identify the position of vehicle and pedestrian respectively backward the total braking time from the collision site. In such case, we assume that AEB’s detection reaction time is 1.0 second with the braking condition increasing to the maximum deceleration of 0.65G in 1.7 seconds and maintaining 0.65G afterwards.

[3] Specify the FOV by which sensor can detect pedestrians. In such case, we assume that the AEB sensor is installed at the center of the front end and the detection range is 1 m forward or backward of the pedestrian by considering steps of pedestrian. Two examples in which vehicles did not start turning right at the timing

specified in [2] were excluded from the study.

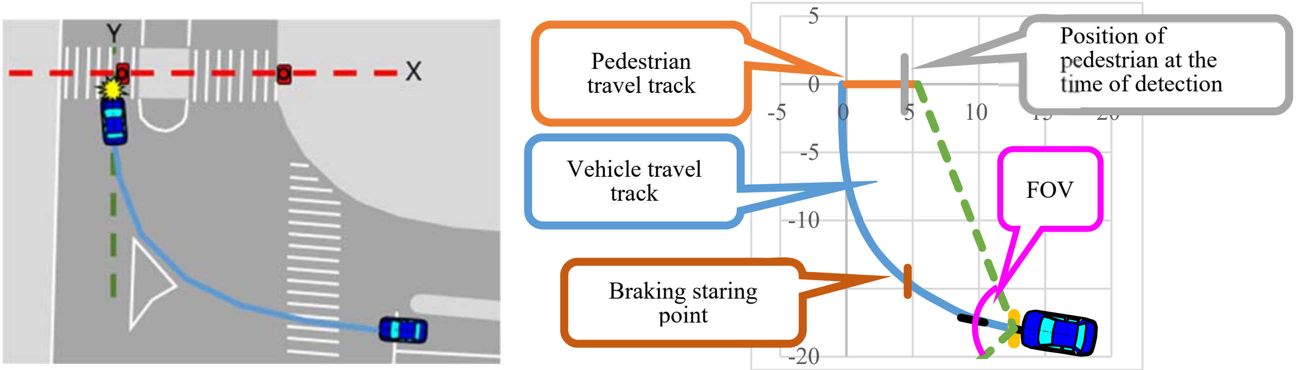


Fig.3 Accident example and schematic drawing that specified FOV

4. Study results and consideration

4-1. FOV at each travelling direction of pedestrians

The FOV varies according to travelling direction of pedestrians. As a result, a collision can be avoided when the FOV is from 40° at the minimum to 70°at the maximum in the case of opposite direction and when the FOV is from 60°at the minimum to 120°at the maximum in the case of the same direction. (Fig.4).

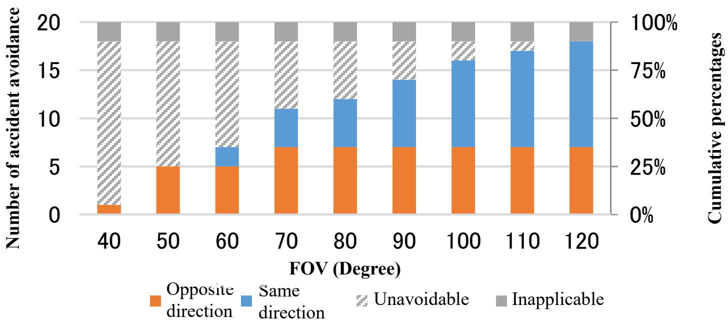


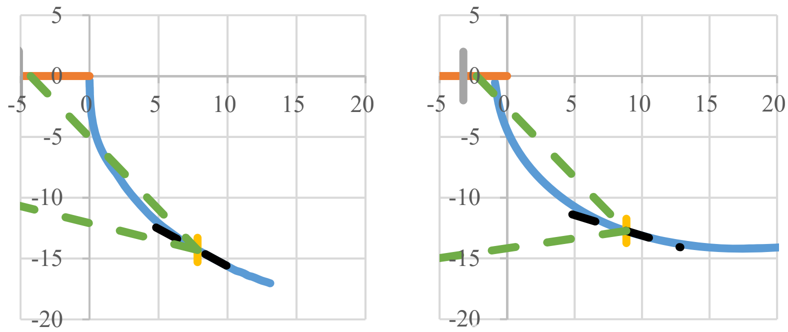
Fig.4 The number of accident avoidance and cumulative percentages of FOV (by travelling direction of pedestrians)

4-2. Study of the difference of FOV

We used the examples where the FOV became the maximum and the minimum according to travelling direction of pedestrians and studied the factors for difference between them.

(1) Examples for pedestrians crossing in the opposite direction

In the cases of pedestrians crossing in the opposite direction, examples that the FOV is the minimum (40°) and the maximum (70°) are shown in Fig.5. The difference between the minimum FOV and the maximum FOV resulted from a difference of the number of lanes of the roads where the vehicle was running before turning right. Whereas the number of opposite traffic lanes before the vehicle turned right was two in the example of the minimum FOV, the number was one in the example of the maximum FOV. Therefore, it can be considered that, in the example that the FOV became the maximum, because the radius of rotation at the time of turning right becomes small, the direction of the vehicle at the time of detection (tangential direction) was not directed toward crosswalk, which made the FOV large.

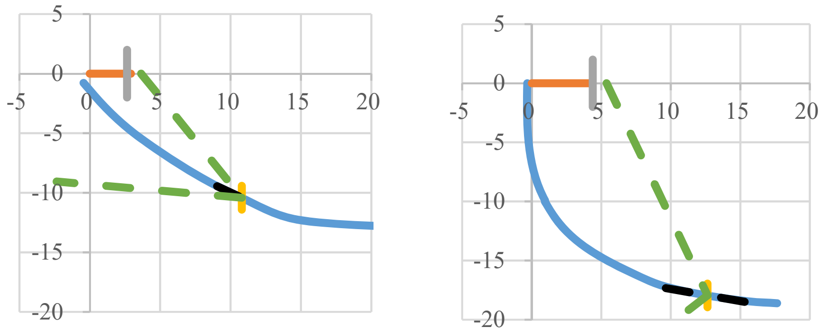


A. Example of FOV 40°   B. Example of FOV 70°

Fig.5 Example of the minimum and maximum FOV when the pedestrian is crossing in the opposite direction

(2) Examples of pedestrians crossing in the same direction

In the cases of pedestrians crossing in the same direction, examples that the FOV is the minimum (60°) and the maximum (120°) are shown in Fig.6. The main factor for the difference between the minimum FOV and the maximum FOV is vehicle speed. The danger perception speed was 20 km/h in the example of the minimum FOV and 30 km/h in the example of the maximum FOV. If the speed is faster, the position where detection is required becomes farther from the collision site due to the relation with braking time. Therefore, the direction of the vehicle at the time of detection (tangential direction) is not directed toward crosswalk, which made the FOV large. Also, using the example C where the FOV became the minimum, we investigated a case where the vehicle speed is increased to 30 km/h.



C. Example of FOV 60°   D.Example of FOV 60°

Fig.6 Example of the minimum and maximum FOV when the pedestrian is crossing in the same direction

The results show that with an increase in speed, the FOV became 70°. Therefore, it can be considered that if the vehicle speed is increased, the FOV also increases.

4-3. When the vehicle speed is assumed at 30 km/h uniformly for all examples

The macro data show that accidents in which the vehicle speed was 30 km/h or less accounts for 98% and the FOV becomes large if the vehicle speed becomes faster. Therefore, we studied the condition where the vehicle speed is assumed at 30 km/h in all examples. In such condition, 19 of 20 cases can be covered with the FOV 120° (Fig.7). Also, the circled example was one of the examples excluded from the study in 3-2 (2). The reason why the relevant example was excluded from the study is that the vehicle did not start turning right at the timing of detection because it was running at 40 km/h. However, when the vehicle speed is decreased to 30 km/h, the detecting position changes to a position after the vehicle turns right.

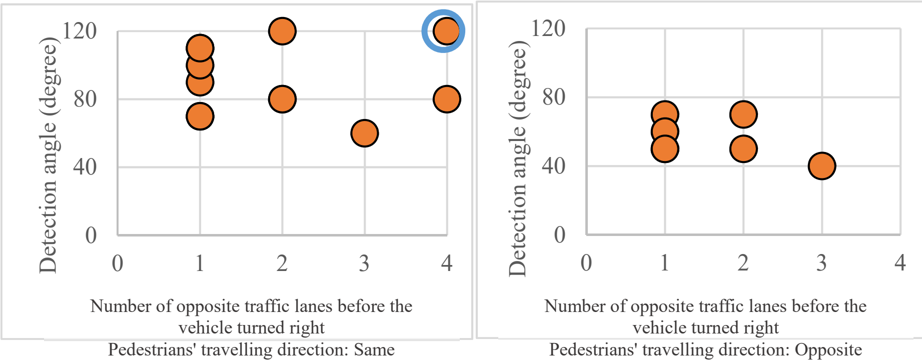


Fig.7 Relation of the number of opposite traffic lanes before vehicles turn right and FOV when the vehicle speed is set uniformly at 30 km/h

5. Summary

5-1. Obtained knowledge

(1) Based on macro data, we analyzed the features of traffic accidents of pedestrians while crossing crosswalk caused by vehicles turning right, which resulted in many numbers of fatalities and seriously injured persons. The results of the analysis show that [1] 98% of the accidents occurred when the danger perception speed was 30 km/h or less, [2] 98% of human factors were delay in noticing and particularly the failure to confirm safety factors (although the driver had intention of confirming safety factors but the confirmation was insufficient) accounted for 82%, [3] 65 years or older accounted for the largest ratio of 63% among pedestrians surveyed.

(2) Based on the results in (1), we studied accident avoidance by AEB for pedestrians and specified the FOV according to travelling direction of pedestrians using actual examples based on micro data. Micro data in 19 of 20 cases can be covered with the FOV 120°of a sensor that corresponds to pedestrians.

5-2. Future main tasks

(1) To prevent malfunction of AEB for pedestrians, develop AEB that does not operate when the vehicle is going straight through coordination with car navigation systems and obtaining information by road-vehicle communication for the purpose of predicting the course for turning right from the point when the vehicle starts turning right

(2) Create algorithm that can corresponds to conditions where there are two or more crossing pedestrians

(3) Enhance the performance of sensors for securing accuracy required even if the FOV is widened.