Evaluation of the Driver Visibility Affecting the Occurrence of Crossing Accidents

Nomura, Takumi
Department of Automotive Science, Graduate School of Integrated Frontier Sciences, Kyushu University

Hirota, Masaki
Department of Automotive Science, Graduate School of Integrated Frontier Sciences, Kyushu University

Sato, Junya
Department of Automotive Science, Graduate School of Integrated Frontier Sciences, Kyushu University

https://hdl.handle.net/2324/4369963

出版情報：Journal cover International Journal of Intelligent Transportation Systems Research, pp.1-, 2021-02-17. Springer Nature
バージョン：

Evaluation of the Driver Visibility Affecting the Occurrence of Crossing Accidents

Takumi Nomura, Masaki Hirota & Junya Sato
Department of Automotive Science, Graduate School of Integrated Frontier Sciences,
Kyushu University
*(744 Motoka Nishi-ku Fukuoka Japan,
hirota.masaki.972@kyushu-u.ac.jp)*

Abstract This research aims to clarify the influence of driver visibility on crossing accidents. We investigated 1,101 accidents occurring at 621 intersections in the Hakata-ku Ward, Fukuoka City, from 2015 to 2017. We calculated the yearly accident rate at each intersection based on the accident data and evaluated driver visibility with surveyed intersection information. It was found that the accident rate was high when visibility was poor regardless of the number of lanes on the secondary road at locations where many accidents occurred, and the accident rate was high when the number of lanes on the secondary road was low throughout Hakata Ward.

Keywords *accident, crossing, environmental factors, visibility*

1 Introduction

The number of traffic fatalities decreased to 3,694 in 2017. However, the rate of decrease has slowed, and new accident measures are needed. When the breakdown of traffic accidents (approximately forty-six million cases) is examined, crossing accidents were the second most common type, accounting for 24.5% of all traffic accidents. Considering the rate of fatal accidents, crossing accidents accounted for 13.5% of all accidents and were the third leading cause fatal accidents.[1, 2].

It is expected that the number of rear-end collisions will decrease in the future due to the widespread use of driving support systems in recent years. In contrast, a crossing accident is "an accident in which the vehicles collided from different directions at the intersections"[3]. Non-intersection collision differ from crossing accidents because they are classified as accidents other than those occurring at intersections. Crossing accidents cannot be prevented without controlling the driving direction of the host vehicle. Existing driver assistance systems primarily control inter-vehicle distance and driving lanes. Therefore, it is difficult to prevent a crossing accident with the current driving direction support system. New measures are necessary. There are several reports on environmental factors and human factors related to crossing accidents. For example, studies have examined driving behavior[4] for the purpose of preventing traffic accidents and the relation between view restriction according to curved mirrors at intersections and the occurrence of crossing accidents[5, 6] . However, few studies have analyzed intersection shapes and actual accident data.

The number of traffic accidents in Fukuoka Prefecture in 2017 was 34,862, the third highest number in Japan. In Fukuoka Prefecture, the Hakata-ku Ward has 1.5 times more crossing accidents than Fukuoka's second largest ward, Chuo-ku[7, 8]. Therefore, we focused on crossing accidents in the Hakata-ku Ward.

We suggest that environmental factors such as poor visibility and human factors such as careless driving are mutually related in causing accidents. However, studies have not sufficiently analyzed whether environmental factors affect crossing accidents. Therefore, we investigated the occurrence of these accidents based on accident data for crossing accidents that occurred in Fukuoka City from 2015 to 2017 that we received from the Fukuoka prefectural police. The accident rate at crossroads is twice as much as that for T-shaped roads[9] .

In this paper, we calculate the probability of crossing accident occurrence by visibility based on the accident data and the structural elements of intersections. Then, we investigate the relation between visibility and the accident rate. In addition, we analyze the change in the accident party by visibility.

2. Analysis Methods

2-1. Investigation procedure of intersection structure

We investigated 1,629 intersections in the Hakata-ku Ward using Google Maps (Fig. 1). This is not all intersections in the Hakata-ku Ward; there are 3,521 intersections throughout this ward. We include four intersections that are in contact with the intersection where an accident occurred. If there are intersections where an accident has occurred in those four places, we also include the four intersections that are in contact with these intersections (Fig. 2). Category A in Fig. 2 shows the intersections where the accidents occurred. Category B shows the intersections where there were no accidents but the intersections are in contact with A. Category C shows intersections where no accidents occurred and where there is no contact with category A. As a result, even if the traffic volume was not identified, the traffic volume could be considered to some extent to compare the area around the accident occurrence. The reason is that encounter accidents occur frequently at small intersections, and traffic information on narrow streets cannot be obtained. Among the intersections, crossing accidents occurred at 621 intersections, and crossing accidents did not occur at 1,008 intersections[10]. We surveyed the four intersections associated with intersections where crossing accidents occurred. The presence or absence of telephone poles and traffic regulations were confirmed on the images using the street view of Google Maps.

To investigate the intersection environment, we identified the traveling direction and position of the vehicle. In addition, we investigated traffic lights, distance from the intersection to buildings, curved mirrors, road width, and sidewalk width (Fig. 3). Regarding the priority of roads, priority roads are those that satisfy the following conditions: roads without a stop sign, roads with more lanes, and wider roads. If all the roads attached to the intersection met the first conditions, the road that met the second and third conditions was the priority road. Additionally, the priority roads were determined with reference to the Road Traffic Act.

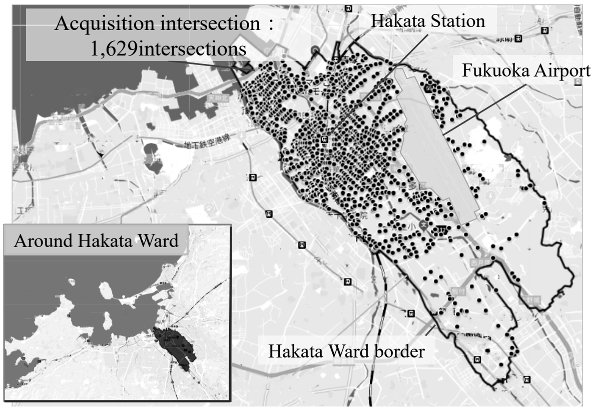
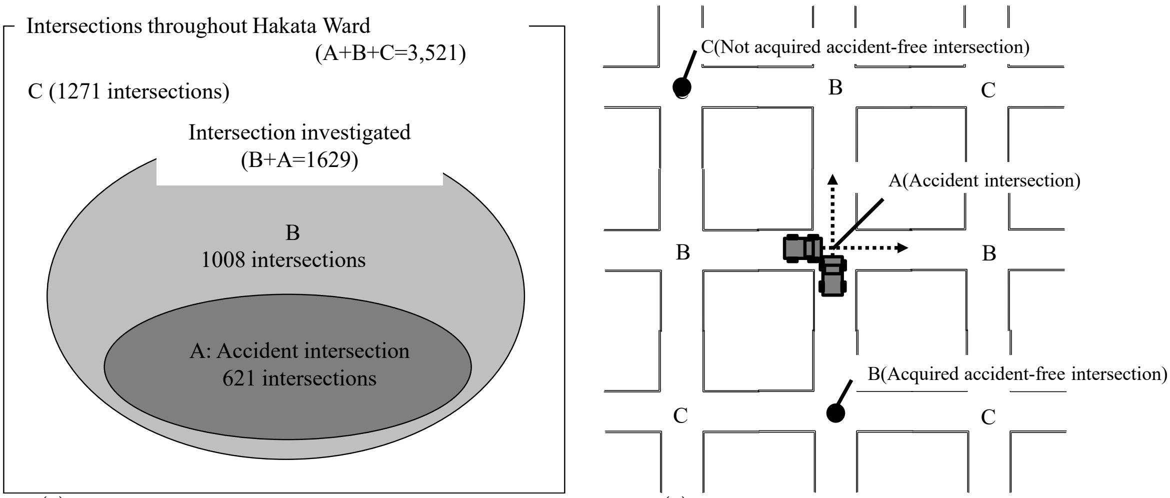
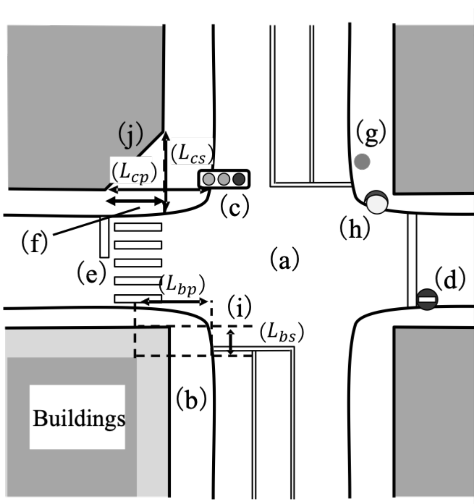


Fig. 1 Intersections in Fukuoka City, Hakata Ward surveyed



(a) Intersection situation in the Hakata-ku ward (b) Intersection acquisition schematic diagram

Fig. 2 Investigation method of intersection structure



	Middle class	Small class
Classification of road structure	Intersection shape (a)	Crossroads, T-shape roads
	Number of lanes	
	Road width	
	Sidewalk width (b)	
	Crossing angle	
	Traffic lights (c)	Nothing, Periodic formula, Semi-sensitive, Single-flash type Push button type
	Traffic regulation (d)	Regulatory direction
	Pause display (e)	With or without
	Stop line position (f)	Distance to intersection border
	Telephone pole (g)	With or without
	Curve-mirror (h)	With or without
	Building location (i)	Height, Road-building distance
	Corner width (j)	With or without(L_{cp}, L_{cs})

Fig. 3. Constituent elements of the intersection

2-2. Method of visibility evaluation

The number of crossroads is approximately the same as the number of T-shaped roads in the Fukuoka and Hakata-ku wards. Intersections without traffic regulations represent 71% of all intersections. Secondary roads with one or two lanes constitute approximately 80% of all intersections in the Hakata-ku Ward (Table 1). Additionally, 76% of Hakata-ku Ward intersections are without traffic lights (Fig. 4) [11]. Therefore, intersections in the Hakata-ku Ward have large and small intersections without traffic lights. The sidewalk width is narrow, and a building is adjacent to the intersection, which blocks the driver's view. Therefore, there are many intersections with poor visibility, and it is likely that visibility is related to crossing accidents.

Fig. 5 shows diagrams for evaluating the left visibility from the secondary road. Here, A [m] represents the sidewalk width on the priority road. B [m] is the sidewalk width on the secondary road. C [m] is the secondary road width, and D [m] is the distance from the sidewalk width on the priority road boundary to the driver point. As shown in Fig. 4, the triangles created by A, B, C and D are right triangles. A, B, C, and D are assumed to be the same as the intersections in the Hakata Ward that were actually investigated. The line-of-sight angle conditions of the left and right can be visually recognized without difficulty, including swing of 45 degree[12]. Both sides are 45 degrees; therefore, the one-side angle is 22.5 degrees. In addition, it is 7-10 m before the intersection, so the entire exit width of the intersection does not fit within the driver's stable viewing angle (22.5 degrees on one side) [12]. There is another reason for defining 10[m] that is related to the stopping distance of a car. A car needs approximately 9 m to stop while driving at 20 km/h. When entering the intersection, the speed will be slightly reduced to approximately 20 km/h. Therefore, this was set to 10[m]. In this paper, the building is also high enough to be evaluated safely. Therefore, the visibility evaluation judges whether a 22.5 degree viewing angle can be seen at 10[m] in front of the intersection boundary. In this case, the height of the building is sufficiently high. Assume that the angle between the driver's point and the edge of the building is 22.5 degrees, and vehicles traveling on the secondary road travel in the middle of the lane. In this triangle, we use the sine theorem to calculate the value of D. We account for the calculation below.

$$\mathrm{D} = \frac{\sin(90° - 22.5°)}{\sin 22.5°} \times \left(B + \frac{C}{2}\right) \tag{1}$$

Next, X [m] is the distance from the intersection boundary to the driver point. The equation for X is shown below.

$$\mathrm{X} = \mathrm{A} + \mathrm{D} \tag{2}$$

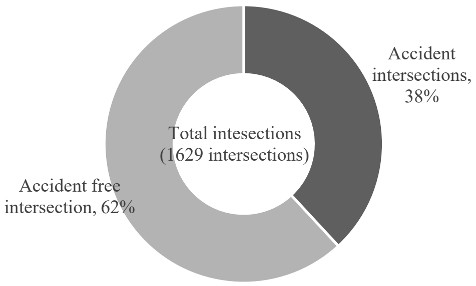
The conditions of the visibility evaluation are shown below.

$$10 \geq \mathrm{X}: \text{Poor visibility} \tag{3}$$
$$10 \leq \mathrm{X}: \text{Good visibility} \tag{4}$$

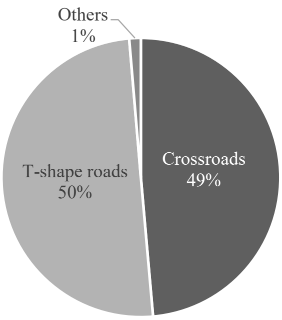
Furthermore, the road width C changes according to the number of lanes on the secondary road, and the position where the driver travels changes in the visibility evaluation (Fig. 6). The vehicle is calculated as running in the middle of the lane.

Table 1 Number of lanes at the intersections surveyed

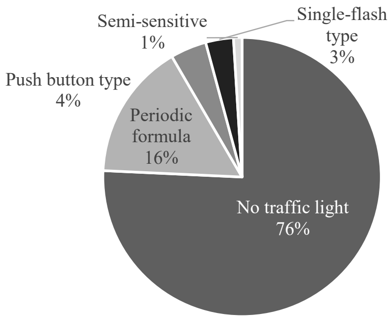
Number of lanes on secondary road	Number of lanes on priority road: 1	2	3	4	5	6	7	8	9
1	**552**	**363**	40	**183**	39	21	7	5	0
2	28	**210**	25	39	25	24	5	3	1
3	0	1	5	5	6	0	2	1	1
4	0	0	0	5	5	2	2	1	0
5	0	0	0	1	12	5	2	2	1
6	0	0	0	0	0	2	0	1	0
7	0	0	0	0	0	0	0	0	1
8	0	0	0	0	0	0	0	1	0



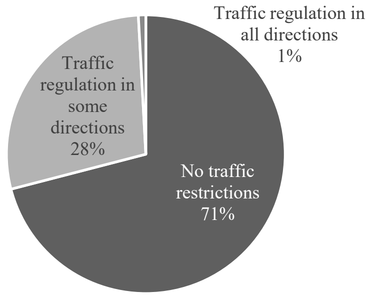
(a) Ratio of accident intersections



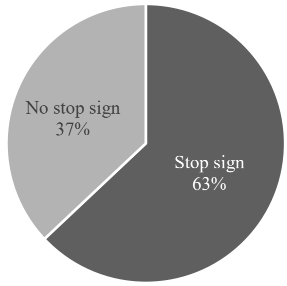
(b) Intersection shape



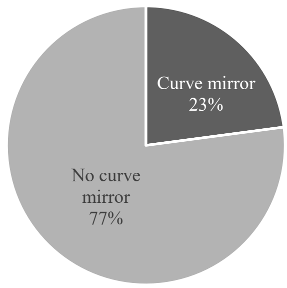
(c) Traffic light type



(d) Traffic regulation



(e) Temporary stop sign



(f) Curve-mirror

Fig. 4. Intersections in the Fukuoka City Hakata-ku Ward surveyed

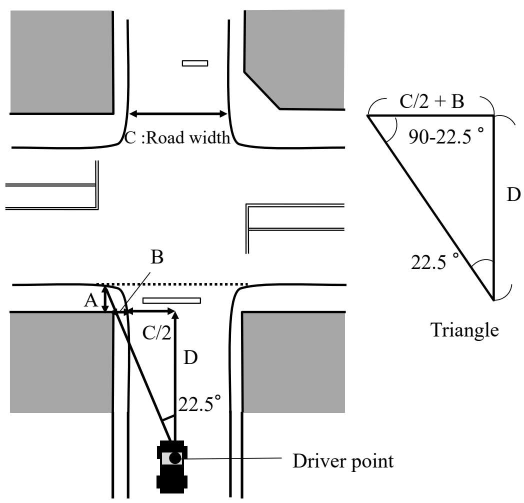


Fig. 5 Visibility evaluation model on the left

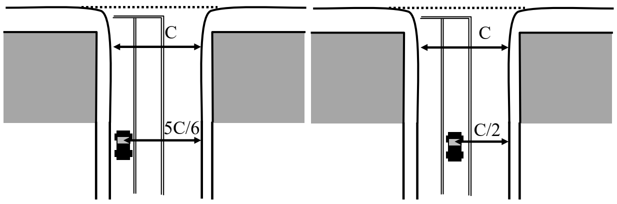


Fig. 6 Visibility evaluation model on another lane

2-3. Evaluation by crossing accident parties

According to the parties, an analysis was conducted using accident statistics data[11] (Table 2) provided by the Fukuoka prefectural police for 1,629 intersections [13]. In the intersections surveyed, intersection accidents occurred more than once at the 621 intersections. There are 53 intersections with four or more accidents at each intersection. Therefore, some intersection accidents occur frequently in the Hakata-ku Ward. These are called frequent accident intersections. Accidents occur between cars, including motorcycles, at crossroad intersections. This differs from the accident factors received from the police. Most of the causes of accidents received from the police involve unconfirmed safety. There are few accidents caused by poor visibility. However, we believe there is a correlation between unconfirmed safety and poor visibility. This is because environmental factors that involve poor visibility may cause human factors with uncertain safety.

Table 2 Statistical accident data

Basic information	Accident content
	Number of casualties
Occurrence time	Date, time, day of the week
Occurrence position	Occurrence address
Other information	Road shape
	Accident related car model
	Age
	Agenda
	Risk recognition speed
	Violation of laws
	Human factor
	Environmental factor
	Influence of parking vehicle

Fig. 7 An example of a frequent accident intersection

3. Analysis Results

3-1. Definition of accident rate

Regarding accident analysis, in addition to the total number of accidents that occurred at intersections, it is possible to compare the likelihood of crossing accidents at each intersection element by the frequency of accidents per intersection. In general, the accident rate is defined as the ratio between the number of accidents that occurred in a given year and the number of traffic volumes during that same year. However, in this paper, traffic volume is not used for calculation. As explained in Section 2, we determined the intersections to be acquired to consider traffic to calculate the number of accidents that occurred in one year per intersection from the accident number at the intersection environment and each intersection of investigation in the Hakata-ku Ward. R_{ij} is the accident rate.

$$R_{ij} = \frac{X_{ij}}{3N_{ij}} \quad (i = 0,1,2, \quad j = 0,3 \ldots 22) \qquad (5)$$

X_{ij} is the number of accidents that occurred at the intersection with elements i and j, respectively. N_{ij} are the number of accidents and the number of intersections that occurred at the intersection having elements of i and j, respectively. Here, i and j refer to Table 3 below. For example, i represents all intersections (i = 0), crossroads (i = 1), and three-way junctions (i = 2), and j is an element constituting the intersections (i = 0, 1, 2). Therefore, j = 3 represents the accident rate at intersections without traffic lights. In this way, the intersection element to be evaluated can be selected by changing the value of j. In the calculation below, we pay attention to the intersections of the entire Hakata Ward (therefore, i = j = 0).

$$R_{00} = \frac{x_{00}}{3N_{00}} = \frac{1101}{3 \times 1629} = 0.23 \qquad (6)$$

Because X_{ij} represents the number of accidents for three years, it is necessary to divide by three as in the above formula. Therefore, the total accident rate in the Hakata-ku Ward is 0.23. If there are 2,300 intersections in the Chuo-ku Ward, the total number of accidents from 2015 to 2017 is 842.

$$R_{00} = \frac{x_{00}}{3N_{00}} = \frac{842}{3 \times 2300} = 0.12 \quad (7)$$

Therefore, it can be determined that an intersection showing an accident rate larger than 0.23 seems to be dangerous.

Table 3 Intersection element number (i, j allocation table)

Large classification		**Planar element**		**Traffic flow control element**												**Vision restriction element**							
Middle classification		Intersection shape		Traffic light type					Traffic regulation			Stop sign			Stop line retreat			Telephone pole		Curved mirror		Corner-cutting of building	
					Exist																		
Intersection element	All intersections	Crossroads	T-shape roads	Nothing	Periodic formula	Push-button	Single-flash type	Semi-sensitive	Nothing	Partial direction regulation	Omni-directional regulation	Nothing	Exist	Exist•Periodic formula	Nothing	Exist in Some secondary road	Exists on all secondary road	Nothing	Exist	Nothing	Exist	Nothing	Exist
i	0	1	2																				
j	0			3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22

3-2. Results of visibility evaluation

Figs. 8 to 13 show the results of the perspective evaluation for 1,629 target intersections.

Fig. 8 is a visibility evaluation of the intersection. There were 62% of intersections with poor visibility on both sides. In addition, 9% of intersections had poor visibility on the left and good visibility on the right, while 19% of intersections had poor visibility on the right and good visibility on the left. Only 10% of the intersections had good visibility. It was found that there are many intersections with poor visibility in the Hakata-ku Ward. Additionally, when looking at only one side, there are many intersections where the right side is worse than the left side.

Fig. 9 shows the results of the visibility assessment of the crossing accidents that occurred in the Hakata-ku Ward. It was found that a crossing accident is likely to occur if visibility is poor. Compared to Fig. 8, the number of intersections and the number of accidents were almost equal. Therefore, because there are a large number of intersections with poor visibility, crossing accidents with frequent occurrences are evaluated in the entire Hakata-ku ward.

Fig. 10 and Fig. 11 show the evaluation of Fig. 8 according to the intersection shape. The total number in Fig. 10 and Fig. 11 is the same as in Fig. 8 and Fig. 9. As shown in Fig. 10, an accident occurred in 74% of cases in which the visibility on the left was poor at the crossroads. However, if one side had good visibility, the accident rate was less than half. Visibility affected the accidents on T-shaped roads. As shown in Fig. 11, 70% of the accidents that occurred in the case of the left and right were due to poor visibility. The results show that T-shaped roads have a greater influence than crossroads.

Table 4 shows the evaluation by lane. The accident rate is the highest on a five-lane road, but it cannot be judged dangerous because there is only one five-lane intersection with poor visibility. In contrast, when comparing the number of lanes separately, the accident rate at two-lane T-shaped roads is found to be much higher. This is not a small number of intersections, as shown in Table 4.

Fig. 12 is an actual photograph of the accident-prone point. This is a T-junction intersection. The main roadside is 3 lanes, and the secondary roadside is 1 lane. As shown in the photo, this is an intersection with a poor view from the secondary road. There is a large amount of traffic on the main roadside. There are also pedestrian crossings, and the presence of bicycles is not very visible. Therefore, this is an example of a very dangerous intersection.

Fig. 13 shows a three-lane T-shaped road intersection with a high accident rate. The secondary roadside is very narrow, and the main road is wide. Additionally, when traveling from the secondary roadside to the main roadside, there is no traffic light. If one side has poor visibility, the driver must make many decisions at once. Therefore, the accident rate is considered to be high.

Fig. 13 presents a comparison of the accident parties divided into car × car accidents and car × bicycle accidents. We find that car x car accidents are likely to occur at well-defined crossroads, while car × bicycle accidents are more likely to occur at poor visibility intersections. Because bicycles are small and difficult to see compared to cars, the number of bicycle accidents is considered to be higher than car × car accidents. The reason the accident rate varies considerably in Table 4 and Fig. 13 is considered to be due to the number of lanes. A small number of lanes means less traffic and fewer accidents, but there are many intersections with narrow roads and poor visibility, which means that accidents are likely to occur. Additionally, the large number of lanes seems to provide a wide area, but this is not the only factor in the intersection. If the side of the secondary road is one lane and there are buildings around it, a driver who is driving on the secondary road not only encounters a large amount of traffic but also cannot go out to the main road and cannot drive further due to poor visibility. Therefore, it seems that the difference between these two graphs is influenced by the number of lanes.

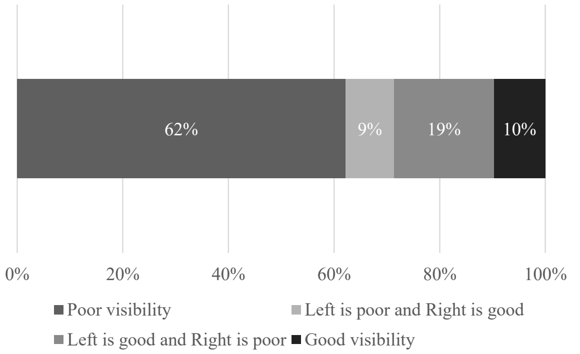


Fig. 8 Intersections by visibility evaluation (all intersections)

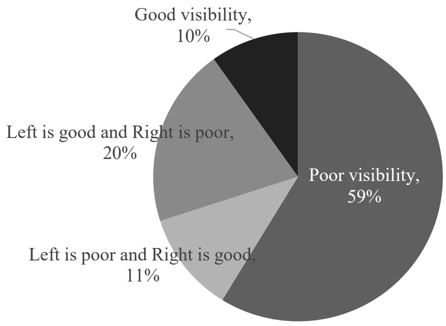


Fig. 9 Accidents by visibility evaluation (all intersections)

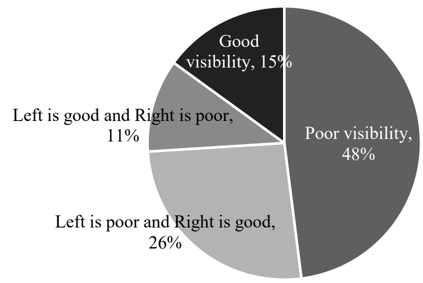


Fig. 10 Visibility evaluation at crossroads

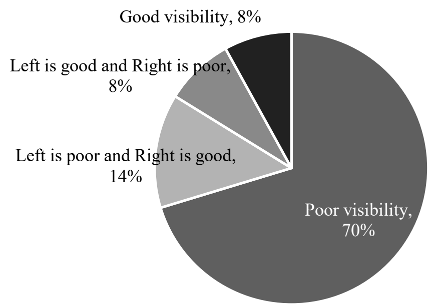


Fig. 11 Visibility evaluation on T-shaped roads

Table 4 Perspective evaluation by intersection shape and individual lanes

		1-lane		2-lane		3-lane		4-lane		5-lane		6-lane		7-lane		Total	
		Crossroads	T-shape roads	Crossroads	T-shape roads	Crossroads	T-shape roads	Crossroads	T-shape roads	Crossroads	T-shape roads	Crossroads	T-shape roads	Crossroads	T-shape roads	Crossroads	T-shape roads
Intersections (Nij)	Good visibility	144	27	140	65	17	3	10	2	22	1	4	0	72	27	409	125
	Poor visibility	427	257	20	6	1	0	0	0	1	0	0	0	214	170	663	433
Accidents (Xij)	Good visibility	71	16	188	19	8	1	13	2	22	2	2	0	72	17	376	57
	Poor visibility	351	55	25	18	1	0	0	0	2	0	0	0	161	55	540	128
Accident rate (Rij)	Good visibility	0.16	0.20	0.45	0.10	0.16	0.11	0.43	0.33	0.33	0.67	0.17	0.00	0.33	0.20	0.31	0.15
	Poor visibility	0.27	0.07	0.42	1.00	0.33	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.25	0.11	0.27	0.10

Fig. 12 3-lane T-shaped road with high accident rate and Google Map

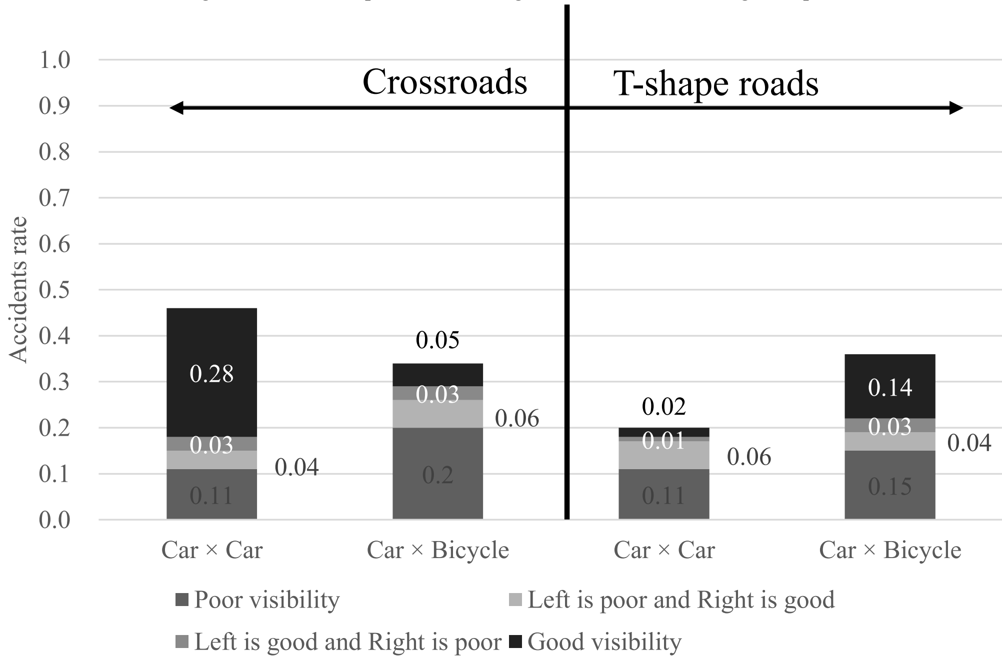


Fig. 13 Visibility evaluation by intersection shape by party

3-3. Visibility evaluation at frequent accident intersections

Here, the evaluation focused on intersections with frequent accidents. Accident-prone intersections are those where accidents occurred four times or more in three years. Fifty-three accident intersections were investigated in this paper. Visibility evaluation at frequent accident intersections only uses the direction in which the accident actually occurred (Fig 14). This allows for a more detailed assessment of the accident. For this reason, if there is an accident from the right at an accident-prone intersection, it is possible to evaluate whether the right-side view is good or bad. Fig. 14 shows part of the accident data from the prefectural police. Our analysis was based on these data. It is clear from Fig. 15 that accidents are likely to occur at intersections with poor visibility. In addition, it was found that the overall crossing collision accident rate in Hakata-ku Ward was higher than 0.23. The results showed that poor visibility was related to multiple occurrences of crossing accidents in the Hakata-ku Ward. Table 5 shows the ratio of accident parties. The direction of the accident is from the side of the secondary road when the accident occurred. This direction indicates which field of view was involved. The results show that there were more accidents that involved collisions from the right side than from the left side. However, there are many accidents in which the left-hand side is bad, and the accident is considered to be largely attributable to the left-hand side. Furthermore, the higher accident rate is related to poor visibility for bicycle accidents and accidents between cars. Regarding car × bicycle accidents, accidents from the right side were found to be likely to occur. When comparing visibility, the visibility on the right side of the intersection is better than the left side. This seems to indicate that the driver's attention is on the more severe left side, and safety confirmation on the right side is insufficient.

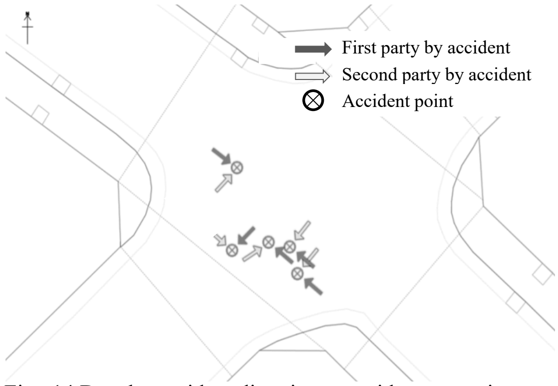


Fig. 14 Data by accident direction at accident-prone intersections

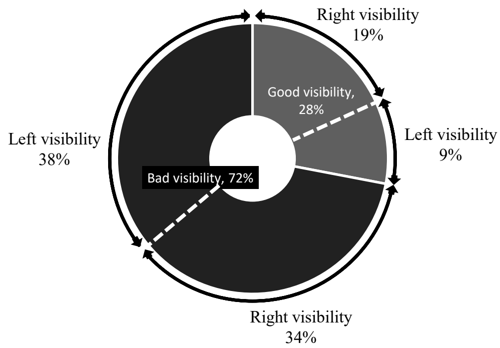


Fig. 15 Visibility of frequent accident intersections

Table 5 Number of accidents by different visibility at frequent intersections (all accident parties)

Accident type	Accident direction	Total	Visivility	Number of accidents
Car × Car accidents	Right	74	Good visibility	30
			Poor visibility	44
	Left	68	Good visibility	18
			Poor visibility	50
Car × Bicycle accidents	Right	78	Good visibility	19
			Poor visibility	59
	Left	54	Good visibility	9
			Poor visibility	45

4. Conclusions

We conducted a factor analysis of visibility and an accident analysis by party for crossing accidents in Fukuoka City. In addition, we calculated the yearly accident rate at each intersection based on the accident data and evaluated driver visibility with surveyed intersection information.

The results of this study are summarized below.

1. It was found that there are more intersections with better visibility on the left side than intersections with poor visibility on the left side in Hakata-ku Ward. In addition, there were many crossing accidents that involved poor visibility in Hakata-ku Ward.
2. At accident-prone intersections, the accident rate at intersections with poor visibility is very high regardless of the lane of the secondary road. Additionally, accident rates at T-junctions are higher at intersections with poor visibility than at crossroads.
3. There are many accidents from the right regardless of the type of accident at the points where accidents occur frequently. However, if the left side has poor visibility and there is a large amount of traffic, the left side is likely to be involved in accidents.

This study showed that the prospects classified as environmental factors were related to crossing accidents. In the future, it is necessary to analyze how visibility changes depending on the height and position of surrounding buildings and the relationship with the occurrence of accidents.

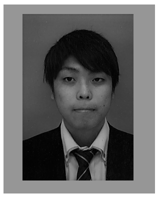
5. Acknowledgments

The survey of intersections in this study received the provision of accident statistics data from the Fukuoka

Prefectural Police Traffic Planning Division. We would like to express our gratitude.

6. References

1) "National Police Agency Transportation Authority, 2017 occurrence of the year of traffic accidents". https://www.npa.go.jp/publications/statics/koutsuu/H29zennjiko.pdf (2018) (in Japanese)
2) "National Police Agency Transportation Authority, 2017 for the development situation and road traffic law violation enforcement situation of the year". https://www.npa.go.jp/publications/statistics/koutsuu/toukeihyo.html (2018)
3) Institute for Traffic Accident Research and Data Analysis, "Koutuuzikotoukeiyougokaisetusyu". www.itarda.or.jp, (2017)
4) Hiroshi, Uno and Hidetoshi, Saruwatari and Yoshihiro, Urai and Suguru, Yoshida, "Experimental Study on Negotiation Behavior of Subssidary Road Vehicle at Crossing", Society of Automotive Engineers of Japan, Volume41 and number2, 2010, pp. 533-538
5) Kazuki, Watanabe and Hideki, Nakamura, "A Statistical Model Analysis on Traffic Accident Factors Based on Road Traffic and Social Environmental Conditions", Japan of Society of Civil Engineers,volume71, number5, 2015, pp. 896-899
6) Seizi, Takamatu and Ryota, Horiguthi and Hirokazu, Akabane, "A Study on Estimating Risk Distribution of Traffic Accidents using Topological Measures of Road Networks", Japan Society of Traffic Engineers, volume44, number1, 2009, pp.54-62
7) Institute for Traffic Accident Research and Data Analysis, "Koutuuzikotoukeinenpou". https://www.itarda.or.jp/page=4 (2018)
8) Fukuoka Prefectural Police Headquarters Traffic Planning Division, "Heise 29nentyuno zinshinziko", https://ckan.open-governmentdata.org (2018)
9) Kojiro, Matsuo and Yasuhiro, Hirobata, "A Model Estimating Accident Risk at Unsignalyzed Intersections in Residential Areas", Japan of Society of Civil Engineers, No.40
10) "GoogleMap", https://www.google.com/maps/?hl=ja
11) Junya, Sato and Masaki, Hirota and Takumi, Nomura, "Analysis of the crossing environment for the collision accident prevention" The 16th ITS Symposium (Kyoto, 2018)
12) Akihiko, Takahashi and Toru, Kumagai and Shin, Tanaka and Edgar, Yoshio and Morales, Teraoka and Tsutomu, Mochida and Testuo, Kurahashi, "Naturalistic Driving Analysis of Crossing Non-signalized Intersections without Right-of-way", Society of Automotive Engineers of japan, volume44, number6, 2013, pp.1465-1470
13) Fukuoka Prefectural Police, "April, 2018 Fukuoka prefectural police provided Statistical information about crossing collision accident, 2018
14) Yuji, Munehiro and Tatsuru, Daimon and Isao, Yamazaki and Masato, Arizumi, "A Study on the Effectivity of Vehicle Warning System at Unsignalized Intersection", Society of Mobile, 2007, pp.11-12



Takumi Nomura He graduated from the Faculty of Engineering Department of Mechanical Systems Engineering, Kumamoto University in 2018. He belongs to the Graduate School of Kyushu University. He is a member of the JSAE.

Masaki Hirota He was born in Tokyo in 1962. He received the ME degree and Dr. Eng. Degree in 1987 and 2006, respectively. He is currently a professor at Kyushu University. He is a member of the IEEJ, JSAE, JITR and JSAP.

Junya Sato He graduated from the Department of Electrical Engineering and Computer Science, Kyushu University in 2017. He graduated from the Department of Automotive Science Graduates School of Integrated Frontier Sciences, Kyushu University in 2019. He is a member of the JSAE.