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Analyzing the causal factors behind the occurrence of bicycle accidents through the use of data on actual accidents: A comparison between accident databases with a focus on crossing collision accidents

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1. Purpose of the research

According to traffic accident statistics from the National Police Agency (NPA),[(1),(2)] of the total number of fatalities from traffic accidents in 2018 of 3,532 people, 453 were fatalities from people riding a bicycle, making it the fourth most common type of accident. The fatality rate (= number of fatalities ÷ number of casualties × 100) for cyclists is 0.54, which is the third highest fatality rate following after those that occur while walking and while riding a motorcycle. Vehicle-bicycle crossing collision accidents accounted for roughly half of both the number of all bicycle accidents and that of fatal bicycle accidents in 2018. Therefore, clarifying the causes of crossing collision accidents presents an important challenge.

Ito et. al.[(3)] used drive recorder data to show that the distribution for speed and allowance time between collisions differs for near misses and minor contact accidents with crossing collision accidents. However, the data used by Ito et. al. was collected with the cooperation of a taxi company, and cases involving only slight contact accounted for the vast majority of their contents. There were few cases in which cyclists suffered injuries, and thus it cannot be said to be representative of accidents on the whole. Since it is expected that fatal and serious injury accidents in particular occur at higher speed ranges, it is necessary to analyze the effect of accident severity on the accident parameters, such as the location where the accident occurred, car speed, and the relative position of the cyclist when the cyclist appeared in front of the car. The purpose of this study is to clarify differences in the collision conditions between fatal and serious injury accidents and minor contact accidents in crossing collision accidents between four-wheel vehicles and bicycles. Traffic accident data collected by the Institute for Traffic Accident Research and Data Analysis (hereinafter abbreviated as "ITARDA") and the aforementioned drive recorder data were used for the analysis.

2. Analytical method

This study used macro data and micro data from ITARDA. The subjects of the analysis are indicated below.

- Statistical data on traffic accidents (macro data)
  Accident years: 2012 - 2016 (five years)
  Contents: Limited to vehicle-vehicle crossing collision accidents and accidents between four-wheel vehicles and bicycles, four-wheel vehicles limited to passenger vehicles
  Numbers: 675 accidents involving fatalities, 16,052 accidents involving serious injuries, and 191,163 accidents involving slight injuries
- In-depth case studies (micro data)
  Accident years: 2009 - 2017 (nine years)
  Contents: Limited to vehicle-vehicle crossing collision accidents and accidents between four-wheel vehicles and bicycles
  Numbers: 103 accidents (of which 21 involved fatalities, 63 involved serious injuries, and 19 involved slight injuries)

The macro data for accidents between four-wheel vehicles and bicycles was used to analyze the distribution of the locations and speeds at which the accidents occurred. We compared the distribution of fatal, serious injury, and slight injury accidents against the drive recorder database (hereinafter referred to as the “drive recorder DB”). As for the search conditions for the macro data, data in which the primary party and secondary party were driving a passenger vehicle (LL, large, small, and kei sized vehicles, as well as mini cars) and a bicycle was selected, from which only the portion consisting of accidents between four-wheel vehicles and bicycles was used. The road configuration (intersections, near intersections, and non-intersections) and their respective widths (intersections: small, small to large, or large; near intersections and non-intersections: 3.5 m and under up to 19.5 m and over) were adopted for use as the analytical items, with the number of accidents aggregated for each of these. The definitions for intersection sizes used here are those proposed by Hagita et al.[4]: "small" being defined as less than 5.5 m, "medium" as being from 5.5 - 13.0 m, and "large" as being 13.0 m and over. This was indicated in the order of the width on the four-wheel vehicle side and then the width on the bicycle side. Just like with the search through the macro data, the analysis of the micro data was restricted to crossing collision accidents involving collisions between four-wheel vehicles and bicycles. From this, the location the accident occurred, the danger perception speed, and the distances from the four-wheel vehicle and bicycle to the point of the collision at the time when they perceived danger (which were recorded on the survey forms) were selected out.

This study will compare the results of an analysis of the drive recorder DB reported by Ito et. al.[3] against accident data from ITARDA. The drive recorder DB was collected from a taxi company within Aichi Prefecture through the efforts of the Aichi Prefecture Automobile Safety Technology Project Team. It included 41 crossing collision accidents involving collisions between four-wheel vehicles and bicycles. In addition to this data, case examples of crossing collisions were sampled from the near-miss incident database[5],[6] maintained by the Tokyo University of Agriculture and Technology and added to the data. For the analysis, collision data on a total of 61 accidents was analyzed. The danger perception speeds as found in the drive recorder DB were defined as the vehicle's speed at the time when the driver took evasive action, such as by suddenly braking. For cases where the timing could not be clearly defined, this was defined as the speed at the time when the bicycle first appeared in the drive recorder video.

The kernel density estimation method[7] was used in order to smooth out the cumulative distribution curve. The kernel density estimation method is expressed as follows:

$$\hat{p}(x) = \frac{1}{nh}\sum_{i=1}^{n} K\left(\frac{x - X_i}{h}\right) \tag{1}$$

where $X_1, \ldots, X_n$ is the data, K is a smoothing function known as a kernel function, and h is the bandwidth that controls the intensity of the smoothing. For this study, the Gaussian function expressed via the following equation was used for the smoothing function.

$$K(x) = \frac{1}{\sqrt{2\pi}}\exp\left(-\frac{x^2}{2}\right). \tag{2}$$

R language Ver. 3.4.0 [8] was used to carry out this smoothing processing.

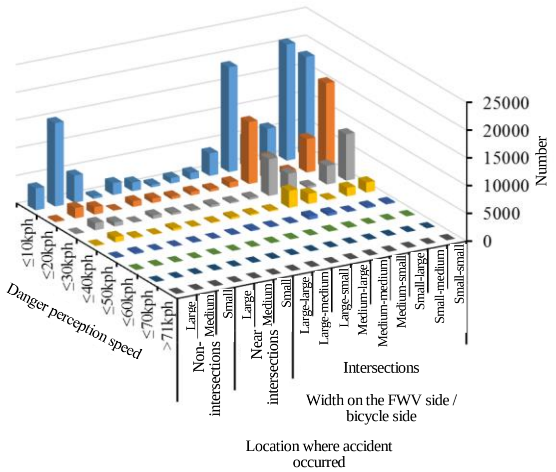
A chi-squared test and a residual analysis were performed to analyze the effect of the intersection conditions on crossing collisions in intersections against both the micro data and drive recorder DB. When the absolute values for the adjusted residuals were larger than 1.96, this was regarded as being $p < 0.05$.

3. Results

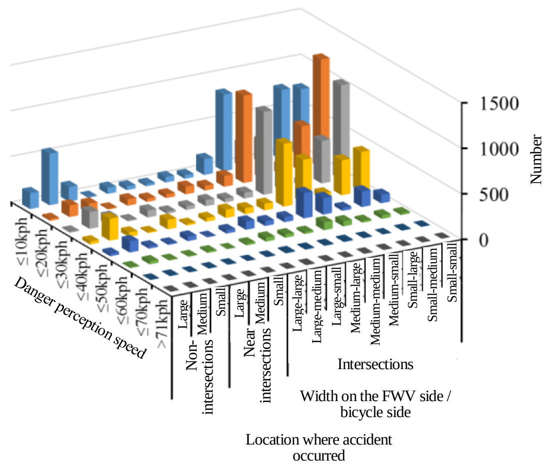
3.1. Comparison against the macro data

Fig. 1 shows a comparison of the locations where accidents occurred and the danger perception speed between the macro data (fatalities, serious injuries, and slight injuries) and the drive recorder DB. Comparing the locations where accidents occurred reveals that fatal accidents often occur at intersections (medium-medium), near intersections (medium), and non-intersections (medium). As opposed to this, smaller intersections (small-small, small-medium, small-large) and near narrow intersections (small) accounted for the vast majority of the occurrences in the drive recorder DB. Moreover, viewing this by speed reveals that fatal accidents often occurred at intersections in a range from 20 - 60 km/h. Whereas speeds of 41 km/h and over accounted for the vast majority of these, in the drive recorder DB accidents at a speed of 30 km/h or less accounted for more than half of the accidents. Moreover, for accidents near intersections as well, in the drive recorder DB many of these occurred at a speed of 30 km/h or less, whereas with fatal accidents there were many cases of these occurring at 31 km/h or faster. In summary, compared with the accidents in the drive recorder DB, which mainly consist of mild collisions, fatal accidents occur in high speed ranges. Conversely, a high proportion of slight injury and serious injury accidents occur at a speed distribution of 30 km/h or slower, demonstrating a trend close to that from the drive recorder DB.

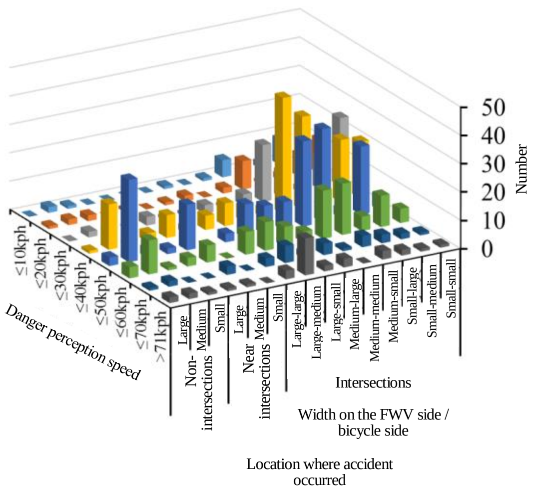
Next, only the danger perception speeds were compared without categorizing the locations where the accidents occurred. The results of normalizing the number of accidents that occurred in each speed range via a total number are shown in Fig. 2. The majority of slight injury accidents occurred at speeds of less than 20 km/h, and that an increase in the severity of injuries is accompanied by a shift of the speed distribution to higher speeds. There is a high frequency of accidents at 30 km/h and below in the drive recorder DB yet few at low speeds, demonstrating a trend that differs from that of the macro investigations.



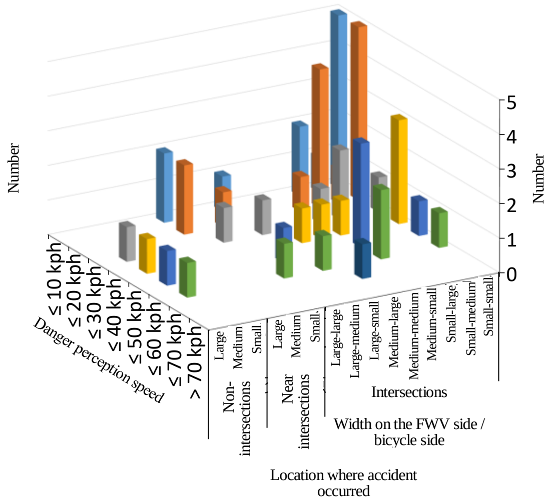
(a) Slight injuries (macro data)



(b) Serious injuries (macro data)

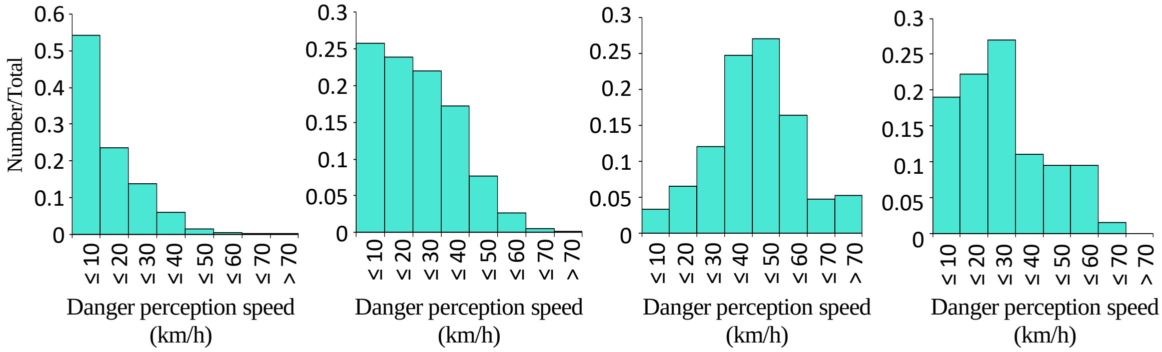


(c) Fatalities (macro data)



(d) Drive recorder DB

Fig. 1. Distribution of the locations where accidents occurred and danger perception speeds (comparison against the macro data)



(a) Slight injuries (macro data) (b) Serious injuries (macro data) (c) Fatalities (macro data) (d) Drive recorder DB

Fig. 2. Distribution of danger perception speeds (comparison against the macro data)

3.2. Comparison against the micro data

The totals for the locations where accidents occurred and the danger perception speeds from the micro data are shown in Fig. 3. The accidents frequently occur at intersections, just like within the macro data and drive recorder DB. Regarding the speed, they frequently occur near the 30-40 km/h range, and when the data on slight and serious injuries from the macro data is compared against that from the drive recorder DB, the distribution is tilted towards the higher speeds. Fig. 4 shows a categorization and comparison of danger perception speeds by the extent of the injuries suffered. The cumulative probability distribution curves were smoothed by the aforementioned method. This figure reveals that the speed distribution from the drive recorder DB is situated on the lower end of the speed range. It also reveals a sizable difference in the speed distribution in that the 50% total for speeds was at roughly 25 km/h, whereas with slight injury accidents this was approximately 40 km/h. From this, it can be seen that there are numerous cases of even slight injuries occurring at relatively high speeds from the micro data.

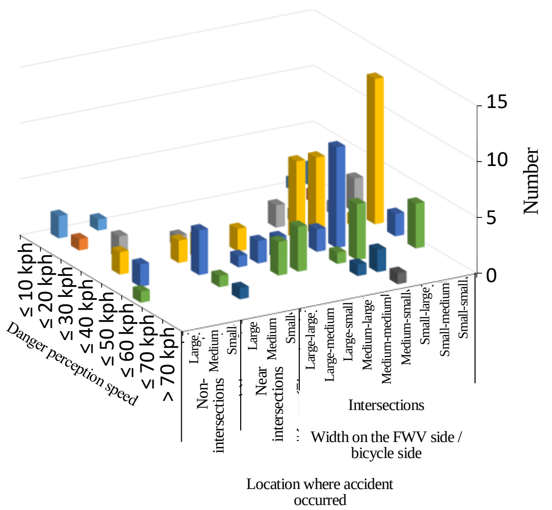


Fig. 3. Distribution of the locations where accidents occurred and danger perception speeds (micro data)

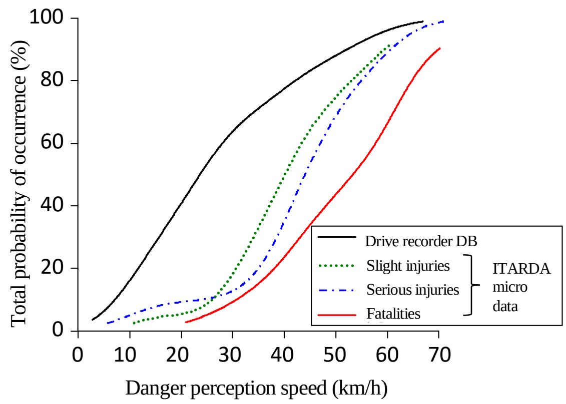


Fig. 4. Distribution of danger perception speeds (comparison against the micro data and drive recorder DB)

Next, the location where the driver perceived the appearance of the cyclist was compared between the micro data and the drive recorder DB. Fig. 5 shows the locations where danger was perceived as categorized for each danger perception speed. Said locations were determined based on the records in written evidence for the micro data, and for the drive recorder DB these were calculated via an analysis of the video. Moreover, for the drive recorder DB the locations were portrayed as of the point in time when the bicycle first appeared in the video data and when the driver began suddenly braking, respectively. The points where cyclists appeared in the micro data are distributed over a relatively narrow angle range from the direction of motion of the four-wheel vehicle going straight towards a relatively small angle and off into the distance, but with the drive recorder DB the distribution that was observed was in the vicinity around the four-wheel vehicle and at a wide angle. While the majority from the micro data is collected within the range of lines in a 25° direction to both sides as listed in the figure, conversely the low speed data in particular is often indicated as falling outside this range with the drive recorder DB. This suggests that when considering the sensing capabilities of autonomous emergency braking system for bicycles, not only those off in the distance, but also the appearance of bicycles from within the vicinity of the vehicle and wide-angle areas should be considered.

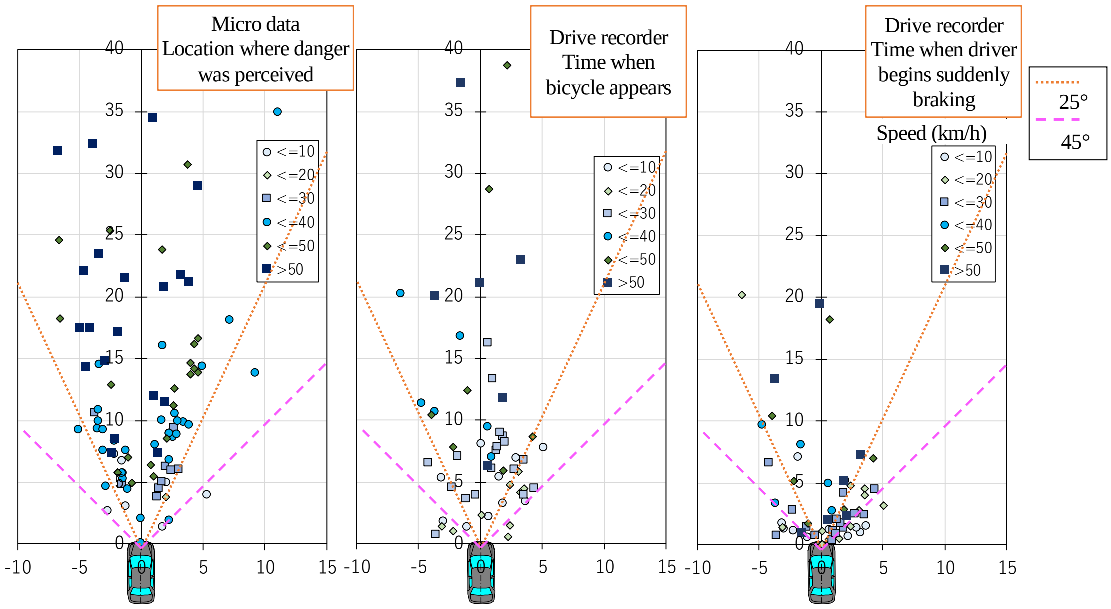


Fig. 5. Relative position of the bicycle when danger was perceived

In order to compare the characteristics of crossing collisions at intersections, a categorization by the configurations of intersections is shown in Table 1. Here, "Other irregular intersections" refer to Y-shaped roads, five-road junctions, crisscrossing intersections, and so forth. Table 1 shows that these other irregular intersections account for a relatively high percentage in the micro data ($p < 0.05$), whereas the percentage of orthogonal, cross-shaped intersections was high in the drive recorder DB ($p < 0.05$). Although these results were derived from a limited number of accidents, this is probably because of differences in the road environment and traffic volume of the area where the data was collected.

Table 1. Configurations of locations where crossing collision accidents occurred at intersections

	Micro data (n=81)			Drive recorder DB (n=57)		
	n	%	Adjusted residuals	n	%	Adjusted residuals
Orthogonal, cross-shaped	51	63	-2.49	47	82	2.49
T-shaped	17	21	1.04	8	14	-1.04
Other irregular intersections	13	16	2.33	2	4	-2.33

In order to compare the characteristics of crossing collision accidents at non-intersections, the accidents were categorized based on the type of accident (Fig. 7). Crossing collision accidents at non-intersections can be categorized into two types. The first type of accident occurred when either a four-wheel vehicle or bicycle entered the road suddenly from a lot off to the side of the road (this includes both cases where a four-wheel vehicle enters the road and cases where a bicycle does so). The second type of accident occurred either before or after a four-wheel vehicle or bicycle crossed the median strip or median line. This type of accident was frequently seen in the micro data, but not seen in the drive recorder DB. With the type where one party crosses the median line, cases caused by a bicycle suddenly changing course were seen, as was a type whereby the bicycle suddenly appeared between or from behind a line of vehicles. Three of the total of four accidents in the drive recorder DB involved a line of vehicles, and this type had a high occurrence frequency compared with the micro data. It is estimated that differences in the road environments and traffic volumes of the areas where the data was collected are important factors, just like with accidents at intersections.

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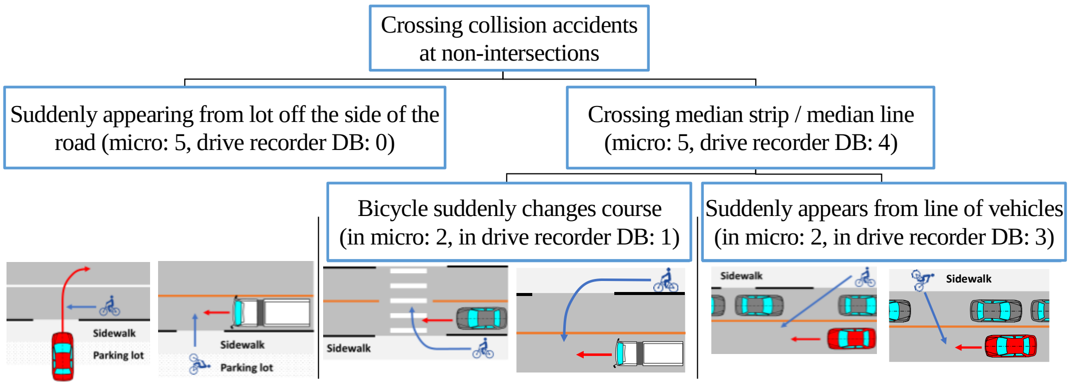

Fig. 7. Causes of crossing collision accidents involving bicycles at non-intersections

The advantages and limitations of the drive recorder DB and micro investigations used for this analysis will be laid out in this section. The first advantage of the drive recorder DB is that it makes it possible to obtain the speed of the bicycle and its relative trajectory just prior to the accident by video analysis of the drive recorder data. Another advantage is that the video data enables us to analyze the effect of moving obstacles on the occurrence of accidents. We can obtain the time at which the driver of the four-wheel vehicle became aware of the bicycle from the video data, even when the bicycle suddenly appeared from behind a row of vehicles in the oncoming lane of traffic that is moving. Conversely, one limitation of the drive recorder DB used for this analysis is that the collected data was sampled from a population consisting of highly safety-conscious professional drivers. In addition, the number of accidents was limited because the data was only provided with the cooperation of several taxi companies.

One advantage of the micro investigations is the fact that information on factors like the vehicle, the victim, and the scene of the accident, as well as the deformation of the vehicle and the extent of the injuries that occurred following the accident (both of which are particularly difficult to analyze from the drive recorder) can be collected by investigators. On the other hand, since investigators are only dispatched to a limited number of cases, there is the possibility that the data is tilted more towards comparatively severe accidents. In addition, one limitation of both data sets is the fact that their data collection regions were limited. Therefore, the effect of the regional differences must be taken into consideration when performing comparisons between the data used in this analysis. Moreover, it will be necessary to develop suitable methods for enlarging and interpolating in order to estimate the extent of accidents nationwide in the future.

4. Conclusion

This paper focused on crossing collision accidents between four-wheel vehicles and bicycles to compare existing drive recorder data with ITARDA's macro and micro accident data, thereby clarifying its characteristics and differences in it. This was done with the objectives of elucidating the causal factors behind the occurrence of crossing collision accidents involving bicycles and further improving the accuracy of accident investigations and causal analyses. The main results from this are indicated below.

- Whereas fatal accidents are distributed more on the high speed side, on the other hand from analyzing the drive recorder DB it was affirmed that there are differences in the trends, such as the appearance of bicycles over a wide range.
- Analyzing crossing collisions at intersections and non-intersections revealed differences in the trends with the locations where these occurred and the types of accidents. However, these could potentially be attributed to differences in the road environment and traffic volume on the sections surveyed.

For the future, ideally a structure should be established based on an understanding of the characteristics of each respective database so that they can be used in a mutually complementary manner in order to clarify the causes of bicycle accidents and develop accident prevention devices.

＜参考文献＞

1) 警察庁交通局　平成 30 年中の交通事故の発生状況
2) 警察庁交通局　平成 30 年中の交通死亡事故の発生状況及び道路交通法違反取締り状況等について
3) Ito D et al. Difference between car-to-cyclist crash and near crash in a perpendicular crash configuration based on driving recorder analysis. Accident Analysis and Prevention, Vol. 117, pp. 1-9, 2018
4) 萩田賢司ら　自転車の進行方向に着目した交差点自転車事故の分析．土木学会論文集 D3, Vol.70, No.5, pp. I_1023-I_1030, 2014.
5) Kamata M et al. Research on incident analysis using drive recorder part 1: toward database construction. Proceedings of FISITA 2006 World Automotive Congress (No. F2006V203), 2006
6) Shino M et al. Research on incident analysis using drive recorder part 3: analysis on relationship driving behavior and traffic circumstance based on forward collision near-miss incident data in car following situation. Proceedings of FISITA 2008 World Automotive Congress (No. F2008-08-123), 2008
7) Chen YC A tutorial on kernel density estimation and recent advances. Biostatistics & Epidemiology, Vol. 1, Issue 1, pp. 161-187, 2017
8) R Development Core Team R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. Vienna, Austria. ISBN 3-900051-07-0. http://www.R-project.org.