FEATURES OF CAR–CYCLIST CONTACT SITUATIONS IN NEAR-MISS INCIDENTS COMPARED WITH REAL-WORLD ACCIDENTS IN JAPAN

Yasuhiro Matsui, Shoko Oikawa
National Traffic Safety and Environment Laboratory
Japan

Kunio Takahashi
Saisei Engineering
Japan

Masahito Hitosugi
Shiga University of Medical Science
Japan

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ABSTRACT

The use of active safety devices that can detect cyclists is considered an effective countermeasure for the reduction of the severity of injuries and number of deaths of cyclists. The detailed features of car–cyclist contact scenarios need to be clarified to develop such safety devices. Because there is limited information on real-world accidents, the present study investigates near-miss scenarios captured by drive recorders installed in passenger cars.

The first purpose of the present study is to ascertain the utility of using near-miss scenarios in clarifying the features of situations of contact between cars and cyclists. The similarities of data of near-miss incidents including video captured by drive recorders and national data of real-world fatal cyclist accidents in Japan are investigated. We used 229 videos of near-miss car–cyclist incidents collected by the Society of Automotive Engineers of Japan (J-SAE) from 2005 to 2009. In scenarios where the car travels straight ahead, 70–84% of cyclists on straight roads or at intersections crossed the road in front of the forward-moving cars both in accidents and near-miss incidents. There are thus similarities between accidents and near-miss incidents and it is possible to estimate the situations of cyclists' accidents from near-miss incident data including video that captures cyclist behavior.

The second purpose of the study is to calculate the time to collision (TTC) from the near-miss incident data. The study analyzed data for 166 near-miss car–cyclist incidents in which cyclists crossed the road in front of forward-moving cars on straight roads or at intersections. We calculated the TTC from the velocity of the car with an installed drive recorder and the distance between the car and the cyclist at the moment the cyclist appeared in the video captured by the drive recorder. The average TTC was 2.1 s (Standard Deviation (SD) of 1.6 s). In terms of the manner in which cyclists emerged in front of cars, the average TTC was the shortest (1.9 s) when cyclists emerged from behind a building or moving vehicle in the opposite lane. We propose that the specifications of a safety device developed for cyclist detection and automatic braking should reflect detailed information that includes the TTC obtained for near-miss situations.

INTRODUCTION

The number of traffic deaths in Japan decreased in the past 20 years to 4373 in 2013[1)]. The Japanese government has an aim to reduce the annual fatality count to less than 2500 by 2018[2)]. Among types of road fatalities between 2012 and 2013, only cyclist fatalities increased in number, from 563 to 600 (by 7%). As an example of a countermeasure implemented by the Japanese government to reduce pedestrian deaths, the safety performances of car bonnet tops have been assessed since 2005. However, there has been no effective regulation for cyclist protection.

To reduce the severity of injuries and the number of deaths, active safety devices such as crash severity mitigation systems using sensors for cyclist detection are regarded as effective countermeasures. Currently, cars installed with crash severity mitigation systems that include a stereo camera as a sensor and automatic braking have been

developed in Japan [3, 4]. Such cars are expected to be further designed with consideration of aspects of car–cyclist contact situations including the time to collision (TTC). However, the contact situations of accidents have not been clarified, because there is limited detailed information on real-world accidents. Rosen et al.[5] investigated the positions of pedestrians and cars at a time 1 s prior to impacts that resulted in fatal accidents, but there have been few other representative examples of research on cyclists and car positions. The present study therefore focused on near-miss incidents captured by drive recorders installed in passenger cars.

A near-miss incident is a situation that a car accident involving a cyclist is avoided by the attention and braking of a driver. Near-miss incidents occur more frequently than accidents. Recently, drive recorders were installed in taxis in metropolitan, Tokyo for the purpose of investigating causes of car accidents and educating car drivers. The data of the drive recorder consist of video captured by a forward-facing camera and a car's velocity, acceleration, and braking signals. If near-miss incidents are similar in nature to accidents, then car–cyclist contact situations or the TTC can be calculated from near-miss incidents. The authors thus analyzed the near-miss incident data captured by drive recorders installed in taxis.

The first purpose of the present study is to ascertain the usefulness of using near-miss situations in clarifying the features of situations of contact between cars and cyclists. The study investigated similarities between the data of near-miss incidents including video captured by drive recorders and the data of real-world fatal cyclist accidents in Japan.

The second purpose of the present study is to calculated the TTC from the near-miss incident data so as to help develop a crash severity mitigation system for the active safety of cars in the future. The study analyzed near-miss car–cyclist incident data where cyclists crossed the road in front of forward-moving cars on straight roads or at intersections. The TTC was calculated from the velocity of the car with an installed drive recorder and the distance between the car and the cyclist at the moment the bicycle appeared in the video captured by the drive recorder. The worst situation was assumed to be that when a car moved toward a cyclist without the driver noticing the cyclist or braking.

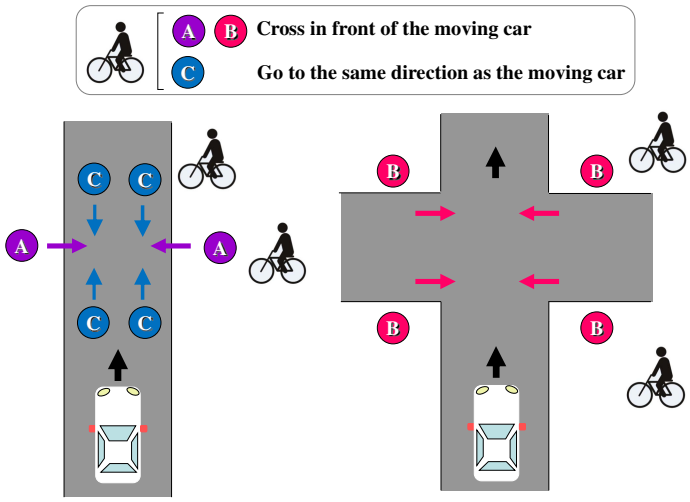
NEAR-MISS IN-DEPTH DATA

J-SAE has collected near-miss incident data[6] consisting of forward-oriented video and the car velocity, acceleration and braking signal obtained from drive recorders for more than 100 taxis in Tokyo from 2005. Each drive recorder was installed on the inside of the front window and consisted of a camera and a three-dimensional accelerometer. The near-miss incident data include events of car–car, car–cyclist, car–bicycle, and car–motorcycle impacts.

The drive recorder's collection of data is triggered by a driver's sudden braking with deceleration exceeding 0.5 G, and the recorder collects data for 10 seconds before and 15 seconds after the triggering. In the present study, the authors used data for 229 near-miss car–cyclist incidents from 2005 to 2009 consisting of 150 incidents during the day and 79 incidents at night.

CONTACT SCENARIOS IN REAL-WORLD ACCIDENTS AND NEAR-MISS INCIDENTS

The Institute for Traffic Accident Research and Data Analysis of Japan investigated car–bicycle contact scenarios in real-world fatal cyclist accidents from 1999 to 2003 in Japan[7]. In accidents on straight roads or at intersections, the fatality rates for working-age and elderly cyclists crossing the road in front of forward-moving cars were 83% and 90%, respectively. We thus compared scenarios of contact between near-miss car–cyclist incidents and real-world fatal car–cyclist accidents when cyclists crossed the road in front of forward-moving cars to clarify the utility of using near-miss car–cyclist incident data. We investigated video captured by drive recorders for 229 near-miss incidents from 2005 to 2009 and national records for 2818 real-world fatal cyclist accidents from 1999 to 2003 in Japan[7], in which cyclists crossed the road in front of forward-moving cars on straight roads or at intersections. The relationships of the moving directions of vehicles and cyclists on straight roads and at intersections are defined in Figure 1. On straight roads, the cyclist crosses the road in front of a forward-moving car in case A while the cyclist travels in the parallel direction as the moving car in case C. At an intersection, the cyclist crosses the road in front of the forward-moving car in what is referred to as case B.



(a) Straight road (b) Intersection

Fig.1. Relationships of moving directions of a vehicle and cyclist.

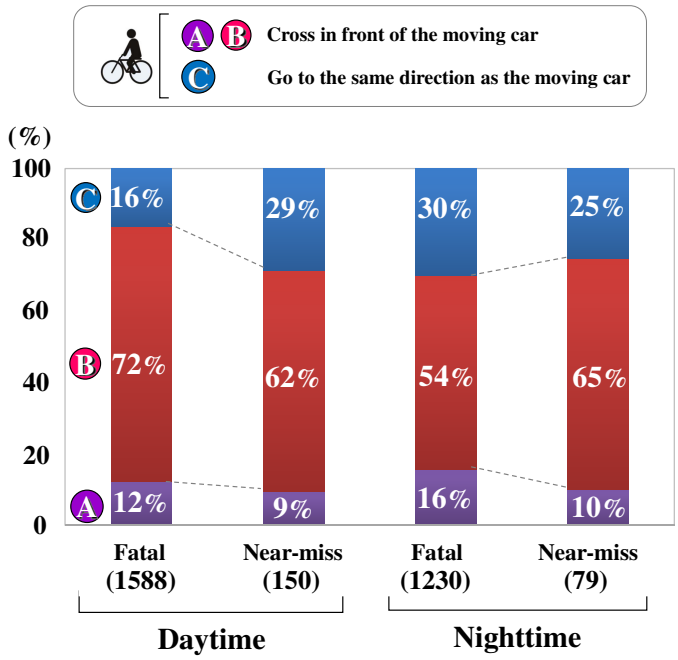


Fig.2. Relative directions of travel of a vehicle and cyclist in accidents and near-miss incidents.

Figure 2 presents the distribution of relative directions of travel of a vehicle and cyclist in accidents and near-miss incidents. Cases A and B together accounted for 84% (fatal) and 71% (near-miss) of incidents during the day and 70% (fatal) and 75% (near-miss) of incidents at night; i.e., 70–84% of incidents involved cyclists on straight roads or at intersections crossing the road in front of forward-moving cars. These results show similarities in cyclists' behavior between accidents and near-miss incidents. Cyclist accident situations can thus be predicted by analyzing near-miss incident data including video that captures the cyclist behavior. The next section investigates situations of cars and cyclists approaching each other in detail using near-miss incident data.

IN-DEPTH ANALYSIS OF NEAR-MISS EVENTS

In-depth analysis of data of near-miss events

In this section, the TTC is calculated from near-miss car–cyclist incident data where cyclists crossed the road in front of forward-moving cars on straight roads or at intersections. A near-miss incident is a situation that an accident is avoided through the attention and braking of the driver of the car. In the present study, the TTC was calculated from the near-miss incident data considering the worst case that the driver did not brake (through, for example, a lack of attention or insufficient reaction time).

The near-miss incident data for situations in which cars and cyclists approached each other were selected for analysis. As a result, 166 near-miss car–cyclist incident data were used, where cyclists crossed the road in front of forward-moving cars on straight roads or at intersections.

Calculation of the TTC

The TTC (s) was calculated as

$$\mathbf{TTC = L/V, (1)}$$

where V (m/s) is the velocity of a car with an installed drive recorder and L (m) is the forward distance between the car and the cyclist at the moment when a cyclist appears in the video captured by the drive recorder as shown in Figure 3. Here, V is the running velocity of the car just before the driver applies the brake after realizing the existence of the cyclist. It was determined whether a driver applied the brakes by checking the braking signal and deceleration signal recorded by the drive recorder.

The study also investigated the lateral distance Ld (m) between one side of the car and the cyclist obtained as

$$\mathbf{Ld = LL - 0.85, (2)}$$

where LL (m) is the distance between the center of the drive recorder camera (the center of the car) and the cyclist (approximately 1.7 m), and the value 0.85 m is half the full width of the car.

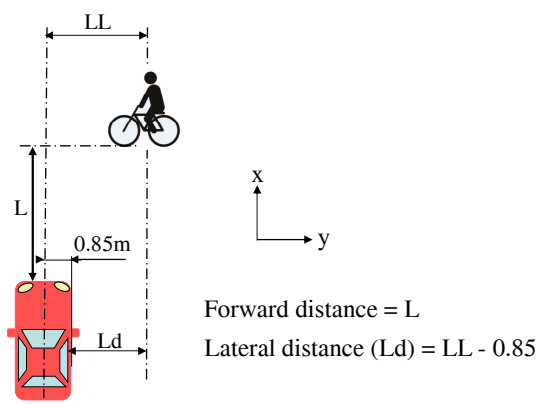


Fig.3. Definitions of forward and lateral distances.

Figure 4 shows the distribution of the calculated TTC the lateral distance (Ld) from the side of the car to the cyclist at the moment the cyclist appears in the video captured by the drive recorder. The TTCs ranged from 0.5 to 10.0 s. In determining the location of a cyclist relative to the center of a car, it was observed that the cyclist was to the right of the car in 86 cases and to the left in 80 cases. The average TTC was 2.2 s (standard deviation (SD) of 1.7 s) for the cases on the right-hand side and 2.1 s (SD of 1.7 s) for the cases on the left-hand side. Because the average TTC was similar for the two sides, the following analyses were performed regardless of whether the cyclist to the left or right of the vehicle. The average TTC was 2.1 s (SD of 1.7 s) for the total 166 cases.

The distribution of the calculated TTC and forward distance (L) between a car and a cyclist is shown in Figure 5. Theoretically, the TTC should increase as the forward distance increases. The figure reveals direct proportionality between the forward distance and TTC.

The distribution of the calculated TTC and the car velocity (V) is shown in Figure 6. Theoretically, the TTC should decrease as the car velocity increases. However, no linear correlation between the car velocity and TTC is observed. There are several possible reasons for the widely scattered data in Figure 6. Therefore, the next section investigates the features of cyclist behavior in detail.

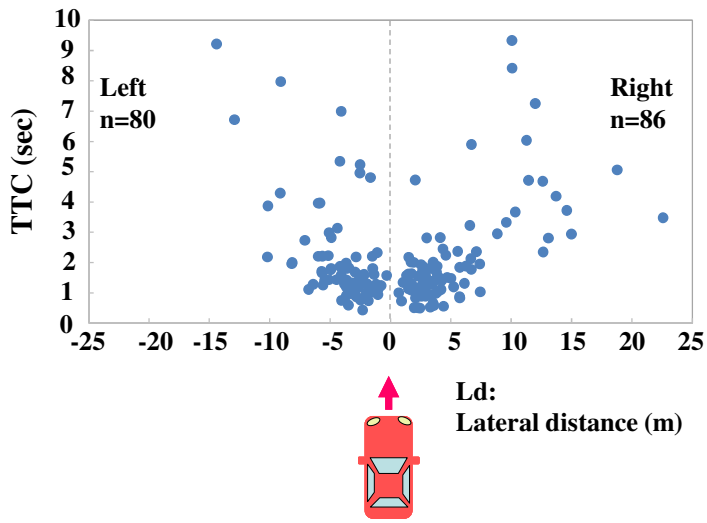


Fig.4. Distribution of the calculated TTC and lateral distance (Ld).

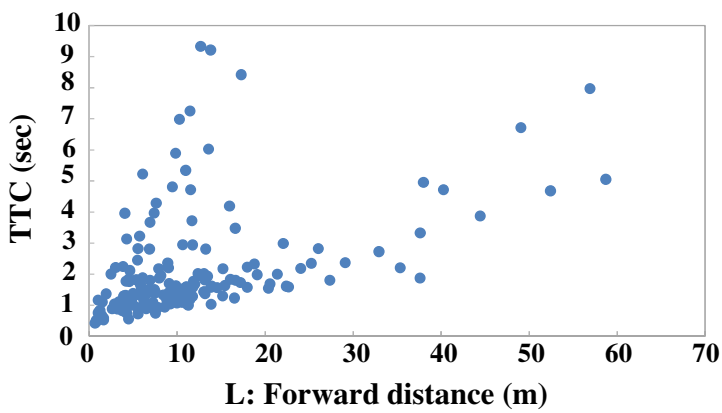


Fig.5. Distribution of the calculated TTC and forward distance (L).

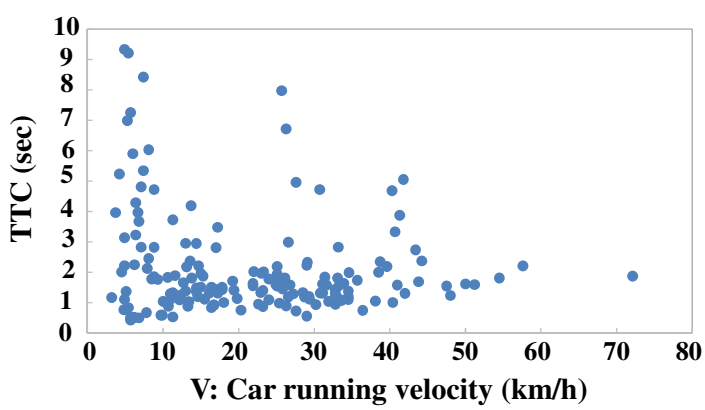
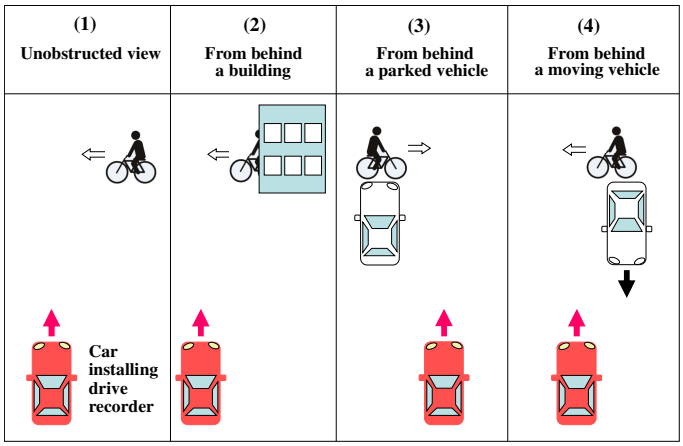


Fig.6. Distribution of the calculated TTC and car velocity (V).

Detailed Features of Cyclist Behaviors

The manner in which cyclists appeared in front of the car was classified into four categories as shown in Table 1. The classifications are (1) the driver having an unobstructed view, (2) the cyclist emerging from behind a building, (3) the cyclist emerging from behind a parked vehicle, and (4) the cyclist emerging from behind a moving vehicle. The average values of the TTC, the forward distance between the car and the cyclist, and the car velocity for the four classifications are presented in Figure 7. The average TTC was longest (3.3 s) for the unobstructed view (1), presumably because of the longer forward distance (averaging 19.5 m) regardless of the higher velocity of the car (averaging 24.7 km/h). The average TTC was shortest (1.9 s) when a cyclist emerged from behind a building (2) or moving vehicle (4), presumably owing to the shorter forward distance between the car and the cyclist (averaging 9.9 m for (2) and 8.7 m for (4)).

Table1.
Four classifications of situations in which the cyclist appears in front of a car.



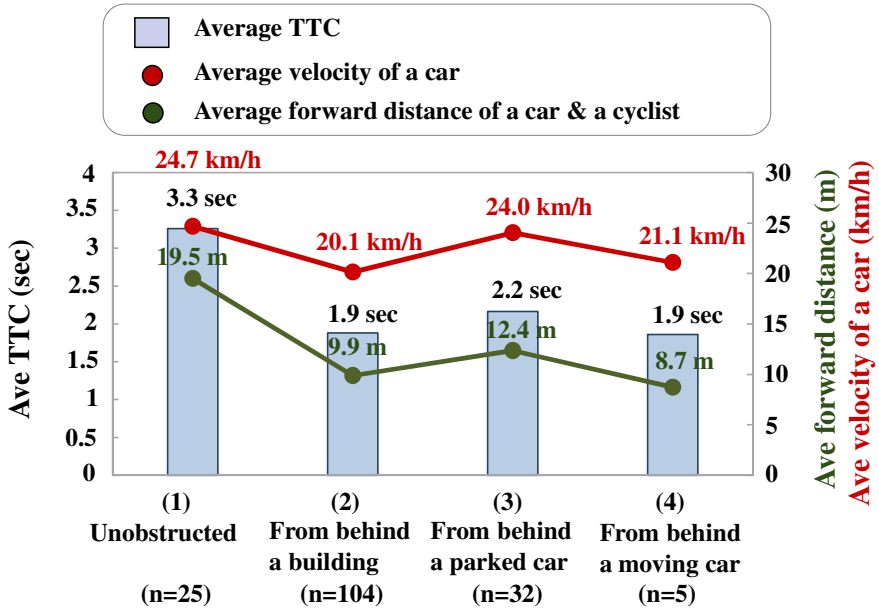


Fig.7. Average values of the TTC, forward distance between the car and the cyclist, and car velocity in the four categories of cyclist emergence.

DISCUSSION AND CONCLUSIONS

The present study investigated the usefulness of near-miss situations in clarifying the features of situations of contact between cars and cyclists, and calculated the TTC using near-miss incident data. A near-miss incident was considered a situation that an accident was avoided through the attention and braking of the driver of the car.

The similarities between the data of near-miss incidents including video captured by drive recorders and national data of real-world fatal cyclist accidents in Japan were investigated. It was found that 70–84% of cyclists involved in accidents on straight roads or at intersections crossed the road in front of forward-moving cars both in cases of accidents and in cases of near-miss incidents. There were thus similarities between accidents and near-miss incidents. It was determined that the situations of car–cyclist accidents could be calculated from near-miss incident data including video capturing cyclist behavior.

The study analyzed data for 166 near-miss car–cyclist incidents in which cyclists crossed the road in front of forward-moving cars on straight roads or at intersections. It is noted that, in the present study, the TTC was calculated from near-miss incident data considering the worst case that the car hits the cyclist without braking. The TTC was calculated from the velocity of the car installed with a drive recorder and the distance between the car and the cyclist at the moment the cyclist appeared in the video captured by the drive recorder. The average TTC was obtained as 2.1 s (SD of 1.7 s). In terms of the manner in which cyclists emerged in front of cars, the average TTC was shortest (1.9 s) when cyclists emerged from behind a building or from behind a moving vehicle in the opposite lane. The authors propose that the specifications of a safety device developed for cyclist detection and automatic braking should reflect detailed information including the TTC obtained for near-miss situations.

As described, the present study obtained TTCs for 166 near-miss car–cyclist incidents. Currently, definition of the near-miss incident has not been determined quantitatively. Because the features of the 166 near-miss car–cyclist incidents were similar to features of accident records, it was possible to define a near-miss incident level for estimating accident situations according to the present analysis results, such as an average TTC of 2.1 s (SD of 1.7 s).

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