

CAR-TO-PEDESTRIAN CONTACT SITUATIONS IN NEAR-MISS INCIDENTS AND REAL-WORLD ACCIDENTS IN JAPAN

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ABSTRACT

The number of traffic deaths in Japan was 4,863 in 2010. When looking at the number of the road accident fatalities (4,863) in 2010, it reveals that pedestrians account for the highest number (1,714, 35%). To reduce the severity of injuries and the number of deaths, active safety devices providing pedestrian detection are considered to be ones of the effective countermeasures. The detailed features of the contact scenarios in car-to-pedestrian are necessary to develop the safety devices. Since the information on the real-world accidents was limited, the authors focused on the 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 for understanding the features of the contact situations between cars and pedestrians. In the present study, the authors investigated the similarities between the data of near-miss incidents including motion pictures captured by drive recorders and the data of national traffic accidents based on real-world fatal pedestrian accidents in Japan. This study used 163 motion pictures of near-miss car-to-pedestrian incident data collected by the Society of Automotive Engineers of Japan (J-SAE) from 2005 to 2009. The results indicated that 70% pedestrians at intersections or on straight roads were crossing the roads in front of the forward moving cars both in accidents and near-miss incidents. Considering the features of pedestrians' behaviors from this result, the authors found similarities between accidents and near-miss incidents. It was made clear that one could estimate the situations in pedestrians' accident from the near-miss incident data which included motion pictures capturing pedestrian behaviors.

The second purpose of the present study is to estimate the time to collision (TTC) from the near-miss incident data. This study analyzed 103 near-miss car-to-pedestrian incident data in which pedestrians were crossing the roads in front of the forward moving

cars at intersections or on straight roads. We calculated the TTC from the velocity of a car with an installed drive recorder and the distance between a car and a pedestrian at the moment a pedestrian initially appeared on a motion picture captured by the drive recorder. As a result, the average TTC was 1.7 seconds (SD 1.3 seconds). The average TTC was 1.8 seconds in cases that pedestrians were walking across a crosswalk, which was longer than the average TTC 1.4 seconds in the cases that pedestrians were walking across the roads without a crosswalk. The authors propose that the specifications of the safety device for the pedestrian detection and for automatic braking should reflect the detailed information including the TTC obtained by the near miss situations, in which the worst situation was assumed that the cars were moving toward pedestrians without braking due to car driver's inattentiveness.

INTRODUCTION

The number of traffic deaths in Japan was 4,863 in 2010. When looking at the number of the road accident fatalities (4,863) in 2010, it reveals that pedestrians account for the highest number (1,714, 35%)¹⁾. The Japanese government has an aim to reduce the annual fatality count to less than 2,500 till 2018²⁾. For example, since head injuries were the most common causes of pedestrian deaths in car-to-pedestrian accidents, the Japanese Ministry of Land, Infrastructure, Transport and Tourism (J-MLIT) started to assess the safety performance of the bonnet top of a vehicle. To reduce the severity of injuries and the number of deaths, active safety devices such as the crash severity mitigation system using sensors for pedestrian detection is regarded as an effective countermeasure. Currently, cars with the crash severity mitigation system with a sensor of a stereo camera and automatic braking installed are produced in Japan^{3,4)}. Those cars are expected to be developed in consideration of car-to-pedestrian contact situations including the time to collision (hereafter referred to TTC). However, the contact situations in accidents have not been made clear so far, because the detailed

information on the real-world accidents is limited. For example, Rosen et al.⁵⁾ investigated the pedestrian locations and car locations one second prior to their impacts that resulted in fatal accidents, but there have been few other representative examples. Hence this study focused on the near-miss incidents captured by drive recorders installed in passenger cars.

The near-miss incident is the situation that a car accident involving a pedestrian is avoided by the attention and braking of a driver. Near-miss incidents occurred more frequently than accidents. Recently, drive recorders were installed in taxis in Tokyo area for the purpose of investigating causes of car accidents and educating car drivers. The data of the drive recorder consist of forward moving pictures captured by its camera, and the cars' velocities, accelerations, and braking signals. If the near-miss incidents were similar in the feature to the accidents, we determined that the car-to-pedestrian contact situations or the TTC could be estimated from the near-miss incidents. So the authors analyzed the near-miss incident data captured by drive recorders installed in taxis.

The first purpose of the present study is to ascertain the utility of using near-miss situations for understanding the features of contact situations between cars and pedestrians. In this study, the similarities were investigated between the data of near-miss incidents including motion pictures captured by drive recorders and the data of national traffic accidents based on real-world fatal pedestrian accidents in Japan.

The second purpose of the present study is to estimate the TTC from the near-miss incident data so as to help develop the crash severity mitigation system of active safety cars in the future. This study analyzed near-miss car-to-pedestrian incident data in which pedestrians were crossing the roads in front of the forward moving cars at intersections or on straight roads. The authors calculated the TTC from the velocity of a car with an installed drive recorder and the distance between a car and a pedestrian at the moment a pedestrian appeared on a motion picture captured by the drive recorder. The worst situation was assumed when a car was moving toward a pedestrian without the attention and braking of the car driver. In the present study, the authors used and analyzed the near-miss car-to-pedestrian incident data by the Society of Automotive Engineers of Japan (J-SAE) from 2005 to 2009 in order to estimate the TTC considering the worst situation.

NEAR-MISS IN-DEPTH DATA

J-SAE has collected near-miss incidents data⁶⁾ consisting of forward movie pictures, and the cars' velocities, accelerations and braking signals which are obtained from drive recorders which has been installed in over one hundred taxis in Tokyo from 2005. The drive recorder was installed on the inner side of the front glass and consisted of a camera and three dimensional accelerometers. The near-miss data include contact events of car-to-car, car-to-pedestrian, car-to-bicycle, and car-to-motorcycle impacts.

Table 1 Vehicle-to-pedestrian near-miss data

Daytime (n=77 incidents)				
Adult or child	Location	Crosswalk	Pedestrian moving direction	Number
Adult (n=72)	Straight road (n=28)	None (n=24)	Go straight	4
			Across	20
		Yes (n=4)	Across	4
	Intersection (n=42)	None (n=4)	Go straight	1
			Across	3
		Yes (n=38)	Go straight	2
		Across	36	
Other* (n=2)	None (n=2)	Across	2	
Child (n=5)	Straight road (n=5)	None (n=5)	Across	5

Other*: in parking areas

Nighttime (n=86 incidents)				
Adult or child	Location	Crosswalk	Pedestrian moving direction	Number
Adult (n=83)	Straight road (n=32)	None (n=29)	Go straight	-
			Across	29
		Yes (n=3)	Across	3
	Intersection (n=51)	None (n=3)	Across	3
			Yes (n=48)	Go straight
	Across	48		
Child (n=3)	Straight road (n=1)	None (n=1)	Across	1
	Intersection (n=2)	None (n=2)	Across	2

The drive recorder's collection of data is triggered by a driver's sudden braking of over 0.5 G deceleration, and the recorder can keep capturing the data for 10 seconds beforehand and 15 seconds after the triggering. In the present study, the authors used 163 near-miss car-to-pedestrian incident data from 2005 to 2009 consisting of 77 incidents in daytime and 86

incidents in nighttime. Table 2 summarizes the age-group (adult or child), near-miss incident location (straight road or intersection), crosswalk, and pedestrian moving direction. In reviewing Table 2, it is seen that the majority of the pedestrians were crossing the roads in front of forward moving cars at intersections or on straight roads regardless of whether it was daytime or nighttime.

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

To clarify the utility of using near-miss car-to-pedestrian incident data, the authors investigated the motion pictures captured by drive recorders of 163 near-miss incidents from 2005 to 2009 and the national traffic accidents records based on 12,283 real-world fatal pedestrian accidents from 1999 to 2003 in Japan⁷⁾. The relationship of moving directions between vehicles and pedestrians on straight roads and intersections is defined as shown in Figure 1. On the straight roads, the cases that pedestrians were crossing the roads in front of the forward moving cars were defined as “A”, and the cases that pedestrians were walking at the same direction with the moving cars were defined as “C”. At the intersections, cars moved in three directions: forward, turning right, and turning left. The cases that pedestrians were crossing the roads in front of the forward moving cars were defined as “B”, and the cases that pedestrians were walking at the same direction with the initial moving cars which later turned right or left were defined as “D”.

The distribution of moving directions between vehicles and pedestrians in accident data and near-miss data is shown in Figure 2. When focusing on the distribution ratio of the cases pedestrians were crossing the roads in front of the forward moving cars (“A” and “B” in Figure 1), it is seen that these were 67% (fatal) vs. 74% (near-miss) in daytime, and 78% (fatal) vs. 69% (near-miss) in nighttime, respectively. The results indicated that approximately 70% pedestrians at the intersections or on straight roads were crossing the roads in front of the forward moving cars. Considering the features of pedestrians’ behaviors from this result, similarities are observed between accidents and near-miss incidents. It was determined that one could predict the pedestrian accident situations by analyzing the near-miss incident data containing motion pictures capturing the pedestrian behaviors. Therefore, in the next section, the authors investigate the detailed situations from the near-miss incident data that cars and pedestrians approached each other.

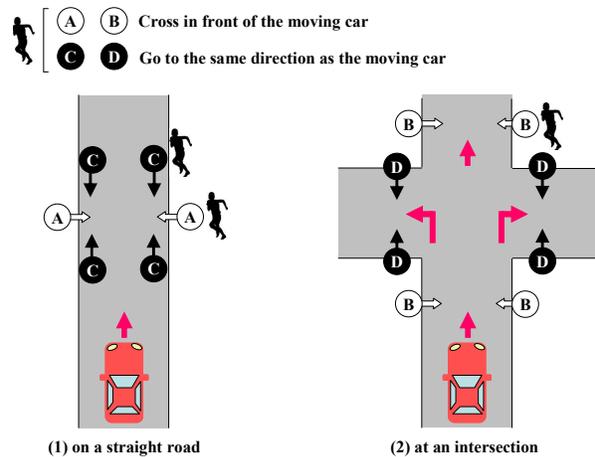


Fig. 1 Relationship of moving directions between a vehicle and pedestrian

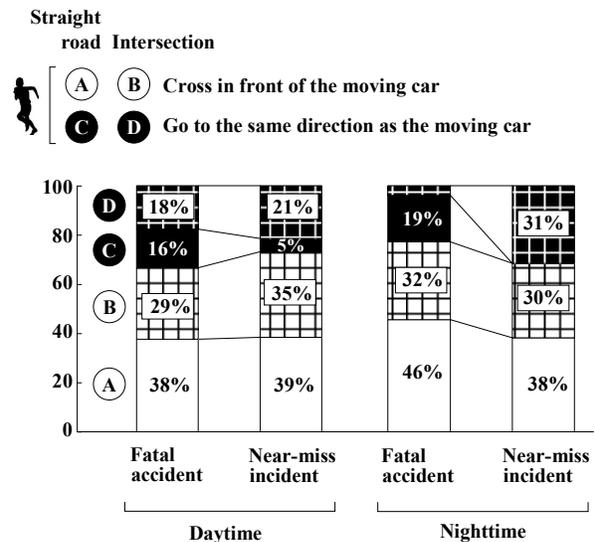


Fig. 2 Distribution of moving direction between a vehicle and pedestrian in accident data and near-miss data

NEAR-MISS IN-DEPTH ANALYSIS

Near-miss in-depth data

In this section, the time to collision (TTC) is estimated from the near-miss car-to-pedestrian incident data in which pedestrians were crossing the roads in front of the forward moving cars at the intersections or on straight roads. Basically, the near-miss incident was in such a situation that the car accident was avoided due to the attention and braking of the car driver. In the present study, the TTC was estimated from the near-miss data considering the worst case that a car moving toward a pedestrian would result in accident without the car driver’s braking.

Table 2 Summary of in-depth analysis of vehicle-to-pedestrian near-miss data (n=103 incidents)

Location	Straight road (n=55 incidents)				Intersection (n=48 incidents)				Total
	Daytime (n=28)		Nighttime (n=27)		Daytime (n=23)		Nighttime (n=25)		
Across from	Right	Left	Right	Left	Right	Left	Right	Left	
Adult pedestrian	10	14	12	14	12	11	13	10	96
Child pedestrian	2	2	0	1	0	0	0	2	7
Total	12	16	12	15	12	11	13	12	103

The near-miss incident data that cars and pedestrians approached each other were selected for the purpose of analysis. As a result, 103 out of 163 near-miss car-to-pedestrian incident data were used; pedestrians were crossing the roads in front of the forward moving cars at the intersections or on straight roads. The age group and near-miss location of the 103 incidents are summarized in Table 2. The numbers of the near-miss incidents were similar in daytime (28 cases) and night time (27 cases) at straight road and in daytime (23 cases) and night time (25 cases) at intersections. The numbers of incidents involving adult and child pedestrians were 96 and 7 cases, respectively.

Calculation of TTC

The TTC (second) was calculated by the following formula using the velocity (V: m/s) of a car with an installed drive recorder and the forward distance (L: m) between a car and a pedestrian at the moment a pedestrian appeared on a motion picture captured by the drive recorder as shown in Figure 3.

$$TTC = L/V \quad [1]$$

Here, V is the running velocity of the car just before the driver applies the brake after realizing the existence of a pedestrian. It was determined whether a driver applied the brakes by checking the braking signal and deceleration signal recorded in the drive recorder.

The authors also investigated the lateral distance (Ld: m) between one side of the car and the pedestrian by using the following formula.

$$Ld = LL - 0.85 \quad [2]$$

Here, LL (m) is approximately 1.7m which is the distance between the center of the drive recorder camera (the center of the car) and the pedestrian, and 0.85 m of the half distance of the full width of the car.

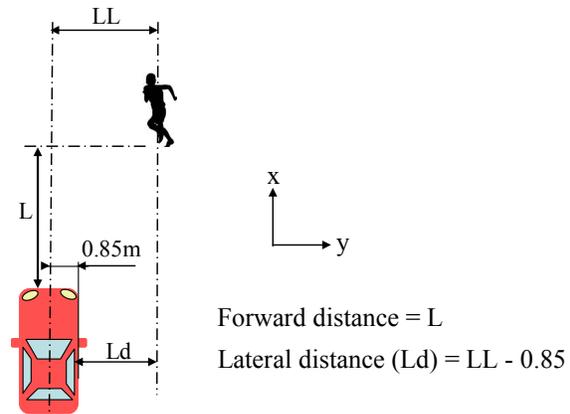


Fig. 3 Definition of a lane and distance

Figure 4 shows the estimated TTC distribution of the lateral distance (Ld) from the one side of a car to the pedestrian at the moment that the pedestrian appears on a motion picture captured by the drive recorder. The TTCs ranged from 0.5 seconds to 5.0 seconds. In determining the location of a pedestrian relative to the center of a car, it is observed that 49 cases were on the right hand side and 54 cases on the left hand side. The average TTC was 1.8 sec (SD 1.5 sec) for the cases on the right hand side, and 1.6 sec (SD 1.0 sec) for the cases on the left hand side. Since the average TTC was similar on both sides, the following analyses were performed regardless of whether the pedestrian was located on the right or left hand sides. The average TTC was 1.7 sec (SD 1.3 sec) for the total 103 cases.

The distribution of the estimated TTC and forward distance (L) between a car and a pedestrian is shown in Figure 5. Looking at the figure, one could observe a linear correlation between the forward distance and TTC theoretically.

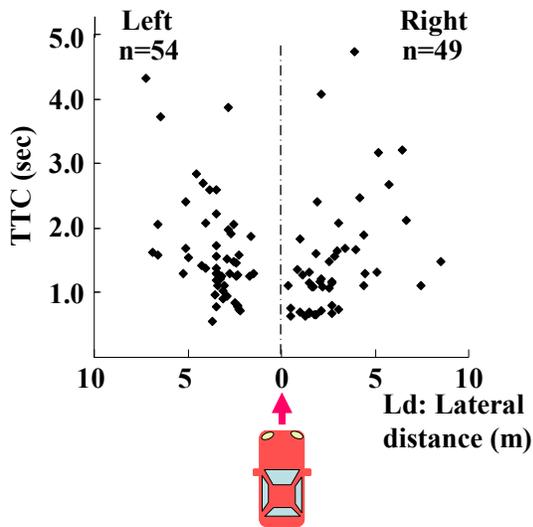


Fig. 4 Distribution of the estimated TTC and lateral distance (Ld)

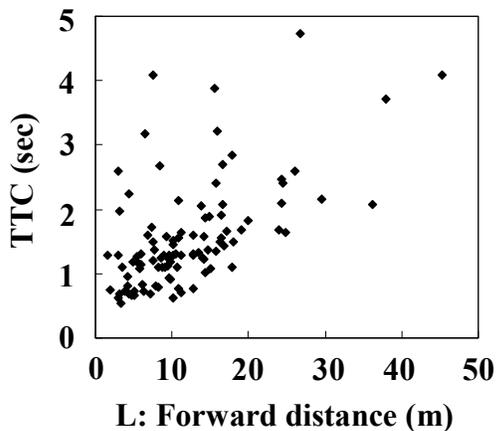


Fig. 5 Distribution of the estimated TTC and the forward distance (L)

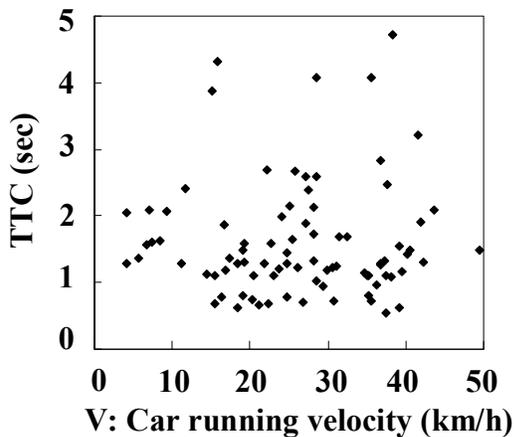


Fig. 6 Distribution of the estimated TTC and the car running velocity (V)

The distribution of the estimated TTC and the car running velocity (V) is shown in Figure 6. Theoretically, the TTC became shorter if the car running velocity was getting higher. On the other hand, no linear correlation between the car running velocity and TTC is observed. One could speculate several reasons for the widely-scattered coordinates in Figure 6. Therefore, in the next section, the authors investigate the detailed features of pedestrian behaviors.

Detailed Feature of Pedestrian Behaviors

The authors classified the pedestrians' popping out patterns in front of the drive recorder installed in a car into four categories as shown in Table 3. The classified patterns are (1) unobstructed view, (2) from behind a building, (3) from behind a parked vehicle, and (4) from behind a moving vehicle. The average of the TTC, the forward distance between a car and a pedestrian, and the car running velocity in classified 4 pedestrian pop out patterns are shown in Figure 7. Looking at the average TTC, the unobstructed view (1) was longest as 2.9 seconds, which was presumably caused by the longer forward distance (Ave 16.2m) regardless of the relatively higher running velocity of a car (Ave 30.3 km/h). The average TTC 1.4 seconds from behind a building (2) was similar to the average TTC 1.3 seconds of from behind a parked vehicle (3). And from behind a moving vehicle (4) was the shortest at 1.2 seconds, which was presumed to be caused by the higher running velocity of a car (Ave 32.9 km/h).

The average of the TTC, the forward distance between a car and a pedestrian, and the car running velocity in classified two pedestrian locations at crosswalk or without crosswalk of each classification is shown in Figure 8. The average TTC in the cases that pedestrians were walking across a crosswalk was longer than the average TTC in the cases that pedestrians were walking on the roads without a crosswalk. It was assumed to result in the effect of a crosswalk that a car driver would have enough time to put on the brake for the crosswalk ahead. When one focuses on the location of a crosswalk, it is observed that the average TTC 1.9 seconds in cases at intersections was longer than the average TTC 1.6 seconds in cases on straight roads. It was assumed that a car driver would recognize that he or she were in more danger of hitting a pedestrian at an intersection than on a straight road. So, it was determined that a car driver would put on the brake and have enough time to reach a crosswalk at an intersection. On the other hand, the average TTC in cases that pedestrians were walking across the roads at an intersection without a crosswalk was shortest as 1.2 seconds in the

four categories described in Figure 8. Even though these were near-miss incidents, it revealed that this condition had the high potential of causing an accident at an intersection without a crosswalk.

Table 3 Classified 4 pedestrian popping out patterns in front of a car installing the drive recorder

(1)	(2)	(3)	(4)
Unobstructed view	From behind a building	From behind a parked vehicle	From behind a moving vehicle

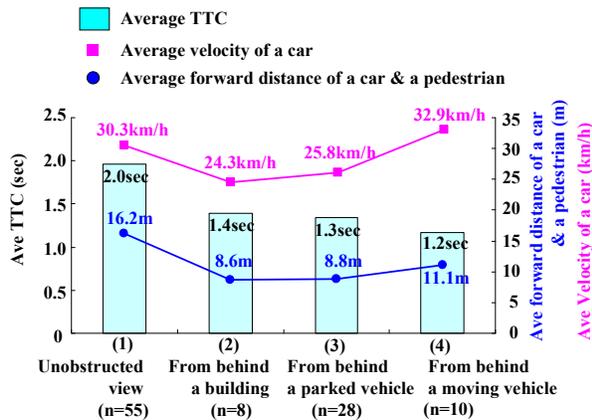


Fig. 7 Averages of TTC, forward distance between a car and a pedestrian, and the car running velocity in classified 4 pedestrian popping out patterns

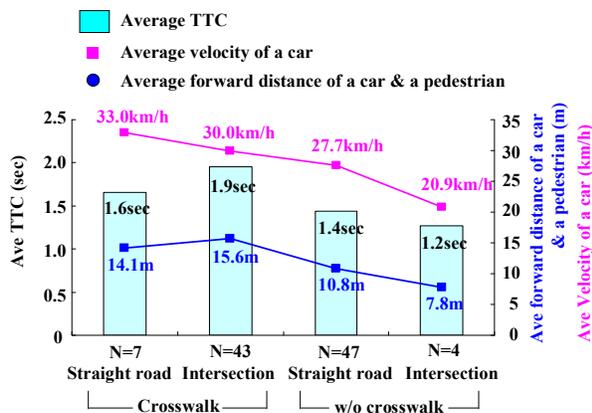


Fig. 8 Averages of the TTC, distance of a car and a pedestrian, and velocity of the drive recorder installed in a car on roads with or without crosswalk

DISCUSSION AND CONCLUSIONS

In the present study, the authors investigated the utility of near-miss situations for understanding the features of the contact situations between cars and pedestrians, and estimated the time to collision (TTC) by focusing on the near-miss incident data. Basically, the near-miss incident was in such a situation that a car accident was avoided by the attention and braking of the car driver.

1) The similarities between the data of near-miss incidents including motion pictures captured by drive recorders and the data of national traffic accidents based on real-world fatal pedestrian accidents in Japan were investigated. The results indicated that 70% pedestrians at intersections or on straight roads were crossing the roads in front of the forward moving cars both in accidents and near-miss incidents. Considering the features of pedestrians' behaviors from this result, similarities were found between accidents and near-miss incidents. It was determined that one could estimate the situations in car-to-pedestrian accidents from the near-miss incident data which included motion pictures capturing pedestrian behaviors.

2) The authors analyzed 103 near-miss car-to-pedestrian incident data in which pedestrians were crossing the roads in front of the forward moving cars at intersections or on straight roads. In the present study, it should be noted here that the TTC could be estimated from the near-miss data considering the worst case that a car moving toward a pedestrian would result in accident without the car driver's braking. The TTC was calculated from the velocity of a car installing a drive recorder and the distance between a car and a pedestrian at the moment a pedestrian initially appeared on a motion picture captured by the drive recorder. From the results, the average TTC was 1.7 seconds (SD 1.3 seconds). When one focuses on the pedestrians popping out patterns in front of the cars, it is observed that the average TTC was the shortest at 1.2 seconds in the cases that pedestrians popped out from behind moving vehicles on the opposite lane. The authors propose that the specifications of the safety device for the pedestrian detection and automatic braking should reflect the detailed information including the TTC obtained by the near miss situations.

3) In the present study, the authors focused on the 103 near-miss car-to-pedestrian incident data in order to obtain the TTC. Since the feature of the 103 near-miss car-to-pedestrian incident data was similar to the feature in accident records, the authors could define the available near-miss incident level for estimating accident situations based on the present analysis results such as the average TTC was 1.7 seconds (SD 1.3 seconds).

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