Study on fatal accidents in Toyota city aimed at zero traffic fatality

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Abstract - Since 2008, the authors inspected fatal traffic accidents on the spot every year, with the cooperation of Toyota police station in Aichi pref. In the jurisdiction, numbers of fatal accidents were 18 in 2008, 12 in 2009, 14 accidents in 2010, and 16 in 2011. We here report the results of our analysis of information obtained by detailed inspection for those that occurred from 2008 to 2010.

We focused on vehicle-to-pedestrian accidents, which accounted for about 45% of all accidents in 2008. Because many accidents occurred on residential roads not far from pedestrians' homes, it was revealed that the decrease of the collision speed by traffic calming such as humps and zone speed management, was highly effective. On the other hand, pedestrian detection technologies seemed to be also effective as a countermeasure on vehicle side. Every pedestrian position against a vehicle was clarified and TTC (Time to Collision) was calculated provisionally.

Pedestrian accidents in intersections were also examined. Among the intersection pedestrian accidents within the jurisdiction, compared with the national average in Japan, the ratio of intersections without a signal and the ratio without a pedestrian crossing were high. According to the comparison of the Japanese traffic accident patterns between 2001 and 2008, pedestrian accidents during turning right and turning left did not decrease much. For elderly drivers, these accidents occurred very often.

Finally, single vehicle accidents were analysed with the accident pattern analysis methods used above. There were high numbers of single vehicle accidents against object on single roads. Although fatal accidents against guardrails decreased, the numbers of fatal accidents against a utility pole and a sign pole were nearly constant. As for the impact with narrow width objects such as utility poles, the fatality rate was very high, and countermeasures of both road infrastructure and vehicles seem to be effective.

INTRODUCTION

There have been a number of in-depth accident studies in the world. As a vehicle manufacturer, the authors have been using many in-depth accident databases, such as NASS-CDS (National Automotive Sampling System - Crashworthiness Data System) in the United States, GIDAS (German In-Depth Accident Study) in Germany, CCIS (Co-operative Crash Investigation Study, quitted in 2009) in the United Kingdom and ITARDA (Institute for Traffic Accident Research and Data Analysis) in Japan. ITARDA is an only public organization approved by Japanese National Police Agency, which can investigate a traffic accident on the spot without any restriction. However, its investigating regions are very limited, and the volume of the database is very small.

Toyota city, the home town of TOYOTA Motor Corporation, is located in the eastern part of Aichi prefecture. Because Toyota city is far from ITARDA Tsukuba office, ITARDA normally do not investigate any fatal accident on the spot there. As a vehicle manufacturer, the authors strongly wish that the number of traffic fatalities in Toyota city would decrease to "zero". In 2008, in collaboration with Toyota police station, we started an accident investigating study on the spot where fatal traffic accidents occurred. In this paper, we summarize the three-year study, especially focusing on three categories: all pedestrian accidents, pedestrian accidents at intersections, and single vehicle accidents.

IN-DEPTH ACCIDENT STUDY IN TOYOTA CITY

Summary of fatal accidents in the jurisdiction of Toyota police station

In 2008, 18 fatal accidents occurred in the jurisdiction of Toyota police station. The data for all cases are summarized in Table 1. Half of fatal victims were elderly, consistent with national proportion (49%) in Japan. Most of them are so-called Vulnerable Road Users, such as pedestrians, bicycles, mopeds and a wheelchair.

Table 1. The summary of fatal accidents in the jurisdiction in 2008

No.	Date			Fatalities		Other party		Remarks	
1	11.Apr.	Fri.	20:30	70s F	Pedestrian	40s M	Std. PC.	Pedestrian was overlooked by a head light of a oncoming car.	Crossing
2	17.Apr.	Thu.	19:25	60s F	Pedestrian	30s F	Mini	Stepped into a roadway to avoid a puddle.	Walking at the same direction
3	21.Apr.	Mon.	13:50	7yo M	Pedestrian	60s F	Std. PC.	Crossing at a crosswalk in front of a park.	Crossing
4	20.May	Tue.	7:20	30s M	Bicycle	10s M	Bicycle	Bicycle collision	Head-on
5	10.Jun.	Tue.	9:50	30s F	Mini	60s M	L Truck	Collided to crossing light truck	Crossing
6	20.Jun.	Fri.	0:40	30s M	Pedestrian	20s M	Std. PC.	Crossing far from a intersection with signal.	Crossing
7	30.July	Wed.	17:00	50s F	Mini Truck	50s M	Std. PC.	On a riverside curve way, departed the lane	Head-on
8	2.Sep.	Wed.	4:10	60s M	Moped	—	—	Falling down	Fall
9	6.Sep.	Sat.	18:50	60s F	Mini	20s M	Std. Truck	Departed a lane after a former collision	Head-on
10	8.Oct.	Thu.	16:55	20s M	Mini	30s M	L Truck	Departed a lane and collided with a large truck	Head-on
11	19.Oct.	Sun	10:15	80s F	Pedestrian (Wheel chair)	50s M	Mini Truck	Electric wheelchair crossing at an intersection without signal.	Crossing
12	26.Oct.	Sun	20:00	20s M	Motorcycle	20s M	Std. Truck	Collided with a side of a turning vehicle	Crossing
13	2.Nov.	Sun	8:45	20s M	Std. PC.	—	—	Uncontrollable with high speed.	Self-loss
14	27.Nov.	Thu.	7:25	80s F	Pedestrian	40s F	Std. PC.	Collided with a pedestrian during right-turn at a intersection without signal.	Crossing
15	28.Nov.	Fri.	9:35	80s M	Moped	60s M	Std. Truck	During right turn at a intersection with signal, collided with a vehicle going straight.	Crosing
16	28.Nov.	Fri.	16:50	80s F	Pedestrian	10s M	Std. Truck	Collided with a pedestrian crossing from the left side at a intersection with signal.	Crossing
17	16.Dec.	Tue.	16:00	80s M	Bicycle	30s M	Std. Truck	Collided with a crossing bicycle during right turn at intersection with signal,	Crossing
18	30..Dec.	Tue.	21:30	50s M	Pedestrian	20s M	Std. PC.	Crossing through a bicycle crossing way.	Crossing

In 2009, 12 fatal accidents occurred in this jurisdiction. Table 2 shows the data for all these cases. During this year, 4 pedestrians, 4 motorcycle riders and 4 vehicle occupants were fatally injured.

Table 2. The summary of fatal accidents in the jurisdiction in 2009

No.	Date			Fatalities		Other party		Remarks	
1	9.Jun.	Fri.	10:40	80s F	Pedestrian	20s M	Mini Truck	Collided with a pedestrian on a crosswalk at an intersection without signal.	Crossing
2	5.Apr.	Sun	15:27	30s M	Motorcycle	40s M	Std. PC.	Collided with a vehicle driving wrong direction on a motor way	Right straight
3	16.Jun	Tue.	9:30	60s M	Motorcycle	50s M	Std. PC.	Collision at an Intersection with poor visibility.	Crossing
4	9.Aug.	Sun	5:45	50s M	Motorcycle	—	—	Collided with a guardrail at a curve road	Single accident
5	12.Aug.	Wed.	20:45	10s M	Motorcycle	30s M	Std. Truck	Collision with a going straight motorcycle during right-turn at an intersection without signal.	Right straight
6	2.Oct	Fri.	23:50	20s M	Std. Truck	—	—	Collided with a guardrail at an intersection curve way.	Single accident
7	29.Oct	Thu.	6:30	60s M	Pedestrian	50s M	Std. Truck	Collided with a crossing pedestrian during going straight at the intersection without signal.	Crossing
8	22.Nov.	Sun	17:30	40s M	Std. Truck	40s M	L Truck	Collided with a oncoming car during overtaking at curve road.	Head-on
9	25.Nov.	Wed.	17:35	80s M	Pedestrian	70s M	Std. Truck	Collided with a crossing pedestrian during go straight at an intersection without signal.	Crossing
10	6.Dec.	Sun	17:15	50s M	Pedestrian	80s M	Std. PC.	Collided with a crossing pedestrian during right turn at an intersection without signal.	Crossing
11	23.Dec.	Wed.	14:20	60s F	Mini Truck	40s M	L Truck	Departed the lane at a curve road and collided.	Head-on
12	23.Dec.	Wed.	14:20	50s F	Std. PC.	ditto	ditto	Collided with the vehicle protruding to a opposite lane by above impact.	Head-on

In 2010, 14 fatal accidents occurred in the jurisdiction, as summarized in Table 3. Many motorcycles and mopeds were involved in fatal accidents in this year.

Table 3. The summary of fatal accidents in the jurisdiction in 2010

No.	Date			Fatalities		Other party		Remarks	
1	14.Jun.	Thu.	22:05	10s M	Moped	–	–	Collided with a left curb of a single lane road	Single accident
2	27.Jun.	Wed.	9:35	30s M	Motorcycle	30s M	Std. PC.	Crossing collision at a intersection without signal.	Crossing
3	8.Mar.	Mon.	13:50	80s F	Bicycle	30s M	L Truck	Collision on a crosswalk at a intersection with signal	Crossing
4	20.Mar.	Sat.	0:30	50s M	Pedestrian	20s F	Mini	Collision on a crosswalk at a intersection with signal	Crossing
5	1.May	Sat.	11:40	30s M	Std. PC.	80s M	Std. PC.	Collision on a crosswalk at a intersection w/o signal.	Crossing
6	24.May	Mon.	9:15	70s F	M Truck	60s M	L Truck	Collided with an oncoming car on an opposite lane of a curve road.	Head-on
7	27.May	Thu.	15:50	80s F	Pedestrian	70s F	Std. PC.	Collision during crossing at a intersection without signal.	Crossing
8	2.Aug.	Mon.	11:50	60s F	Bicycle	40s F	Std. PC.	Crossing collision at a intersection without signal.	Crossing
9	31.July	Sat.	14:50	70s M	Std. PC.	–	–	Collided with a pole on side of a road at right curve.	Single accident
10	29.Aug.	Sun	9:05	40s M	Motorcycle	40s M	Std. PC.	Fell down and protruded to the opposite lane at a left curve road.	Head-on
11	11.Sep.	Sat.	18:25	10s F	Std. PC.	60s M	Mini Truck	During turning right according to signal, collided with a vehicle ignored signals and going straight.	Right straight
12	6.Dec.	Mon.	5:50	30s M	Motorcycle	20s M	Std. PC.	Collided with a going straight vehicle during right turn. (to parking lot)	Right straight
13	22.Dec.	Wed.	12:45	90s M	Moped	40s M	Std. PC.	Crossing collision at a intersection without signal.	Crossing
14	28.Dec.	Tue.	17:25	70s F	Moped	40s F	Mini	Collided with a going straight car during right turn at a intersection with signal.	Right straight

In 2011, 16 fatal accidents occurred in this jurisdiction. As summarized in Table 4, the fatalities were mostly elderly peoples and bicycle riders during this year.

Table.4 The outline of fatal accidents in the jurisdiction in 2011

	Date			Fatalities		Other party		Remarks	
1	7.Jun.	Fri.	9:25	90s M	Pedestrian	30s M	M Truck	Collided with a pedestrian at an intersection without crosswalk.	Crossing
2	11.Jun.	Tue.	15:20	80s F	Pedestrian	60s M	Std. PC.	Collided with a crossing-pedestrian at a single road.	Crossing
3	16.Feb	Wed.	0:30	60s M	Pedestrian	10s M	Mini	Collided with a pedestrian at intersection with signal.	Crossing
4	7.Mar.	Tue.	17:09	80s F	Std. PC.	40s M	Bus	Departed the lane at a curve road and collided with a bus.	Head-on
5	16.Apr.	Tue.	18:20	20s M	Std. PC.	40s M	M Truck	Departed the lane at a curve road and collided with a truck.	Head-on
6	30.May	Fri.	16:10	10s F	Bicycle	60s M	L Truck	Collided with a bicycle crossing at a crosswalk according to signal.	?
7	10.Aug.	Wed.	3:10	10s F	Moped	40s M	L Truck	Came out on a road from a parking and collided with a large truck.	Crossing
8	12.Aug.	Wed.	19:10	70s M	Bicycle	50s M	Std. PC.	Crossing collision at intersection without signal.	Crossing
9	10.Aug.	Sat.	4:35	70s M	Pedestrian	20s F	Std. PC.	Departed a road and collided with a pedestrian of opposite sidewalk at single road.	Passing the back-side
10	5.Oct.	Thu.	7:40	80s M	Mini Truck	20s M	Std. PC.	Crossing collision at a intersection without signal.	Crossing
11	28.Oct.	Sun	23:10	40s M	Bicycle	20s M	Std. PC.	Collided with a oncoming bicycle on wrong lane at two lanes road.	(Head-on)
12	15.Dec.	Sun	8:50	70s F	Bicycle	20s M	Mini	Collided with a bicycle rear-end at curve road.	Rear-end collision
13	12.Dec.	Sun	15:45	60s M	Std. PC.	40s M	L Truck	Departed a lane and collided with oncoming truck at a single lane road.	Head-on
14	18.Nov.	Thu.	6:00	30s M	Bicycle	Unknown	(Mini)	Hit-and-run after bicycle to bicycle collision.	?
15	28.Dec.	Fri.	18:15	70s F	Std. PC.	40s M	Std. Truck	Departed a lane and collided with oncoming truck at a single lane road.	Head-on
16	30.Dec.	Fri.	10:10	50s F	Moped	60s F	Std. PC.	Crossing collision at an intersection with signal.	Crossing

Figure 1 shows numbers of fatalities by their conditions for each year from 2008 to 2011 and for 4-year total in Toyota city, as well as the number for Japan in 2010. Because of small numbers of

causalities in Toyota city, these numbers fluctuated from year to year. However, the total numbers summed up for all four years were comparable to the national statistics of Japan in 2010.

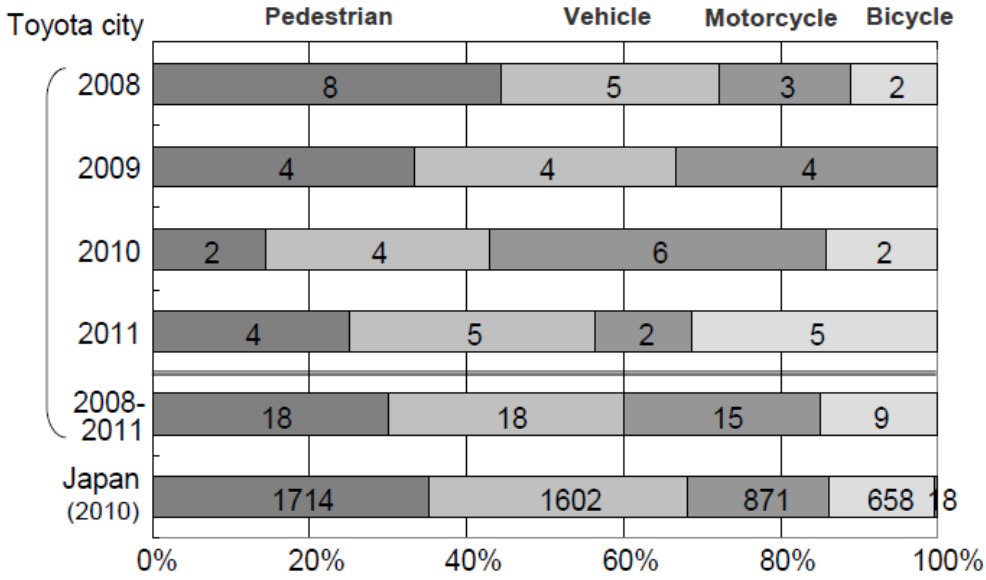


Figure 1. Traffic accident causalities by conditions in Toyota city and Japan

PEDESTRIAN ACCIDENT

Feature of pedestrian accidents

Figure 2 shows the spatial distribution of pedestrian accidents in the jurisdiction of Toyota Police Station in 2008 and 2009. Twelve pedestrians, including one in a wheelchair, were fatally injured. Seven pedestrians were elderly adults, and 5 were children and young adults. Regarding locations of accidents, most of them occurred on residential roads and streets, which were not far from pedestrians' homes in the centre of Toyota city.

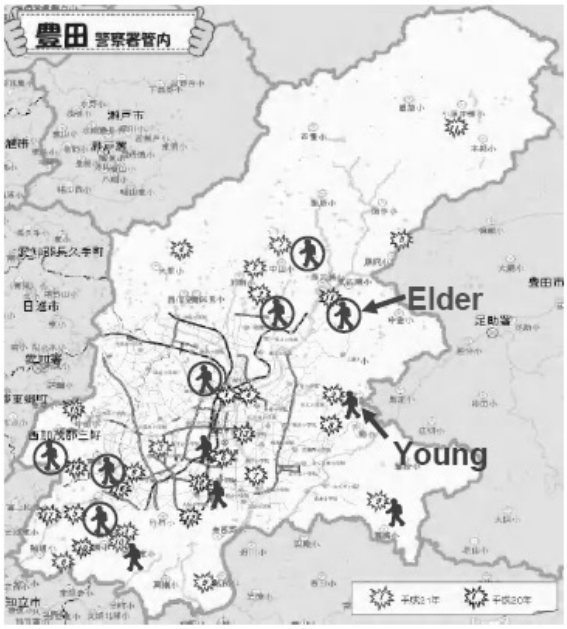


Figure 2. Spots of fatal pedestrian accidents in 2008 and 2009

Figure 3 shows the impact speed analysis comparing between Toyota city and Japan. Because of a lack of impact speed data in the Japanese accident database, we used the speed at which driver

recognized a risk of an impact. These data suggested that decreasing impact speed was very important for pedestrian accident. As countermeasures of pedestrian accidents, for example, the area management of travelling speed control (such as Zone 30 kph project) using a hump or a sign to decrease a travelling speed seems to be very effective, especially in the central area of the city.

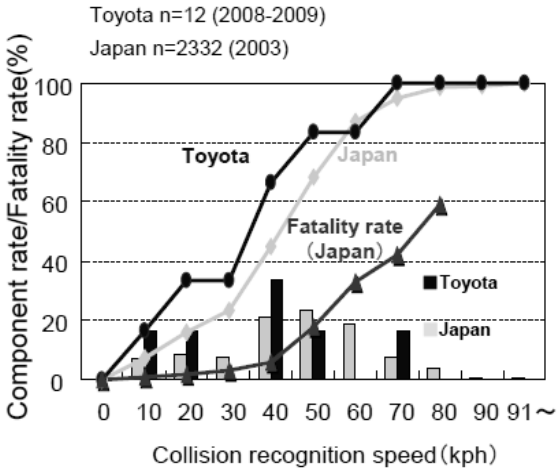


Figure 3. Distribution of vehicle speed for fatal pedestrian accidents

In-depth study for pedestrian detection system

Figure 4 shows the TTC (Time to Collision) of each pedestrian accident in the jurisdiction. To calculate the TTC, a typical pedestrian detection system with millimetre-wave radar and stereo cameras

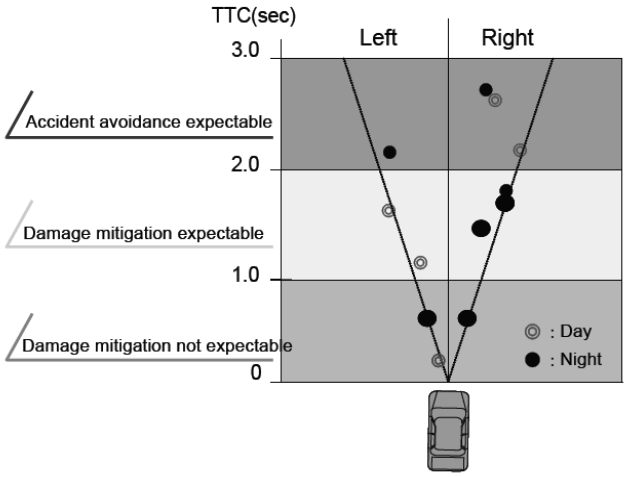


Figure 4. Plot of TTC for fatal pedestrian accidents

was used. We then classified the TTC into three categories. When the TTC was over 2.0 sec., accident avoidance would be expectable. When the TTC was over 1.0 sec. and less than 2.0 sec., damage mitigation would be expectable. Finally, when the TTC was less than 1.0 sec., damage mitigation would be difficult. On the assumption that both pedestrian accidents in Japan and those in the jurisdiction have the same distribution of TTC, we made a trial calculation of mitigation of pedestrian fatalities. In 2009, 1717 pedestrians were fatally injured in Japan. Based on this assumption, 711 pedestrians could have been saved if the system were installed on all vehicles in Japan.

Typical accident case in the jurisdiction

Figure 6 shows a sample case of fatal accidents. In this case, the driver was distracted from a frontal attention because of a conversation with other occupants in his car and hit the crossing children on a pedestrian crossing. As shown in Figure 6, if his vehicle was equipped with the pedestrian detection system, it could have found children far from the impact point, and they might not sustain fatal and severe injuries.

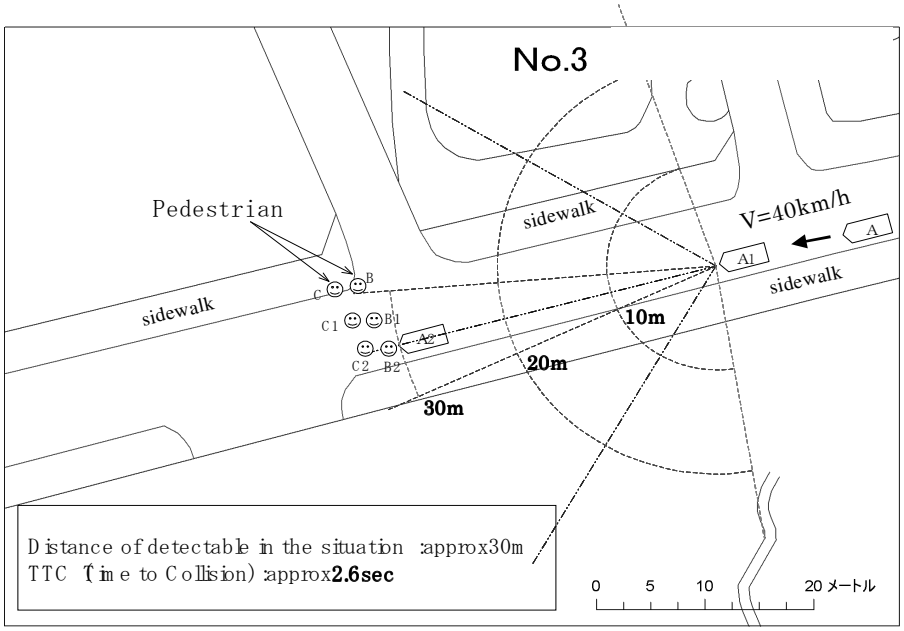


Figure 6. A sample case of fatal pedestrian accidents in Toyota city

INTERSECTION PEDESTRIAN ACCIDENT

Feature of pedestrian accidents at an intersection

The upper part of figure 7 shows the proportion of intersection with and without a signal in Toyota city and in Japan for fatal pedestrian accidents. Seventy-three percent of all accidents in Toyota were without a signal. In Japan, 53% were without a signal. The lower part of Figure 7 shows the same comparison with and without a pedestrian crossing. Again, 73% of all accidents in Toyota were without a crossing. In Japan, 44% were without a crossing. These data revealed that in Toyota city, most of pedestrian accidents occurred at intersections without signals or pedestrian crossings. It means intersection accidents in Toyota are similar to crossing accidents in a single road.

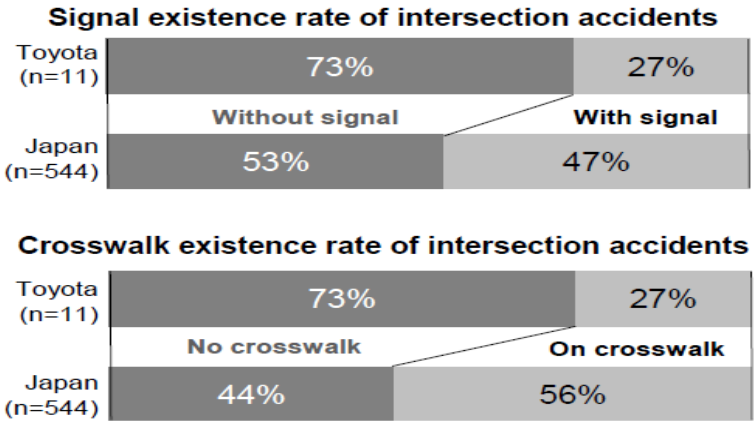


Figure 7. Existence of signals and crosswalks at intersections with fatal pedestrian accidents

Vehicle manoeuvre of pedestrian accidents at an intersection

We next analysed the numbers of fatal pedestrian accidents at intersections in 2001 and 2008 by vehicle manoeuvre: "start and go straight", "turning right" and "turning left". As shown in Figure 8, there was an average of 30% reduction in pedestrian accidents at intersections over the 7 years for all vehicle manoeuvres. When a vehicle started or went straight, the reduction rate was 33%. By contrast, when a vehicle turned right or left, the reduction rate was 18% and 12%, respectively. These values are very low comparing with the average rate (30%). Moreover, elderly drivers were more likely to be involved in fatal pedestrian accidents at intersections during turning right or turning left.

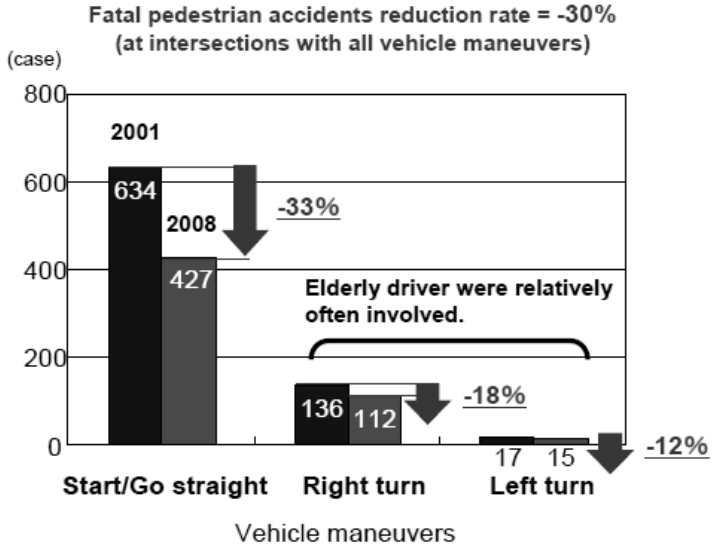


Figure 8. Numbers of fatal pedestrian accident at an intersection

Typical accident case in the jurisdiction

Figure 9 shows a sample case of fatal accidents at an intersection without signals. In this case, an elderly driver (in the 80s) did not notice that a pedestrian started crossing a road in the twilight. The driver began to turn right and hit the pedestrian. However, the driver did not realize that his vehicle ran over the pedestrian at all and continued to drive his car. There were no signal and no crossing lane where the pedestrian started crossing.

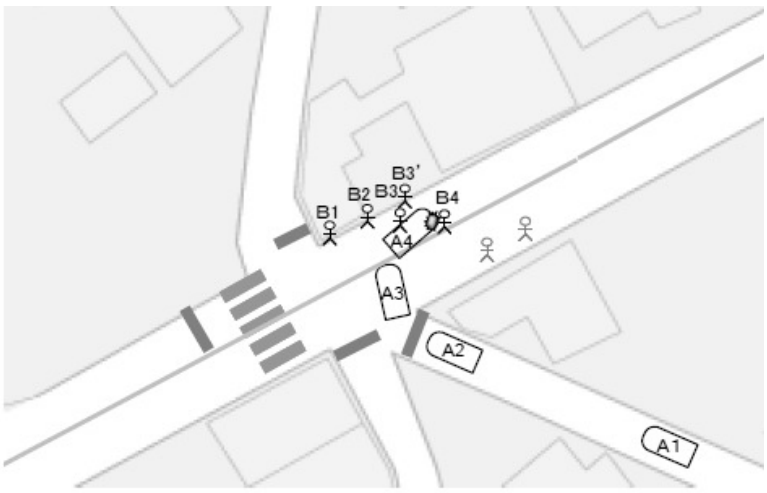


Figure 9. A sample case of fatal pedestrian accidents at an intersection

SINGLE VEHICLE ACCIDENT

Feature of single vehicle accidents against a fixed object

For vehicle occupants, single vehicle accidents against fixed objects are the worst scenario among fatal accidents. As shown in Figure 10, the distributions of single vehicle accidents by road types and objects were compared between 2001 and 2008. The numbers in circles mean numbers of fatal accidents in 2008 and the numbers in brackets mean indices compared with those in 2001.

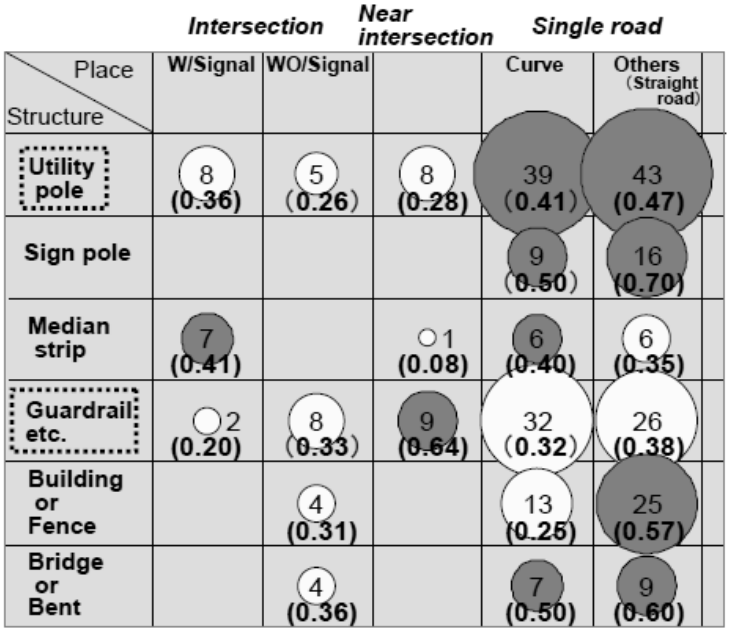


Figure 10. Numbers of single vehicle accidents against an object

Most of these accidents occurred on single roads. The numbers of fatal single vehicle accident against a guard rail decreased significantly. On the other hand, the numbers of fatal single vehicle accidents against a utility pole or a sign pole stayed nearly constant.

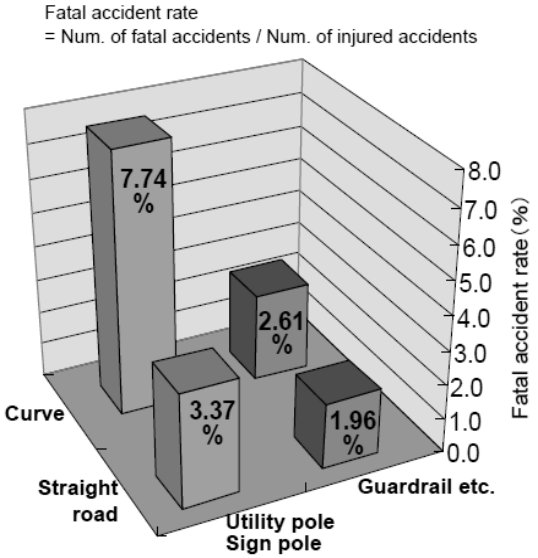


Figure 11. Fatal accident rates of single vehicle accidents against objects

Figure 11 shows the results of a comparison of the fatal single-vehicle accident against a pole and against a guardrail. Both on a curved road and on a straight road, the rate of the pole accidents was much higher than that of guardrail accidents.

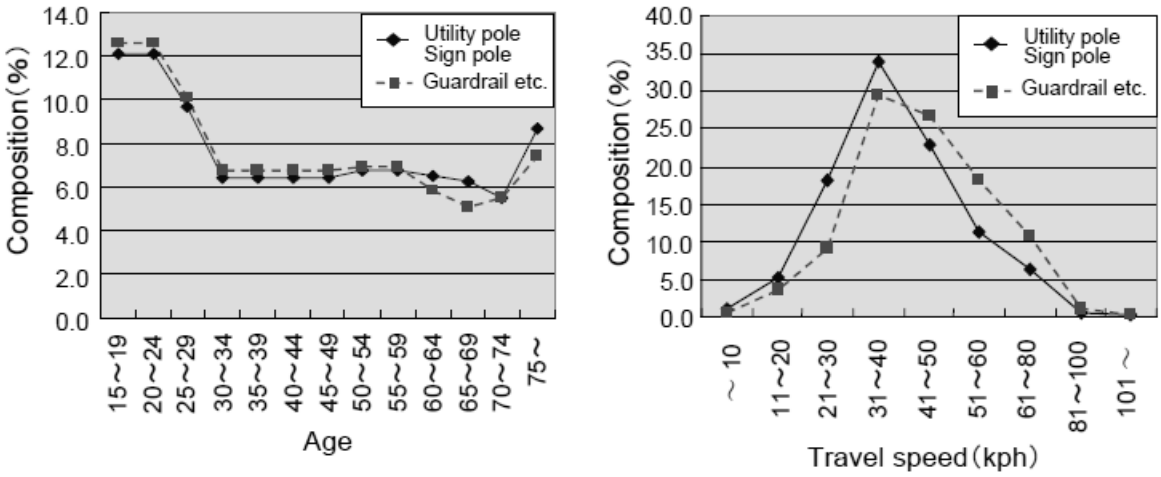


Figure 12. Distribution of driver age and travel speed for fatal single accidents

The left panel of Figure 12 shows the frequency distribution of fatal accidents against a guardrail and a pole in Japan by drivers' age. Comparing middle-aged drivers, the frequency of young drivers (under 30) and elderly (over 75) drivers are significantly high. However, between a guard rail and a pole, frequencies were comparable. We next examined vehicle travel speed for both accident types. The right panel of Figure 12 shows frequency of fatal accidents against a guardrail and a pole in Japan by vehicle travel speed at every 10 kph. Accidents against both a guardrail and a pole have a peak velocity at 31-40 kph. As in the age distribution, only small differences were found between the accident types.

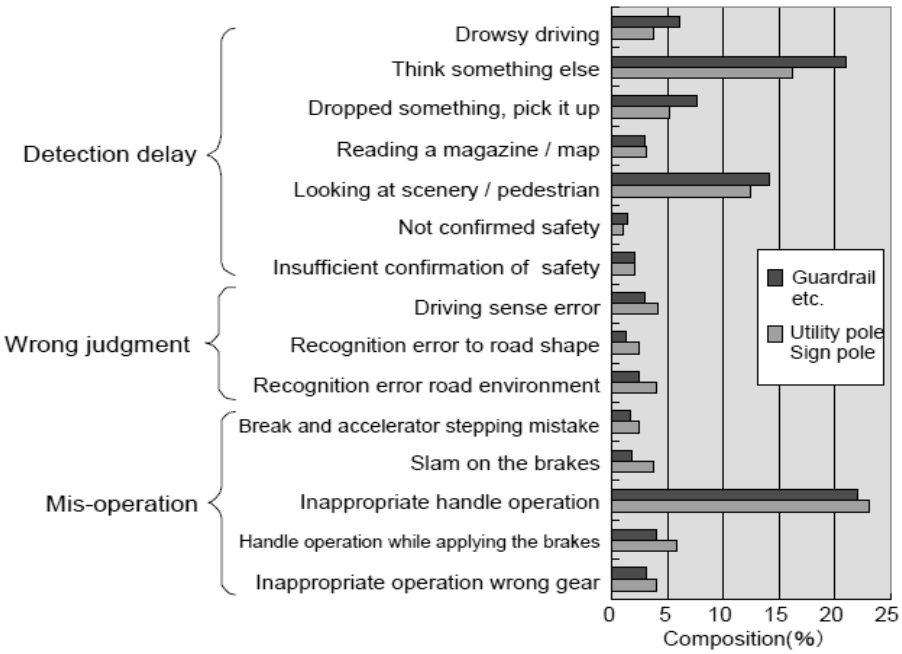
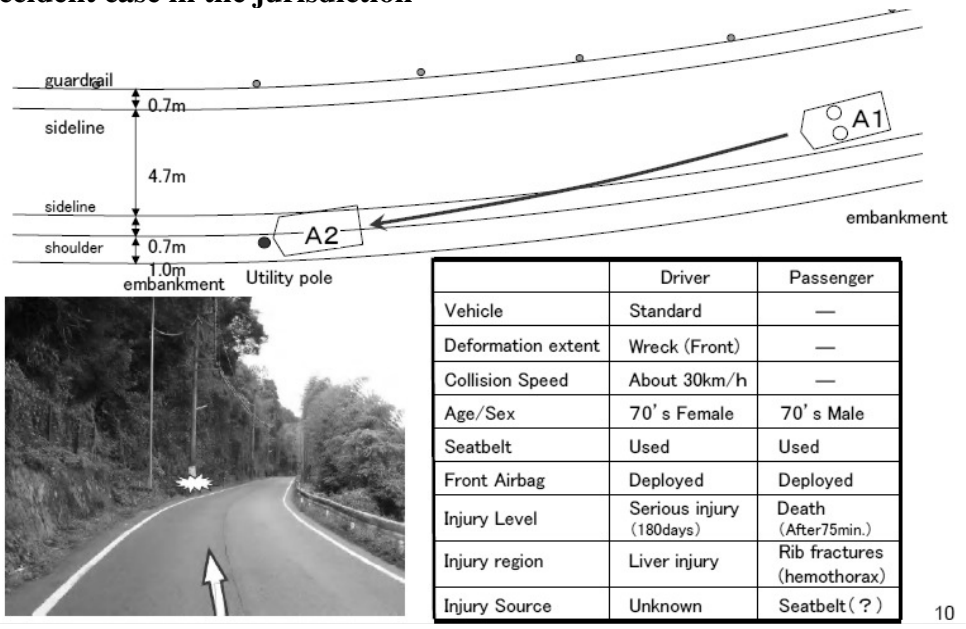


Figure 13. Driver behaviours in single vehicle accidents against a guard rail and a pole

As shown in Figure 13, behaviours of drivers were very similar between accidents against a guardrail and against a pole. After these analyses, we concluded that driver's injury severity might be determined by the object that his/her vehicle hit against, either a guardrail or a pole.

Typical accident case in the jurisdiction



	Driver	Passenger
Vehicle	Standard	—
Deformation extent	Wreck (Front)	—
Collision Speed	About 30km/h	—
Age/Sex	70's Female	70's Male
Seatbelt	Used	Used
Front Airbag	Deployed	Deployed
Injury Level	Serious injury (180days)	Death (After75min.)
Injury region	Liver injury	Rib fractures (hemothorax)
Injury Source	Unknown	Seatbelt(?)

Figure 14. A sample case of a single vehicle accident against a pole (Frontal impact)

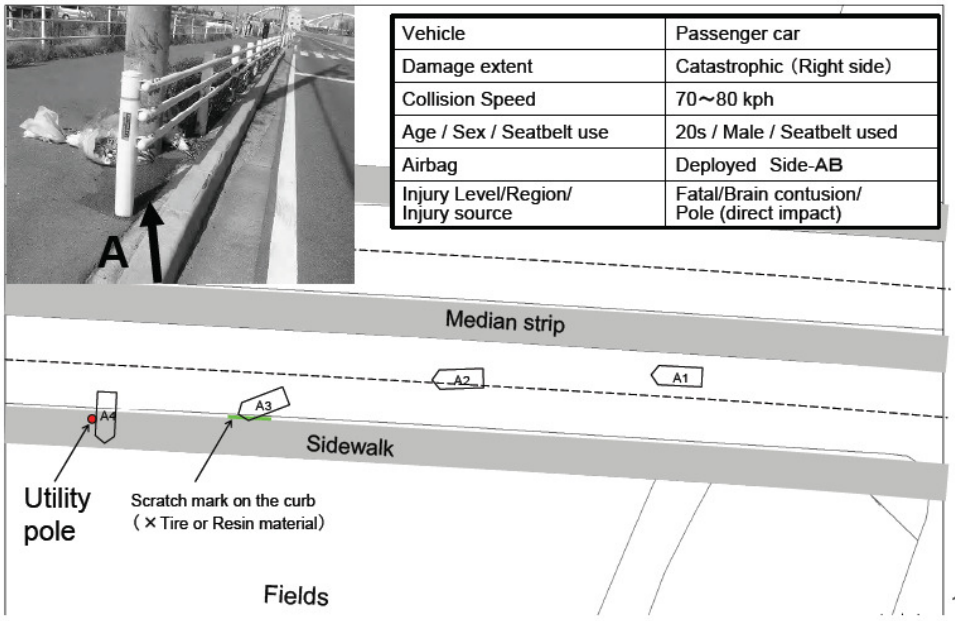


Figure 15. A sample case of a single vehicle accident against a pole (Lateral impact)

Figure 14 shows a sample case of a fatal single vehicle accident against a pole. In this case, the vehicle went straight against a pole beside a road, and an elderly passenger (in the 70s) with a seatbelt was sustained fatal injuries on his chest.

Figure 15 shows another example of fatal lateral impact against a pole. In this case, because of a high travelling speed, a young driver lost control of his vehicle and hit the driver side of his vehicle against a pole. He hit his head against the pole directly and sustained fatal injuries on his head. Unfortunately, a guardrail did not cover the pole fully and did not prevent the vehicle from a catastrophic deformation.

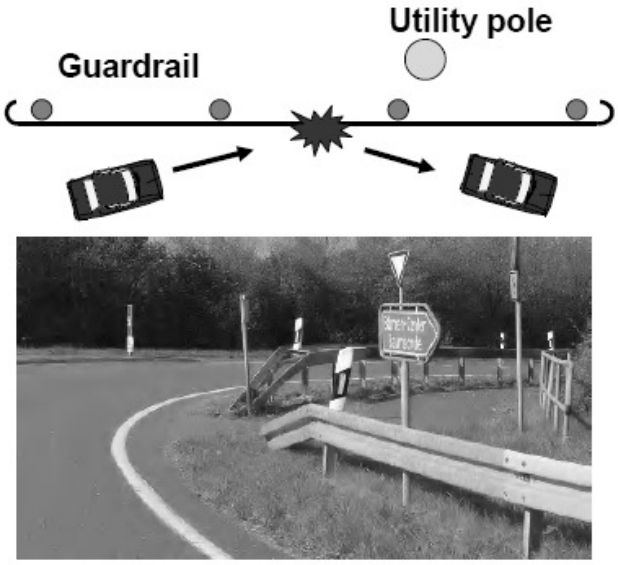


Figure 16. Structure of a guardrail edge

Figure 17. Restraint system for impact against a pole

Figures 16 and 17 show the countermeasure of both infrastructure and a vehicle for these accident cases. Impacts against a narrow object, such as a pole, resulted in very high fatality rates. For accidents such as these, countermeasure from both road infrastructure and vehicles might be effective.

DISCUSSION

For vehicle manufacturers, accident investigation is critical for the improvement of vehicle safety. In Japan, many manufacturers believe that an accident investigating activity is restricted by Japanese traffic law.

On the other hand, a collaborative study with a local police department that we report here is possible. In spite of the police cooperation, information on each fatal accident is very limited. We could not obtain any pictures of deformed vehicles or any documents with detailed information, not only for occupant injuries but also for vehicle deformations. The contractual agreement between a manufacturer and a police station to keep information classified might be a solution to receive detailed

information on accidents. There is still a small chance for a vehicle manufacturer's accident investigation to cooperate with an emergency hospital. Such studies seem to have been started already.

CONCLUSIONS

The study in the first year revealed that most of pedestrian accidents in the jurisdiction occurred on residential roads near the pedestrians' homes. In order to decrease the occurrence of these accidents, impact speed of vehicle needs to be reduced. The area speed limiting management, such as ZONE 30 kph and humps on residential roads, might be very effective to reduce travelling speed of vehicles, especially in the central area of Toyota city. On the other hand, equipping vehicles with pedestrian detecting systems will also be effective.

In the second year study, we focused on fatal pedestrian accidents at intersections. Compared to national averages, the percentage of crossing accidents without signal or crosswalk were very high in Toyota city. In order to decrease the number of pedestrian crossing accidents, road infrastructure measures such as signals, crosswalks and sidewalks would be effective.

In the study that we conducted in the third year, single vehicle accidents were examined. Severity of injuries to vehicle occupants depended mainly on what object their vehicle hit against: a guardrail or a pole. For these accidents, countermeasures should be approached from both road infrastructure and vehicles.

ACKNOWLEDGEMENT

We would like to express our appreciation to Toyota Police Department, for supporting our accident investigating activity on the spots.

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