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Utilizing Data from Event Data Recorders and Dashboard cameras for Micro-level Surveys

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1. Introduction

In finding measures for preventing the recurrence of traffic accidents and mitigating damage, it is necessary to collect as much information and data on accidents as possible, after which that information and data must be analyzed both scientifically and comprehensively in order to investigate the causes of accidents. Also, when investigating the cause of an accident, it is necessary to reproduce accident conditions as accurately as possible.

In micro-level surveys conducted by the Institute for Traffic Accident Research and Data Analysis (hereinafter, "ITARDA"), accident conditions are reproduced by using collected information and data to create a situation map that shows the situation before and after a collision on a road diagram of the accident site.

Furthermore, in recent years, vehicle reference information has been collected by event data recorders (hereinafter, "EDRs") in the form of chronological data including pre- and post-collision vehicle behavior and driver operation status, as well as by dashboard cameras in the form of footage showing the road traffic environment surrounding vehicles. Using these data to reproduce accident situations makes it is possible to create drawings (hereinafter, "reconstruction diagrams") that add objective information to situation maps, such as vehicle behavior immediately prior to a collision, driver operation status, and the road traffic environment surrounding vehicles.

The purpose of this research was to improve ITARDA's accident analysis technology by creating reconstruction diagrams using data from two actual accident case studies and by examining accident analysis methods using these reconstruction diagrams.

2. Reconstruction methods

2-1. Data recorded from EDRs

Data recorded from EDRs is categorized as either pre-crash or post-crash data, with the timestamp at which the collision was detected serving as the reference point. In this research, pre-crash data was used for reconstruction diagrams. Pre-crash data records several types of information in the form of chronological data, such as vehicle behavior immediately prior to an accident, driver operation status, and the operation status of electronic vehicle control systems. Examples of such information include vehicle speed, yaw rate, service brake ON/OFF status, as well as various data such as that regarding the operation status of the anti-lock braking system (hereinafter, "ABS") and collision damage mitigation braking system (hereinafter, "AEB"). Furthermore, during this research, service brake ON status refers to when the brake pedal is pressed, while service brake OFF status refers to when the brake pedal is not pressed.

2-2. Creating reconstruction diagrams

During this research, a vehicle equipped with an EDR and dashboard camera was used to reproduce the situation before a collision when the vehicle encountered an accident. Figure 1 shows an overview of how reconstruction diagrams are created.

In Step 1, the vehicle's travel trajectory was calculated using the pre-crash data. In this calculation

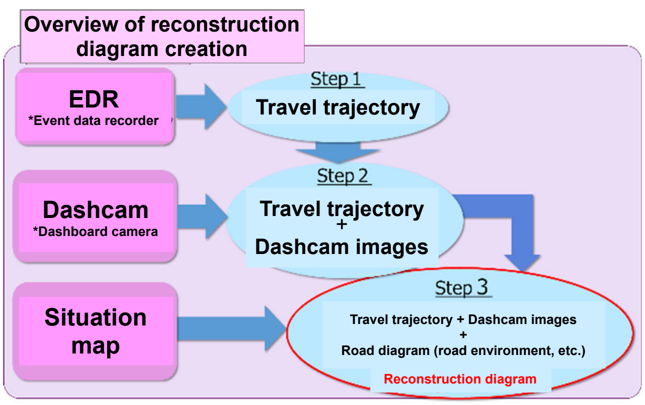

Fig. 1 Overview of reconstruction diagram creation

method [1], the vehicle speed and yaw rate are integrated for each timestamp of the pre-crash data, enabling the travel trajectory before the collision to be estimated. Also, the positions of each point on the estimated travel trajectory correspond one-to-one with each timestamp of the pre-crash data. For this reason, the position of each point for the travel trajectory is linked with recorded data for each timestamp of the pre-crash data. Furthermore, in this research, the positions of vehicle parts at each point of the travel trajectory are assumed to correspond to the installation location of the yaw rate sensor.

In Step 2, dashboard camera images are combined with each trajectory point of the travel trajectory estimated in Step 1. The timestamp of the moment at which the collision is detected in the pre-crash data is set as zero. The pre-crash data and dashboard camera video are then synchronized by aligning this zero-timestamp with the timestamp for moment in the video recorded by the dashboard camera in which the vehicle is assumed to have collided. Next, images from the dashboard camera that correspond to each timestamp in the pre-crash data are extracted and matched with the points of each trajectory point of the travel trajectory.

In Step 3, the travel trajectory from Step 2 is projected onto the situation map. As shown in (1) of Figure 2, the area of the vehicle subject to collision is identified from the vehicle investigation results, after which the location of the yaw rate sensor and the positional relationship with the vehicle center line (α) is confirmed from vehicle specifications, etc.

In order to match this positional relationship with the travel trajectory, a straight line (β) passing through two points (one at the time of collision and one at the timestamp just before the collision) is obtained. The location of the yaw rate sensor is then adjusted to the point at the time of collision, and vehicle center line (α) is matched with straight line (β).

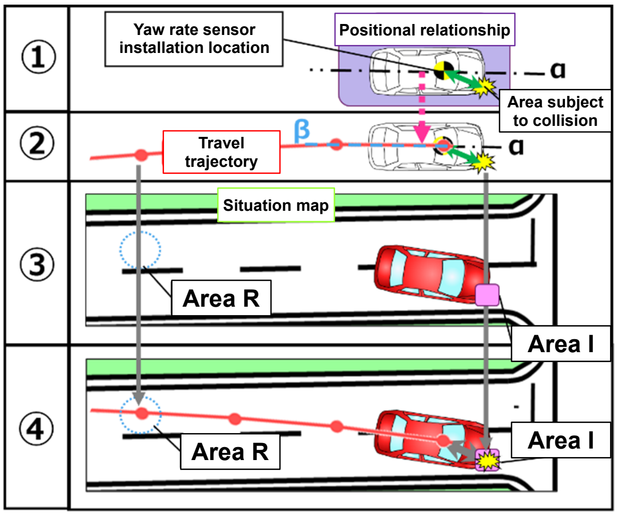

Fig. 2 Travel trajectory projection method [Step 3]

As shown in (3) of Figure 2, the location near where the vehicles are thought to have collided (hereinafter, “Area I”) is determined on a drawing of the situation map using information taken from interviews of the drivers involved in the accident and images recorded by the dashboard camera. Area I is a projection onto the ground surface of the area of the vehicle subjected to collision when the vehicle collision occurred. Additionally, the area where the installation location of the vehicle yaw rate sensor passed within the range traveled from 5 seconds before the collision detection timestamp until the collision detection timestamp (hereinafter, “Area R”) is obtained from the dashboard camera video.

Finally, as shown in (4) of Figure 2, the travel trajectory is projected onto drawing of the situation map, by aligning area of the vehicle subjected to collision with Area I so that the points of the travel trajectory before the collision pass through Area R.

3. Applying reconstruction methods to accident case studies

3-1. Applying reconstruction methods to Case Study 1

Accident category	Four-wheeled vehicle × Four-wheeled vehicle	Accident type	Right-turn against accident

	Vehicle A	Vehicle B
Type	Medium-sized passenger vehicle	Mini-vehicle
Year first registered	March 2020	April 2012
EDR	Yes	No
Dashcam	Yes	Yes
AEB installation	Yes	No
Occupant	70 years old woman	60 years old woman
Accident overview	While turning right from the right lane at a crossroad intersection with traffic lights, Vehicle A collided with Vehicle B, which was going straight in the first lane of the opposite direction.	
SIP accident pattern	PCC-TR11-TR2	

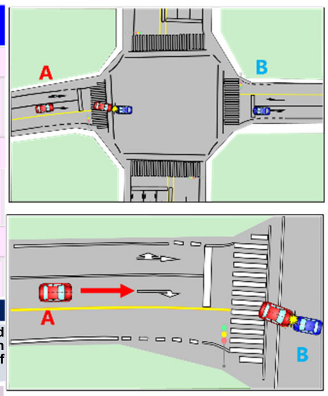

Fig. 3 Accident summary and situation map for Case Study 1

Figure 3 shows the accident summary and situation map for Case Study 1. Case Study 1 involved an accident at an intersection with traffic lights in which a right-turning four-wheeled vehicle (hereinafter, "Vehicle A") collided with a straight-moving four-wheeled vehicle (hereinafter, "Vehicle B") on a road with two lanes in each direction intersecting a road with four lanes in each direction. After waiting to turn right, Vehicle A commenced its right turn by following the preceding vehicle, at which time it collided with Vehicle B, which was proceeding straight in the opposing lane. In this case, Vehicle A was a medium-sized passenger vehicle, while Vehicle B was a mini-vehicle. Vehicle A was equipped with an EDR, dashboard camera and AEB functions, while Vehicle B was only equipped with a dashboard camera.

During an interview, the driver of Vehicle A stated, "I started to turn right after the car in front of me, after which I collided with the oncoming vehicle (Vehicle B), which was making a right turn." Because the driver did not notice the oncoming vehicle until the collision occurred, they could not brake or steer to avoid the collision. The driver also stated that they thought the automatic brakes may have operated. In this case, an interview with the driver of Vehicle B could not be obtained.

3-2. Reconstruction results for Case Study 1

Figure 4 shows the estimated travel trajectory obtained using the pre-crash data of the EDR of Vehicle A using the method shown in Step 1 of 2-2. The point of the travel trajectory at 0.00 sec. in Figure 4 indicated the timestamp for the moment the vehicle collision was detected. Also, Figure 5 shows a reconstruction diagram for Vehicle A obtained using the method shown in 2-2.

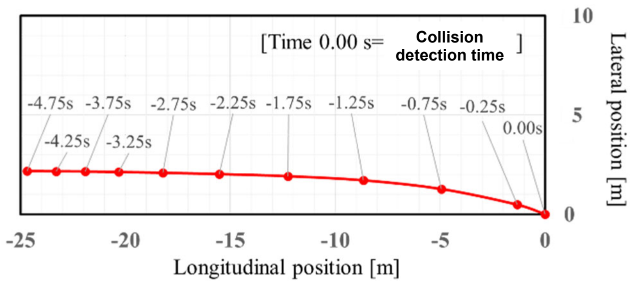

Fig. 4 Travel trajectory of Vehicle A in Case Study 1

Figure 5 shows a portion of the pre-crash data (timestamps, vehicle speed, and ON/OFF statuses of the service brake, ABS, and AEB) and images from the dashboard camera for each point of the travel trajectory once the traffic light turned yellow, starting from -2.25 seconds. The yellow boxes in the dashboard camera images show the vehicle ahead of Vehicle A while the blue boxes show Vehicle B.

The data for each point shown in Figure 5 are as follows:

・ The vehicle speed was approximately 22 km/h at -2.25 seconds, approximately 25 km/h at -1.75 seconds, approximately 27 km/h at both -1.25 and -0.75 seconds, approximately 26 km/h at -0.25 seconds, and approximately 15 km/h at 0.00 seconds.

- The service brake was OFF from -2.25 seconds to -0.75 seconds, and ON from -0.25 seconds to 0.00 seconds.
- The ABS was OFF between -2.25 seconds and -0.25 seconds, and ON at 0.00 seconds.
- The AEB was OFF for the entire time from -2.25 seconds to 0.00 seconds.
- The traffic light in the front of the vehicle was yellow at -2.25 seconds, but red between -1.75 and 0.00 seconds.

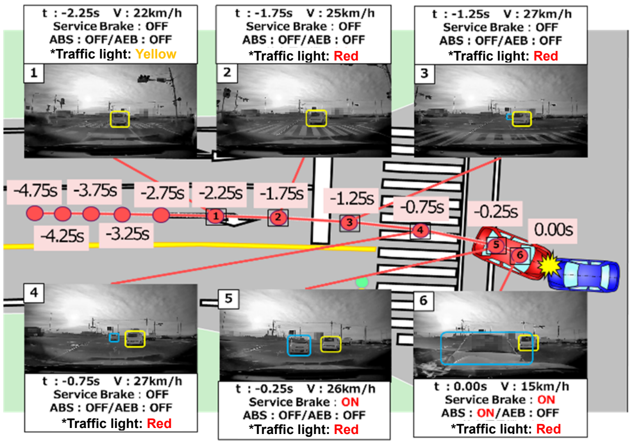

Fig. 5 Reconstruction diagram for Vehicle A in Case Study 1

3-3. Applying reconstruction methods to Case Study 2

Figure 6 shows the accident summary and situation map for Case Study 2. Case Study 2 involved a crossing collision between two four-wheeled vehicles at an intersection.

In this case, Vehicle A was a mini-vehicle, while Vehicle B was a medium-sized passenger vehicle. Vehicle B was equipped with an EDR, dashboard camera and AEB function.

In an interview with the driver of vehicle A, they stated, "I stopped inside the intersection to make a right turn and collided with Vehicle B". Furthermore, in an interview with the driver of Vehicle B, they stated, "When entering the intersection at approximately 60 km/h, I felt a sense of danger and applied the brakes, but ended up colliding with the other vehicle. Also, I don’t think the AEB operated when the accident occurred”.

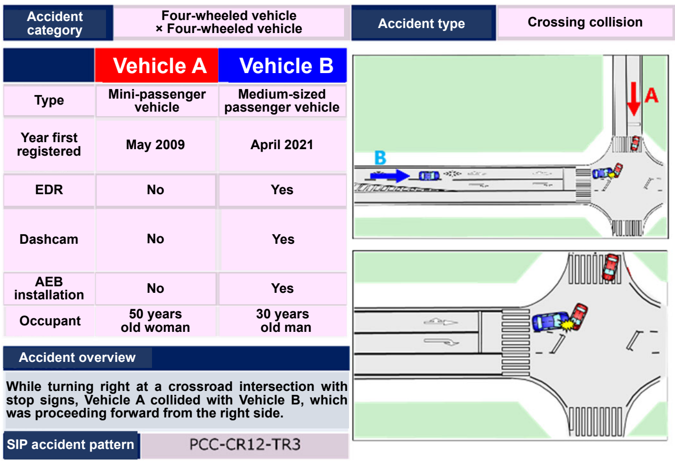

Fig. 6 Accident summary and situation map for Case Study 2

3-4. Reconstruction results for Case Study 2

In Case Study 2, Figure 6 shows a reconstruction diagram for Vehicle B obtained using the method shown in 2-2.

Also, Figure 7 shows an image of when the vehicle started to enter the intersection.

This figure shows a portion of the pre-crash data (timestamps, vehicle speed, and ON/OFF statuses of the service brake, ABS, and AEB) and images from the dashboard camera for each point of the travel trajectory starting from -1.70 seconds. The red boxes in the dashboard camera images show Vehicle A, which collided with Vehicle B. Also, the reconstruction diagram in Figure 6 shows data starting from -1.70 seconds.

The data for each point shown in Figure 7 are as follows:

- The vehicle speed was approximately 56 km/h at -1.70 seconds, approximately 56 km/h between -1.20 seconds and -0.20 seconds, and approximately 54 km/h at -0.00 seconds.
- The service brake was OFF from -1.70 seconds to -0.70 seconds, and ON from -0.20 seconds to 0.00 seconds.
- The ABS was OFF for the entire time from -1.75 seconds to 0.00 seconds.
- The operating status of the AEB was not included in the pre-crash record for Vehicle B. For this reason, we checked the audio recorded by the dashboard camera of Vehicle B, and because no warning sounds could be heard from this recording, it is assumed that the AEB did not operate before the collision.

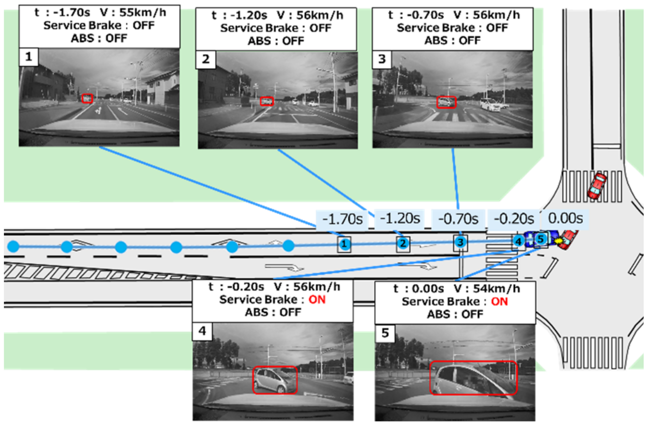

Fig. 7 Reconstruction diagram for Case Study 2

4. Examining accident analysis methods using reconstruction results

4-1. Estimating driver danger perception speed

When investigating and analyzing accidents, the vehicle speed at which the driver perceives danger (danger perception speed) is an important value, such as for when the probability of death or serious injury is estimated by the automatic emergency call system (D-call net). However, in many cases, information on the danger perception speed cannot be obtained from interviews with drivers, which is a problem when collecting information during accident investigations. Therefore, in this research, we estimated the driver's danger perception speed in the reconstruction diagrams for Case Studies 1 and 2.

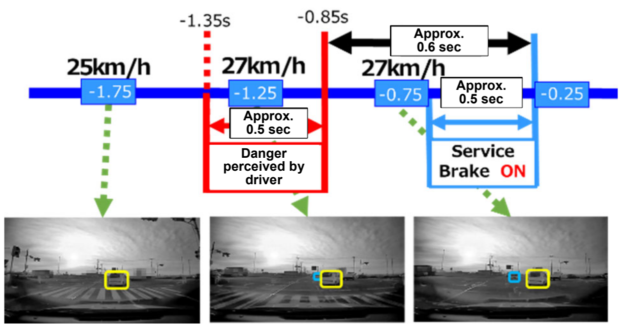

Fig. 8 Danger perception speed of driver of Vehicle A in Case Study 1

As mentioned in 3-1, the driver of Vehicle A in Case Study 1 stated, "I could not brake because I didn't notice Vehicle B until the collision occurred". However, in the reconstruction diagram shown in Figure 5, because the service brake was ON at -0.25 seconds, it is conceivable that the service brake was ON between -0.75 seconds and -0.25 seconds. If we assume that activation of the service brake (service brake ON status) is a result of the driver perceiving danger, and relying upon the literature [(2)] which suggests a reaction time of approximately 0.6 seconds from the driver's danger perception until the driver starts pressing braking pedal, it can be assumed that the driver of Vehicle A perceived danger between -1.35 seconds and -0.85 seconds. Therefore, as shown in Figure 8, the danger perception speed was estimated to be 25 km/h or 27 km/h, which was the vehicle speed at timestamps for the three pre-crash data (-1.75 seconds, -1.25 seconds, -0.75 seconds) including this time range.

In Case Study 2, the danger perception speed of the driver of Vehicle B was estimated using the reconstruction diagram.

As mentioned in 3-3, the driver of Vehicle B stated, "I entered the intersection at approximately 60 km/h". Accordingly, the information gained from the interview led to the danger perception speed being estimated as approximately 60 km/h.

In the reconstruction diagram shown in Figure 7, the service brake status was ON at -0.20 seconds.

Accordingly, it is conceivable that the service brake of Vehicle B was ON between -0.70 seconds and -0.20 seconds. Using the same method as that from Case Study 1, it is conceivable that the driver of Vehicle B perceived danger between -1.30 seconds and -0.80 seconds. Therefore, as shown in Figure 9, the danger perception speed was estimated to be 55 km/h or 56 km/h, which was the vehicle speed at timestamps for the three pre-crash data (-1.70 seconds, -1.20 seconds, -0.70 seconds) including this time range. From this, we can see that in Case Study 2 there was a difference of approximately 5 km/h between the danger perception speed stated by the driver of Vehicle B and the figure obtained from the reconstruction diagram. If we consider that the danger perception speed stated by the driver is rounded to the nearest 5 km/h (using cash rounding), a difference of approximately 5 km/h is not considered significant.

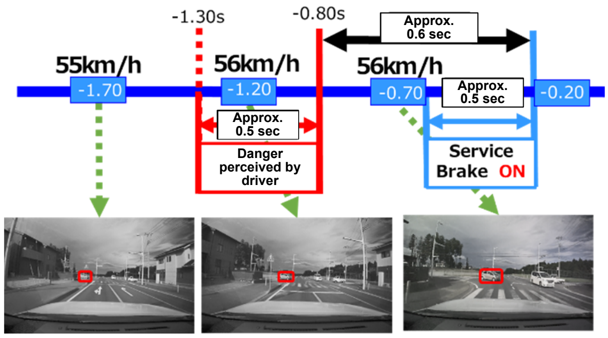

Fig. 9 Danger perception speed of driver of Vehicle A in Case Study 2

The above suggests that estimations of driver danger perception speeds can be inferred through the use of reconstruction diagrams.

4-2. Analysis of AEB operation status

Using the reconstruction diagrams from Case Studies 1 and 2, we analyzed the operation status of the vehicle AEB systems.

As seen in 3-2 and 3-4, the AEB did not operate for Vehicle A in Case Study 1 or Vehicle B in Case Study 2. To find the reason why the AEB failed to operate, we examined the conditions made evident from resources such as reconstruction diagrams, as well as the AEB operating conditions listed in the specifications of each vehicle's owner's manual.

Table 1 shows the AEB operating conditions for Vehicle A in Case Study 1 when turning right and was taken from the specifications [(3)] shown in the vehicle's owner's manual.

The reconstruction diagram in Figure 5 shows that the speed of Vehicle A before the start of braking (-0.75 seconds) was approximately 27 km/h, while the video recorded by the dashboard camera estimated the speed of Vehicle B before the collision to be approximately 45 km/h.

・Intersection turning assistance (pre-crash brake)

Operation target	Own vehicle speed	Oncoming vehicle speed	Relative speed
Vehicle	Approx. 15 to 25 km/h	Approx. 30 to 45 km/h	Approx. 45 to 70 km/h

Table 1. AEB operating conditions of Vehicle A in Case Study 1

Based on this information, it conceivable that the

AEB did not operate because the relative speed of Vehicles A and B at the start of braking was approximately 72 km/h, which was outside the specified range for AEB operating conditions (approx. 40 km/h to 70 km/h). Furthermore, as shown by the dashboard camera images in Figure 5, because Vehicle B could not be seen by the driver of Vehicle A until -1.25 seconds due to the vehicle in front of Vehicle A, detection of Vehicle B by the forward-facing sensors and camera of Vehicle A was delayed, or was not possible.

Table 2 shows the normal AEB operating conditions for Vehicle B in Case Study 2 and was taken from the specifications [(4)] shown in the vehicle's owner's manual.

▪ Pre-crash brake

Operation target	Own vehicle speed	Relative speed
Vehicle	Approx. 15 to 25 km/h	Approx. 45 to 70 km/h

Table 2. AEB operating conditions of Vehicle B in Case Study 2

The reconstruction diagram in Figure 6 shows that the speed of Vehicle B before the start of braking was approximately 56 km/h, while the relative speed of Vehicles A and B was approximately 56 km/h, which both fall within the specified range for AEB operating conditions (approximately 10 km/h to 180 km/h). However, according to the specifications [(4)] listed in the owner's manual of Vehicle B, it states, "the AEB system may not operate properly when approaching a vehicle in front that is facing sideways or in the direction of your vehicle". Because this description may be applied to the situation in Case Study 2, it is possibly the reason why the AEB did not operate in the case of this accident.

5. Conclusion

The purpose of this research was to improve accident analysis capabilities by creating reconstruction diagrams using data from EDRs and dashboard cameras for use in actual accident case studies and by examining accident analysis methods using these reconstruction diagrams.

- The creation of reconstruction diagrams enabled us to use pre-crash data linked to each trajectory point of the vehicle travel trajectory to show information on vehicle control, such as vehicle speeds and service brake on/off statuses. Also, from the dashboard camera images at the time of the accident, we were able to confirm the road traffic environment surrounding the vehicle.
- Our study of accident analysis methods using reconstruction diagrams enabled us to show a method of estimating the driver danger perception speed and an method of analyzing the AEB operation status.

6. Sources

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