2022
25th Presentation Session for Traffic Accident Investigations, Analysis, and Research

"Analysis of Situation Regarding Occurrences of Rear-End Collision Accidents at Expressways and Effects of AEB"

Shinpei Yoshida
Researcher, Autonomous Driving Section, Autonomous Driving Group

1. Introduction

1-1. Background and objectives of research

In recent years, in Japan, based on government strategies such as the "Public-Private ITS Initiative/Roadmaps" and the "Advanced Safety Vehicle (ASV) Promotion Plan," various initiatives have been promoted with the aim of the early realization of autonomous driving. In order to realize a safe automotive society, it will be important to not only develop and popularize advanced safety vehicles and autonomous vehicles that are equipped with driving support functions, but also to build road traffic environments that support the operation of driving-support functions and autonomous-driving functions. In order to achieve this, it will be necessary to understand the types of road traffic environments under which traffic accidents involving vehicles that have driving support functions are occurring.

In the research on this occasion, we focused on autonomous emergency braking systems (hereinafter referred to as "AEB") and targeted rear-end collision accidents that have occurred on expressways. We compared the situations regarding accident occurrences among AEB-equipped vehicles and non-AEB-equipped vehicles, and, based on this, we analyzed the accident reduction effects of AEB according to traffic characteristics and lane-configuration differences.

1-2. Overview of autonomous emergency braking (AEB)

Using sensors such as in-vehicle cameras and millimeter-wave radar, AEB detects frontward vehicle, pedestrians, and so on, and if there is a risk of a collision, it encourages the driver to operate the brake via a warning, and if the system has determined that a collision is unavoidable, it controls the brakes autonomously. Thus, AEB is a type of device that avoids collisions and mitigates damage in the event of a collision. In Japan, in 2020, the percentage of new passenger vehicle equipped with AEB(1) amounted to 91% (3,701,104 vehicles equipped with AEB among the total of 4,044,976 vehicles produced), and further popularization is anticipated in the future due to factors such as AEB installation incrementally being made obligatory for new vehicles starting in November 2021.

2. Overview of analysis

2-1. Data used

In our analysis, we matched and analyzed various types of data (traffic accident statistics, vehicle information, road traffic information, and AEB information) that is in the possession of the Institute for Traffic Accident Research and Data Analysis (hereinafter referred to as "ITARDA") (Figure 1). When matching the data, we connected the vehicle identification number, which is included in AEB information and vehicle information (automobile registration data), and the registration number, which is included in vehicle information and traffic accident information. Furthermore, based on

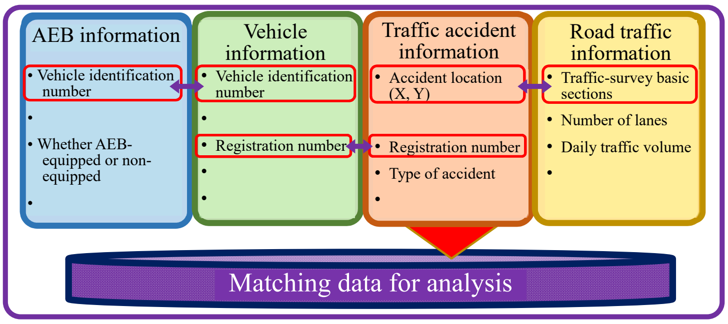


Figure 1. Image of creation of matching data for analysis

latitude and longitude information regarding accident locations that is included in the accident information, we connected the accidents with the traffic-survey basic sections that are included in the road traffic information (National Survey of Road and Street Traffic Conditions). As a result, we were able to identify accidents caused by vehicles regarding which the status of AEB-equipment was clear, and the road traffic conditions at the locations of these accidents.

2-2. Analysis conditions and analysis methods

In our analysis, we targeted rear-end collision accidents that occurred on main roads such as national expressways (excluding interchanges, junctions, and areas near toll booths) in which the primary party was a passenger vehicle, as shown in Chart 1. In cases in which the vehicle was AEB-equipped, and in cases in which the vehicle was non-AEB-equipped, we calculated the "numbers of rear-end collision accidents per vehicle owned" as indicators showing accident-proneness, and compared the differences. We calculated the specific indicators by dividing the sum of the numbers of rear-end collision accidents among AEB-equipped vehicles and non-AEB-equipped vehicles that occurred during the targeted analysis period (2017 to 2020), by the sum of the numbers of registered/filed vehicles during the same time period (Chart 2). As a result, in regard to the "numbers of rear-end collision accidents per vehicle owned," we do not take into consideration information related to section distances and section traffic volumes, such as the "casualty accident rate (number of accidents per traveler kilometer)," which is used for road performance assessments and so on. In addition, since our analysis is focused on traffic characteristics and differences regarding road traffic environments such as lane configurations, we do not take into consideration factors such as the generation and grade of AEB.

In the analysis, we carried out a chi-squared test regarding whether there is a significant correlation between whether vehicles are AEB-equipped or non-equipped, and the number of rear-end collision accidents. If there is a significance level of 1% ($p < 0.01$), this is shown with "**", and if there is a significance level of 5% ($p < 0.05$), this is shown with "*".

Chart 1. Analysis conditions

Vehicle (primary party)	Private ordinary passenger vehicle, private compact passenger vehicle, private light four-wheel passenger vehicle
Division by road type	National expressways, national limited highways, urban expressways, other limited highways
Road section	Cruising lane (traffic lane 1, traffic lane 2 or above), passing lane, climbing lane, acceleration/deceleration lane & shoulder
Type of accident	Vehicle-to-vehicle rear-end collision accidents
Time period	2017 to 2020 (total of 4 years)
Remarks	AEB generation and grade, etc. are not taken into consideration.

Chart 2. Numbers of registered/filed vehicles used in analysis

Time period	Non-AEB-equipped	AEB-equipped
2017 to 2020	41,179,081 vehicles	47,637,856 vehicles

*The figures in this chart do not include vehicles of unknown AEB-equipment status and some imported vehicles.

3. Analysis of situation regarding occurrence of rear-end collision accidents among AEB-equipped and non-equipped vehicles based on differences in road type

With regard to each road type ("national expressways," "national limited highways," "urban expressways," and "other limited highways,") we calculated the numbers of rear-end collision accidents per vehicle owned among AEB-equipped and non-equipped vehicles, and the rate of reduction in rear-end collision accidents brought about by AEB-equipped vehicles (Figure 2).

The result was that for both AEB-equipped and non-equipped vehicles, the numbers of rear-end collision accidents per vehicle owned were highest regarding "national expressways," with non-AEB-equipped at 13.84 cases/million vehicles, and AEB-equipped at 12.83 cases/million vehicles. Meanwhile, for both AEB-equipped and non-equipped vehicles, the numbers were lowest regarding "national limited highways," with non-AEB-equipped at 1.31 cases/million vehicles and AEB-equipped at 0.92 cases/million vehicles. It seems that the differences are largely due to the effects of road length and the amount of traffic volume. Furthermore, the rate of reduction in rear-end collision accidents brought about by AEB-equipped vehicles was lowest regarding "national expressways," at 7.3%, and there did not appear to be a significant difference between AEB-equipped and non-equipped vehicles. Meanwhile, the rate was highest regarding "other limited highways," at 52.0%, and there appeared to be a significant difference between AEB-equipped and non-equipped vehicles. The rates regarding "national limited highways" and "urban expressways" were similar, at around 30%, and in the results, a significant difference between AEB-equipped and non-equipped vehicles could be seen regarding "urban expressways."

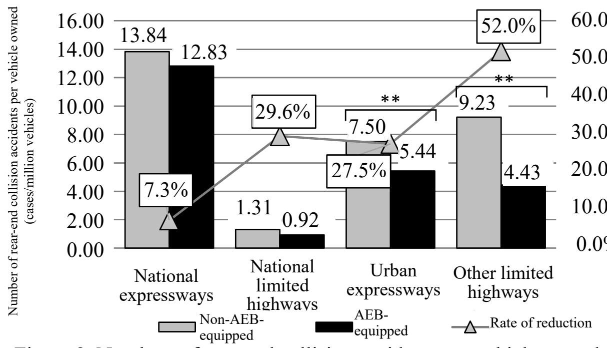


Figure 2. Numbers of rear-end collision accidents per vehicle owned among AEB-equipped and non-equipped vehicles, and rates of reduction in rear-end collision accidents brought about by AEB-equipped vehicles (by road type)

4. Analysis of reduction effects of AEB-equipped vehicles on rear-end collision accidents with focus on national expressways

4-1. Situations regarding occurrence of rear-end collision accidents divided by accident content

We calculated the numbers of rear-end collision accidents per vehicle owned among AEB-equipped and non-equipped vehicles, and the rates of reduction in rear-end collision accidents brought about by AEB-equipped vehicles at national expressways, divided by accident content (Figure 3).

In the results, "fatalities & serious injuries" amounted to 0.56 cases/million vehicles regarding non-AEB-equipped, and 0.55 cases/million vehicles regarding AEB-equipped, and thus the rate of reduction in rear-end collision accidents brought about by AEB-equipped vehicles was 2.3%. Meanwhile, "slight injuries" amounted to 13.28 cases/million vehicles regarding non-AEB-equipped and 12.28 cases/million vehicles regarding AEB-equipped, and thus the rate of reduction in rear-end collision accidents brought about by AEB-equipped vehicles was 7.6%. In both cases, there did not appear to be a significant difference

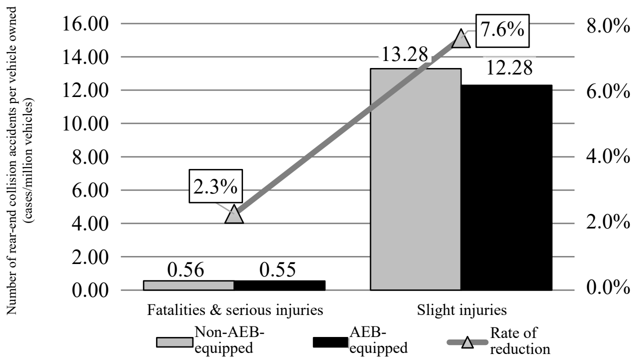


Figure 3. Numbers of rear-end collision accidents per vehicle owned among AEB-equipped and non-equipped vehicles, and rates of reduction in rear-end collision accidents brought about by AEB-equipped vehicles (at national expressways, by accident content)

between AEB-equipped and non-equipped vehicles.

4-2. Reduction effects on rear-end collision accidents divided by speed limit

We calculated the numbers of rear-end collision accidents per vehicle owned among AEB-equipped and non-equipped vehicles, and the rates of reduction in rear-end collision accidents brought about by AEB-equipped vehicles at national expressways, divided by speed limit (Figure 4).

In the results, for both AEB-equipped and non-equipped vehicles, rear-end collision accidents frequently occurred at sections of “50 km/h or below,” “80 km/h or below,” and “no specified speed limit, etc.” Since our analysis is limited to main-road sections, in the case of “50 km/h or below,” the rear-end collision accidents occurred when there was a temporary restriction on the speed limit. In such cases, for both AEB-equipped and non-equipped vehicles, approximately 60% of the rear-end collision accidents occurred when the speed limit was restricted due to traffic congestion (Figure 5). Meanwhile, “no specified speed limit, etc.” refers to sections where a speed limit is not set, and thus it means sections with a legal speed limit of 100 km/h for the targeted analysis vehicles (passenger vehicles). As such, in the case of “80 km/h or below” and “no specified speed limit, etc.,” the rear-end collision accidents are thought to have occurred at the general speed-limit sections of national expressways.

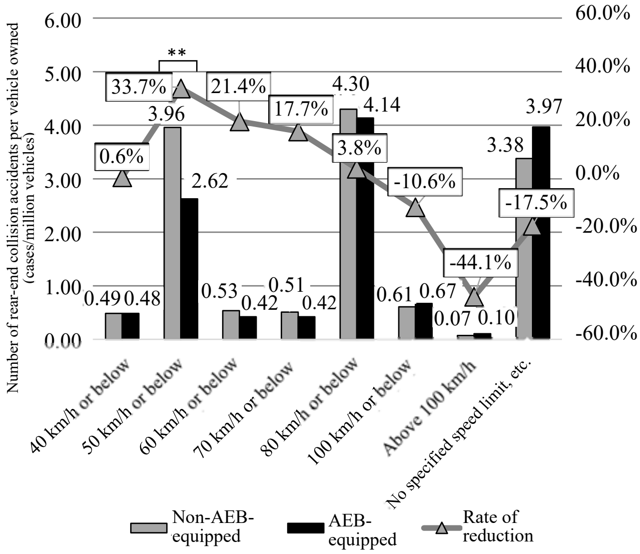


Figure 4. Numbers of rear-end collision accidents per vehicle owned among AEB-equipped and non-equipped vehicles, and rates of reduction in rear-end collision accidents brought about by AEB-equipped vehicles (at national expressways, by speed limit)

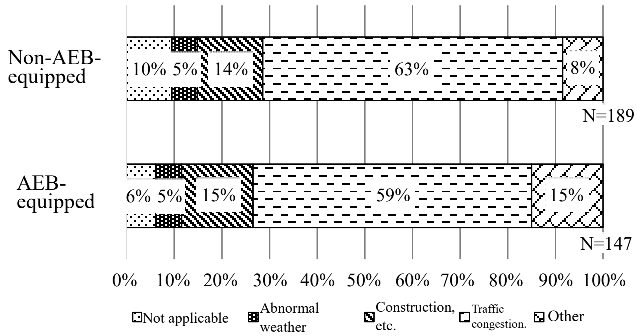


Figure 5. During rear-end collision accidents that occurred at national expressways, causes of speed limit being temporarily set to 50 km/h or below

Chart 3. Requirements for AEB certification systems

	Content
Requirement (1)	When the vehicle is running at 50 km/h and approaching a frontward vehicle that is stopped, it must not collide with the other vehicle, or the speed in the event of a collision must be reduced to at least 20 km/h.
Requirement (2)	When the vehicle is running at 50 km/h and approaching a frontward vehicle that is running at 20 km/h, it must not collide with the other vehicle.
Requirement (3)	In Requirement (1) and Requirement (2), a warning must be given to the driver encouraging collision avoidance operations at least 0.8 seconds before the AEB starts to operate.

Furthermore, looking at the rates of reduction in rear-end collision accidents brought about by AEB-equipped vehicles, the highest level was 33.7% regarding “50 km/h or below”, and in the results, there appeared to be a significant difference between AEB-equipped and non-equipped vehicles. At sections with other speed limits, although there did not appear to be a significant difference between AEB-equipped and non-equipped vehicles, a trend could be seen in which the rate of reduction decreased as the speed limit increased. According to the requirements of the AEB certification system set forth by the Ministry of Land, Infrastructure, Transport and Tourism as shown in Chart 3, there are no requirements regarding cases in which the vehicle is approaching another vehicle at more than 50 km/h. Taking this point into consideration, it seems that in the case of running at more than 50 km/h, there are many difficult situations in which the operable range of the AEB is exceeded, or a collision cannot be avoided even if the AEB is able to operate.

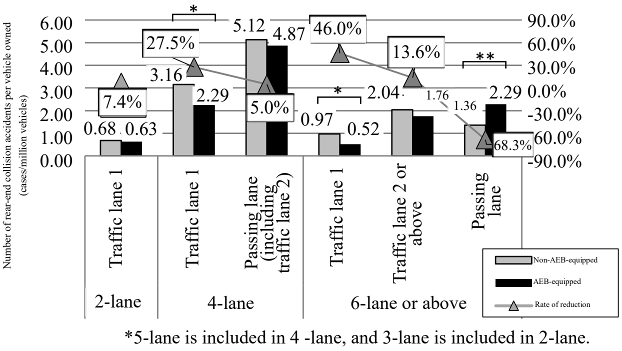
Furthermore, as shown in Figure 2 mentioned above, there was a result in which, at national expressways, the rate of reduction in rear-end collision accidents brought about by AEB-equipped vehicles was lower compared with other road types. As for the reason for this, it seems that one factor may be the fact that since national expressways have the highest designated speed limit, the speeds of cruising vehicles may be high compared with other types of roads.

5. Analysis of reduction effects of AEB-equipped vehicles on rear-end collision accidents according to lane-configuration differences

We calculated the numbers of rear-end collision accidents per vehicle owned among AEB-equipped and non-equipped vehicles, and the rates of reduction in rear-end collision accidents brought about by AEB-equipped vehicles, divided by lane configuration, regarding the two different road types "national expressways" and "urban expressways" (Figure 6, Figure 7).

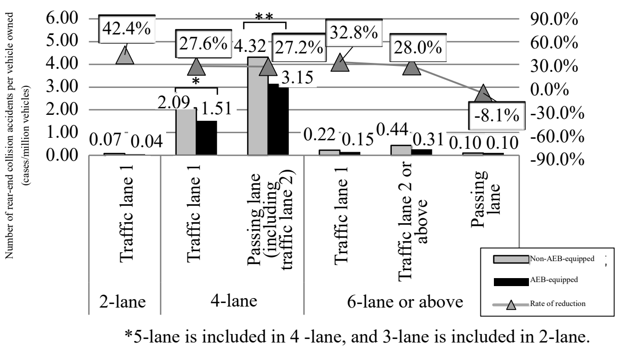
For example, focusing on the numbers of rear-end collision accidents per vehicle owned regarding "4-lane," in the results, at both types of roads, the numbers were lower regarding "traffic lane 1" than "passing lane" for both AEB-equipped and non-equipped vehicles. Furthermore, looking at the rates of reduction in rear-end collision accidents brought about by AEB-equipped vehicles regarding "4-lane," in the results, at national expressways, the rate was lower regarding "passing lane" (5.0%), than it was regarding "traffic lane 1" (27.5%). Meanwhile, at urban expressways, the rate was 27.6% regarding "traffic lane 1" and 27.2% regarding "passing lane," and thus there did not appear to be a notable difference concerning the driving lane.

At 4-lane-or-above national expressways, vehicle groups running in traffic lane 1 have a cruising speed that is relatively low. As such, compared with the passing lane, the number of occurrences of rear-end collision accidents is low, and this seems to explain the trend of a higher rate of reduction in rear-end collision accidents brought about by AEB-equipped vehicles. Meanwhile, at 4-lane urban expressways, there is a trend in which vehicle groups have a low cruising speed due to the designated



*5-lane is included in 4 -lane, and 3-lane is included in 2-lane.

Figure 6. Numbers of rear-end collision accidents per vehicle owned among AEB-equipped and non-equipped vehicles, and rates of reduction in rear-end collision accidents brought about by AEB-equipped vehicles (by lane configuration at national expressways)



*5-lane is included in 4 -lane, and 3-lane is included in 2-lane.

Figure 7. Numbers of rear-end collision accidents per vehicle owned among AEB-equipped and non-equipped vehicles, and rates of reduction in rear-end collision accidents brought about by AEB-equipped vehicles (by lane configuration at urban expressways)

speed limit being low, and due to the structure of such roads, there are entrances and exits on the right side, and distances for merging are short. Thus, it is envisioned that there are no significant differences in the speeds of vehicle groups running in the traffic lane 1 and the passing lane, and this seems to explain the result in which the rates of reduction in rear-end collision accidents were similar.

6. Conclusion

For the research on this occasion, we carried out matching regarding various types of data in the possession of ITARDA (traffic accident statistics, vehicle information, road traffic information, and AEB information), and this enabled us to identify accidents caused by AEB-equipped and non-equipped vehicles, and the road traffic conditions at the locations of the accidents. Furthermore, we targeted rear-end collision accidents that occurred at expressways, and compared the situations regarding accident occurrences among AEB-equipped vehicles and non-AEB-equipped vehicles (numbers of accidents per vehicle owned). In the results, we were able to quantitatively show the reduction effects of AEB-equipped vehicles on rear-end collision accidents according to road type and lane-configuration differences.

We are considering carrying out analysis in the future that targets low-speed general roads (regarding which AEB is expected to be highly effective for accident avoidance and damage mitigation), and additionally makes use of property-damage information. Furthermore, looking ahead to the popularization of autonomous vehicles, it seems that it will be important to carry out analysis regarding road traffic environments with a focus on driving support functions such as adaptive cruise control. Nevertheless, since such analysis would require taking into consideration whether such functions are turned on or off, it seems that examining new analysis and evaluation methods will be a challenge.

<Acknowledgments>

This research was implemented with support from the Intelligent Transport System (ITS) Promotion Office, Road Traffic Control Division, Road Bureau, Ministry of Land, Infrastructure, Transport and Tourism. We would like express our appreciation here.

<Citations and references>

(1) Ministry of Land, Infrastructure, Transport and Tourism: Comprehensive Automotive Safety Information, Survey on the Status of the Popularization of ASV Technologies, https://www.mlit.go.jp/jidosha/anzen/01asv/data/r3souchakudaisu.pdf

(2) Ministry of Land, Infrastructure, Transport and Tourism: Overview of Autonomous Emergency Braking Certification System, https://www.mlit.go.jp/jidosha/AEBS.html

(END)