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Supplementary analysis of the results of collision damage mitigation brakes (Automatic Emergency Brakes: AEB) in reducing rear-end accidents

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1. Introduction

In recent years, much attention has been paid to the frequent occurrence of accidents caused by human factors. We can now be said to be gradually approaching a period in which the spread and increased use of various preventive safety devices will expand on account of the fact that such devices are now being equipped on vehicles as a countermeasure to such accidents. On this account, at last year's research presentation session there was a report on the results of an analysis concerning the results collision damage mitigation brakes (Automatic Emergency Brakes (AEB)) have had in reducing rear-end collision casualty accidents with four-wheel vehicles. Based on this, the fact that equipping AEB on vehicles has proven effective at reducing casualty accidents has been confirmed across various different vehicle parties, danger perception speeds, times of day, and by the age of the driver. Yet at the same time, rear-end collision casualty accidents still continue to occur with great frequency even when AEB are equipped. This has clearly revealed the importance of preventing overconfidence in the sense that people believe that just having AEB equipped will cause their vehicle to stop automatically, enabling them to avoid accidents.
Therefore, rear-end collision casualty accidents that occurred despite the vehicle being equipped with AEB were taken up and a multiple regression analysis performed on them this year. From this, the results of considering the connection between the effects of AEB with various variables will be reported. What is more, in an analysis by driver age from last year, the age distribution of the licensed population was used to estimate the number of vehicles owned by whether or not they were equipped with AEB and by the owner's age group. However, it is difficult to make the claim that this is consistent with the distribution of vehicles equipped with AEB owned by age group. Therefore, the notion of traffic exposure was introduced in order to once more estimate the number of said vehicles and reanalyze this, with the results of this reported here. In conjunction with this, the results from using traffic exposure to analyze this by the number of years that have elapsed since the driver obtained their license will be reported. This report will begin by indicating the results of an analysis by age and by the number of years that have elapsed since the driver obtained their license through the use of traffic exposure, before moving on to providing an explanation of the results of the multiple regression analysis. In the previous study, the analysis was performed by dividing vehicles up by kei sized vehicles, small sized vehicles, and medium sized vehicles that are all privately owned. However, segregating out the number of registered vehicles led to a decrease, thereby leading to results that were not statistically significant. On account of this, this study performed a batch analysis by lumping together all private passenger cars.

[Explanation of how Automatic Emergency Brakes (AEB) function]
Just to reiterate from the previous study, but the mechanism by which AEB operates is shown once more in Fig. 1. First, radar or cameras detect the presence of a leading vehicle up ahead while the vehicle in question is in motion. Next, if it detects that the distance between the vehicles is now shorter than a distance that has been set in advance, the device will determine that there is the possibility of a rear-end collision occurring and sound a warning to alert the driver of danger. Moreover, it is designed so that should the driver fail to apply the brake and the distance between vehicles were to shrink, it will immediately pressurize the brakes in order to get ready to apply them. Should this distance between vehicles shrink still further, it would determine that the risk of a rear-end collision was extremely high and automatically apply the brakes. However, it is not necessarily always the case that automatically applying the brakes will make it possible to avoid accidents, and there may be cases in which collisions still occur, albeit at a reduced rate of speed. It is for this reason that such devices are also called as collision damage mitigation brakes.

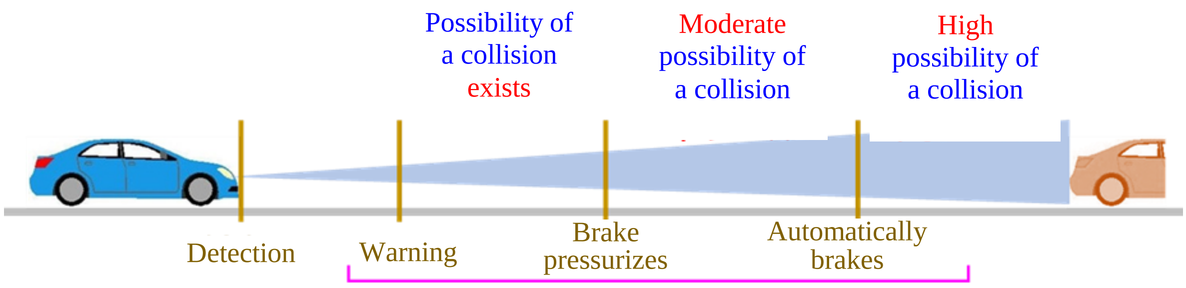

Fig. 1. Mechanism by which collision damage mitigation brakes operate

2. Number of registered vehicles by whether or not AEB is equipped on them

The previous study used the number of vehicles registered at the end of each year from 2015 - 2017, but this study newly added in registration data from the end of 2018 (Table 1). Fig. 2 shows the trends in the number of vehicles, indicating that there has been a sudden surge in the number of vehicles equipped with AEB.

Table 1. Number of registered vehicles at the end of the year by whether or not they are equipped with AEB

	End of 2015	End of 2016	End of 2017	End of 2018
AEB not equipped	626,149	1,498,747	2,118,382	2,463,351
AEB equipped	1,034,115	2,957,496	5,729,421	9,285,942

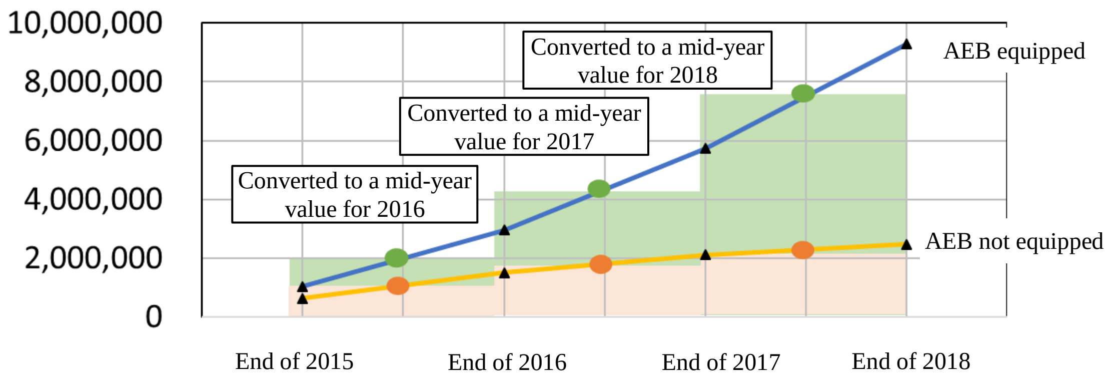

Fig. 2. Trends in the number of vehicles registered by whether or not they have AEB equipped and the number when converted to mid-year values

In the subsequent analysis, the number of accidents per 100,000 vehicles will be calculated for both those vehicles with and without AEB systems equipped. The number of vehicles that will be used for this will not be the year-end value. Rather, a mid-year value for the number of vehicles from the beginning of the year (or more accurately, the end of the previous year) and the end of the year will be used. Fig. 2 shows the mid-year values for the number of vehicles from each year between 2016 - 2018. The total values for the number of vehicles converted to mid-year values for 2016 - 2018 (as calculated from this yearly median number of vehicles) is shown in Table 2. This number of vehicles is what will be used in the subsequent analysis.

Table 2. Number of registered vehicles between 2016 - 2018 used in the analysis

No. of vehicles converted to mid-year values for 2016 - 2018	AEB	
	Not equipped	Equipped
Private passenger cars	5,161,879	13,846,946

3. Analysis of the effects of reducing rear-end collision casualty accidents

3-1. Traffic exposure

Traffic exposure is an indicator expressing the usage frequency of road traffic. The number of secondary parties, who are not at fault when traffic accidents occur, is often used for this. For example, when the number of vehicles that were collided with and thus not at fault during vehicle-vehicle accidents (the secondary party) were compared for Vehicle A and Vehicle B, the results indicated that the ratio for this was 10:1 for Vehicle A:Vehicle B. From this, it can be estimated that the ratio of the number of vehicles with traffic exposure for Vehicles A and B traveling on the roads is also 10:1. See "A study on techniques for determining the characteristics of traffic behavior based on an analysis of traffic accidents," which contains a reference analysis at the end of the paper, for details.

This technique was also used for this analysis. The number of vehicles on the receiving end of rear-end collisions when rear-end collision accidents occurred was used to calculate the traffic exposure.

Fig. 3 shows the process by which traffic exposure was introduced to calculate the estimated number of vehicles by the age of the driver and whether or not they have AEB equipped.

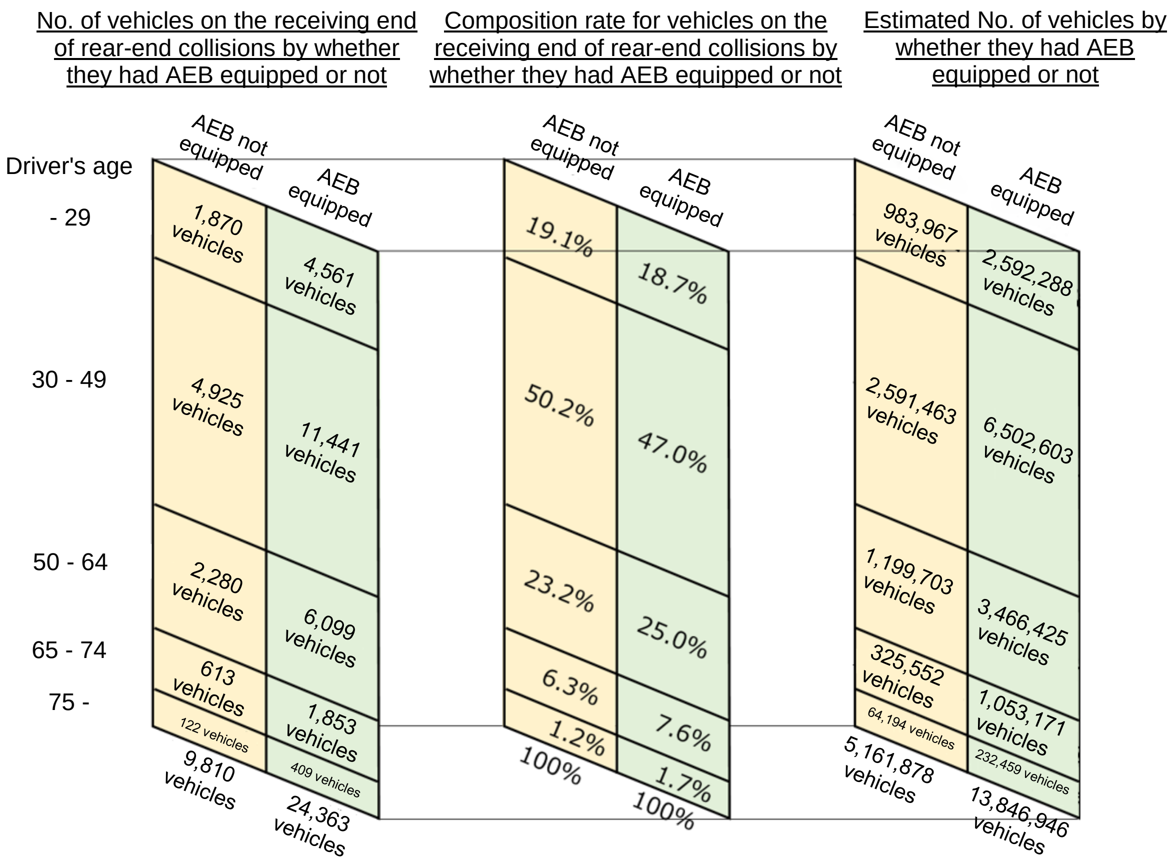

Fig. 3. Relational diagram for the estimated number of vehicles by driver age

To begin with, the number of vehicles on the receiving end of rear-end collisions (secondary party) in rear-end collision accidents between 2016 - 2018 was tabulated by whether or not they were equipped with AEB systems, with the results of this indicated on the left-hand side. Figures expressing the composition rate for this are shown in the middle, which can be considered an indication of the number of vehicles both with / without AEB via this ratio on the road. Then, the results of allocating the number of registered vehicles from Table 2 according to the ratio in the center form the figures on the right-hand side. In this manner, the number of registered vehicles was calculated for each age group.

3-2. Results of reducing rear-end collision casualty accidents by the driver's age

The number of rear-end collision accidents by the age group of the driver that caused said accidents (the primary party) was divided by the number of registered vehicles by each age range found from Fig. 3 and converted to a basis of 100,000 vehicles. The results of this are shown in Fig. 4. From this, high figures were found for the cohort of young people age 29 and younger and the cohort of elderly people age 75 and older, revealing that these age groups are at an elevated risk of causing rear-end collision accidents. It can be pointed out that results of reducing rear-end collision accidents from AEB were obtained with a degree of confidence of a 1% significance level for whole of these age groups. The thin line inscribed on each bar graph shows the confidence interval via an F distribution. The numerical figures for the reduction rate are listed to serve as a reference for the values obtained when this is compared against the average values from when AEB is equipped and not equipped.

3-3. Results of reducing rear-end collision casualty accidents by the number of years since the driver obtained their driver's license

Just like with the driver's age, the number of vehicles on the receiving end of a rear-end collision (secondary party) was tabulated by the number of years since the driver obtained their driver's license for both vehicles with and without AEB. The estimated number of registered vehicles was then found for both those with and without AEB from this composition rate and the number of registered vehicles in Table 2. The number of rear-end collision accidents was divided using this number of vehicles for each number of years since the driver obtained their driver's license for the driver that caused the rear-end collision accident (primary party). This was then converted to a 100,000 vehicle basis, with the results of this shown in Fig. 5. This provided a good understanding of the situation, in which the risk of a rear-end collision accident is highest immediately after one obtains one's license, but then falls as the driver amasses driving experience. AEB proved effective at reducing rear-end collision accidents across every age group.

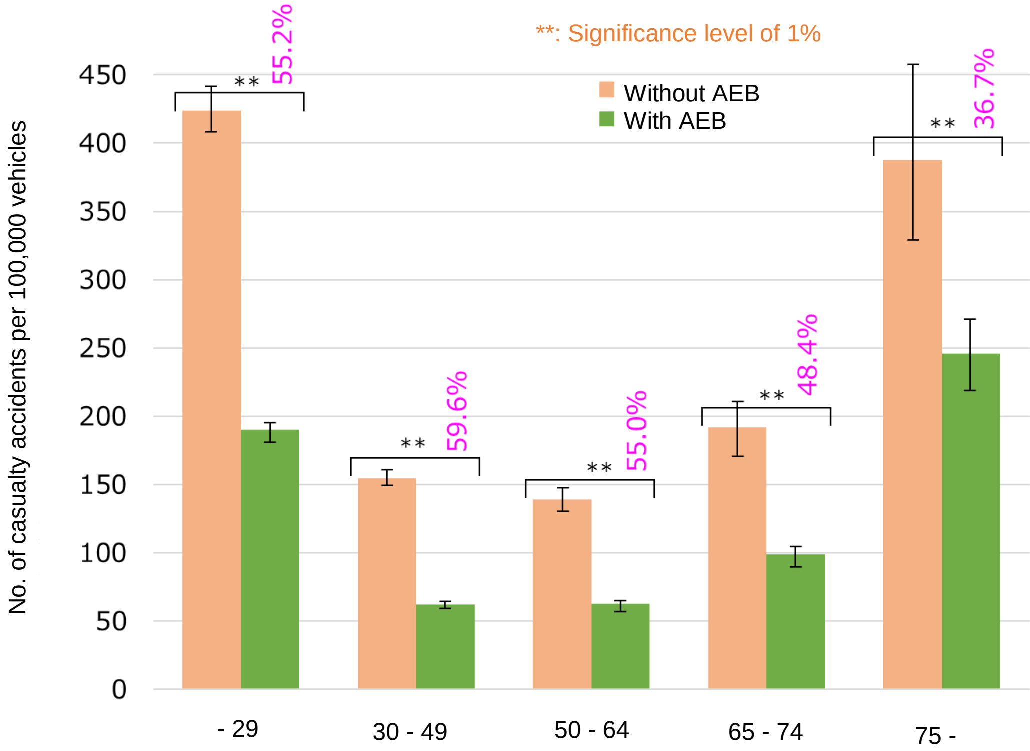

Fig. 4. Results of AEB by driver age

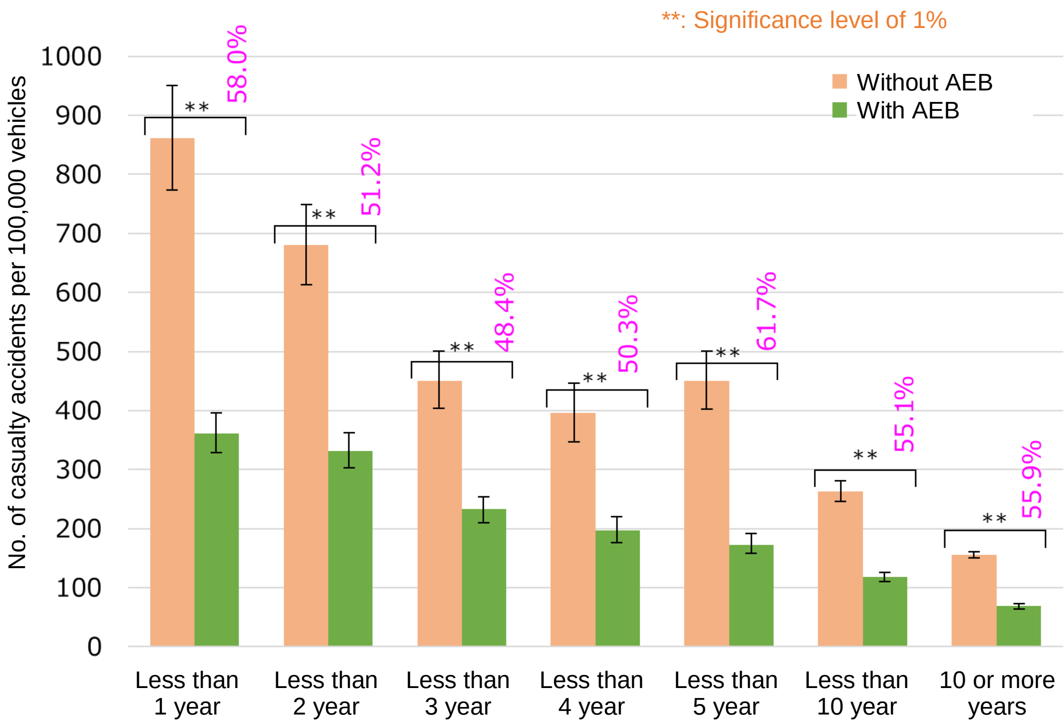

Fig. 5. Results of AEB by the number of years since the driver obtained their driver's license

4. Multiple regression analysis regarding rear-end collision accidents caused by AEB-equipped vehicles

The analyses performed thus far have proven that numerous rear-end collision accidents still occur even when AEB systems are equipped on vehicles. Therefore, this section will focus on rear-end collision accidents caused by AEB-equipped vehicles to explain the results obtained by attempting to explore the factors that affect the results of AEB via a multiple regression analysis.

The weighted least squares (WLS) technique was employed for the analysis, and optimal combinations were found via a reduction method to find the solution. This technique has also been adopted in papers such as a research report entitled "Results of an analysis of the correlation between traffic accidents, drivers, and vehicles" published by ITARDA in the past.

The number of rear-end collision accidents per the number of registered vehicles was adopted as the dependent variable for the multiple regression equation, while the 14 items shown in Table 3 were set as the explanatory variables for this. Regarding these items, factors acknowledged as potentially affecting the AEB results were selected by confirming the trends from the macro data in advance. The details of this will be omitted to avoid an overly lengthy explanation.

Table 3. List of explanatory variables

Category	Explanatory variable
Danger perception speed of the primary party	30km/h or less
	Over 60km/h
Terrain	Urban area
Road configuration	Uninterrupted road section
Signal	No signal
Road surface condition	Wet
Age of the primary party driver	29 and younger
	65 and older
No. of years since primary party driver obtained their driver's license	Less than five years ago
Traffic purpose	Commuting
	Work
	Shopping
Type of movement	Starting up
	Accelerating / decelerating in a straight line

The number of registered vehicles by model for the vehicles equipped with AEB is needed for the analysis, and likewise so is the number of rear-end collision accidents by model. The figures for each of these are provided below.

Number of vehicle models equipped with AEB: 473 models

Number of vehicles equipped with AEB: 13,591,448 vehicles

Number of rear-end collision accidents caused by AEB-equipped vehicles: 18,935 accidents

The data to be entered that was prepared from the above conditions was plugged into the multiple regression equation. However, in order to complete the processing in the ordinary manner, it was necessary to narrow the focus down to models for which 54 rear-end collision accidents or more had occurred. As a result, in the end the processing was carried out via the data listed below.

Number of vehicle models equipped with AEB: 63 models

Number of vehicles equipped with AEB: 9,494,650 vehicles (69.9%)

Number of rear-end collision accidents caused by AEB-equipped vehicles: 15,548 accidents (82.1%)

The results of the analysis are indicated in Table 4. In general, the results of multiple regression analyses involve the output of numerous cases depending on the combinations of the explanatory variables. Then a figure known as an Akaike Information Criterion (AIC) is used as a criterion for determining which of these offer a high degree of statistical reliability, with the smaller this value being the higher the reliability. Therefore, for this study three cases were taken up and expressed from among the combinations with a small AIC. Variables with a negative regression coefficient have the effect of causing a drop in the dependent variables (in this case, the number of rear-end collision accidents per number of registered vehicles). Looking at the results of this indicates that the factors of: obtained one's license less than five years ago ⇒ urban area ⇒ danger perception speed of 30km/h or less appeared to contribute the most to reducing rear-end collision accidents in this order. The thinking behind this is that traveling speed is moderated within urban areas, and is correlated with a danger perception speed of 30km/h or less to a certain extent. If we were to summarize these findings in an easy to understand manner, we would see that novice drivers who only recently obtained their licenses tend to be most prone to the effects of AEB assistance, with AEB most likely to prove effective in comparatively low speed ranges where the traveling speed is 30km/h or less in particular. Most vehicles equipped with AEB, which were the focus of this analysis, are believed to be vehicles equipped with initial systems that have their target activation speed set lower than around 30km/h. As such, these results in which the benefits are not obtained in speed ranges that exceed 30km/h could be described as valid. To put it another way, in order to expand the effectiveness of AEB at reducing rear-end collision accidents in the future, it will presumably be necessary to disseminate AEB that target high speed ranges, the installation of which has already begun in earnest.

Table 4. List of the results of the multiple regression analysis

Vehicles equipped with AEB systems								
No	Explanatory variable	Regression coefficient	Standard error	t value	F value	R2 value	5% F value	5% t value
1	30km/h or less	-0.0040	0.0208	-0.195	-0.462	0.173	2.377	2.002
	Urban areas	-0.0061	0.0478	-0.127				
	29 and younger	0.0084	0.0511	0.163				
	Less than 5 years	-0.0111	0.0626	-0.177				
	Work	0.0035	0.0432	0.081				
	Constant term	0.0082	0.0328	0.249				
2	30km/h or less	-0.0051	0.0227	-0.223	-0.392	0.186	2.266	2.003
	Urban areas	-0.0054	0.0488	-0.110				
	Uninterrupted road section	-0.0046	0.0400	-0.114				
	29 and younger	0.0089	0.0527	0.169				
	Less than 5 years	-0.0121	0.0655	-0.185				
	Work	0.0045	0.0434	0.103				
	Constant term	0.0112	0.0427	0.262				
3	30km/h or less	-0.0038	0.0215	-0.175	-0.560	0.172	2.531	2.002
	Urban areas	-0.0042	0.0494	-0.085				
	29 and younger	0.0073	0.0527	0.138				
	Less than 5 years	-0.0092	0.0640	-0.144				
	Constant term	0.0068	0.0327	0.207				

With this study, the R^2 value (coefficient of determination) was smaller than 0.2, meaning the analytical results are somewhat lacking in explanatory power. Therefore, efforts should be made to improve the accuracy of the results by accumulating a greater number of data points for the future.

5. Conclusion

(1) The effects of AEB were calculated by both the driver's age and the number of years since the driver obtained their driver's license via traffic exposure

- Both those 29 and younger and 75 and older have an elevated risk of causing rear-end collision accidents.
- The risk of causing a rear-end collision accident decreases the longer one has had one's license.
- AEB was confirmed to be effective across each age group.

(2) Multiple regression analysis on rear-end collision accidents using vehicles equipped with AEB

- Benefits were obtained for factors in the order of: Obtained one's license less than five years ago ⇒ urban area ⇒ danger perception speed of 30km/h or less
- The expectation is that rear-end collision accidents can be further reduced by expanding the spread of next-generation AEB that active in high speed ranges of over 30km/h as well in the future.

＜引用・参考文献＞

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