Analysis of the results of reducing rear-end collision accidents via AEB

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Preface

In recent years, vehicles equipped with a variety of preventive safety technologies, such as Automatic Emergency Brakes, Lane Departure Warning devices, rear-view cameras, and more have become widely prevalent. Moreover, there has recently been a rise in the number of vehicles equipped with new devices such as those that prevent the vehicle from starting to move when the pedals have been misapplied. As vehicles equipped with the latest safety devices such as these become widespread, determining what sort of changes they bring about in the occurrence of traffic accidents as a result will be crucial when it comes to considering traffic safety measures in the future. Conventionally, public databases concerning vehicles equipped with such preventive safety technologies have been lacking, and so it has not been possible to analyze their performance. Recently, with the cooperation of the Japan Automobile Manufacturers Association, Inc. and Japan Automobile Importers Association, since FY2016 it has been possible to aggregate and analyze traffic accident data by using information on whether or not each individual vehicle is equipped with preventive safety equipment. Therefore, this study will focus on Automatic Emergency Brakes (hereinafter referred to as "AEB") to analyze their results in reducing rear-end collision accidents with four-wheeled vehicles (hereinafter referred to as "rear-end collision accidents"), while also considering scenarios in which they fail to perform satisfactorily in conjunction with this.

Prerequisites for the analysis are indicated below.

- The vehicles causing the rear-end collision (hereinafter referred to as the "primary party") were restricted to four-wheeled, private passenger cars, with the number of medium- / small-sized passenger cars initially registered and the number of kei-passenger cars (small passenger cars in Japan with an engine displacement upto 660cc) initially reported between April 2015 and December 2017 used. However, data in which it was unclear whether or not the vehicle was equipped with AEB was excluded, and certain imported vehicles were also not included in this.
- A macro database was used for the aggregated accident data, with the focus placed on rear-end collision accidents that occurred in 2016 and 2017 in which the abovementioned vehicles were involved as the primary party. The vehicles on the receiving end of the rear-end collision (hereinafter referred to as the "secondary party") were restricted to four-wheeled vehicles, and whether or not they were equipped with AEB was not taken into consideration.
- The AEB's function and grade were not taken into consideration, only whether or not the vehicle was equipped with such a system at the time of the completion inspection was considered.

The results of reducing rear-end collision accidents were analyzed by determining the extent to which the presence of AEB reduced the number of rear-end collision accidents that occurred per 100,000 vehicles sorted by those with and those without AEB.

1. Explanation of how Automatic Emergency Brakes (AEB) operate

The mechanism by which AEB operates is shown in Fig. 1. First off, while the user's vehicle is in motion, radar and cameras are used to detect the presence of any leading vehicles. Subsequently, when the distance between vehicles shrinks below a pre-set distance, the device determines that there is the possibility of a rear-end collision and issues a warning to alert the driver of the danger. If the driver still fails to apply the brakes and the distance between vehicles grows shorter still, the device will pressurize the brakes as a precaution to enable them to be applied immediately. If this distance shrinks further still and the device determines that there is an extremely high possibility of a rear-end collision, then it will automatically apply the brakes. However, just because the brakes activate automatically does not necessarily mean that an accident can be avoided, and there are cases where the vehicle decelerates but a collision still occurs. Therefore, this device is also called a Collision Mitigation Braking System.

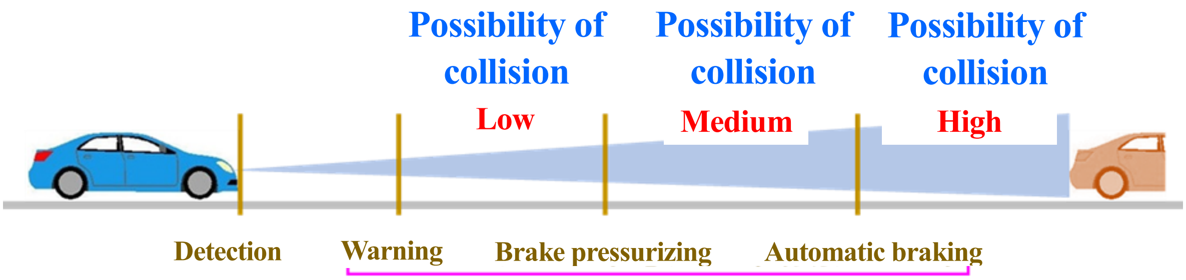

Fig. 1. Mechanism by which Automatic Emergency Brakes operate

The results obtained from AEB are expected to come in two types: (1) Avoiding accidents by stopping the vehicle prior to a collision and (2) Mitigating damage when a collision does occur by decelerating the vehicle prior to said collision. Since most of the bodily harm due to rear-end collision accidents only amounts to slight injuries, the expectation is that the results of mitigating damage from (2) will result in no injuries. However, there is no data on accidents resulting in no injuries (which is to say accidents only involving property damage) among the statistical data on traffic accidents in Japan, so this study was unable to explore the results of mitigating damage from (2). Due to the aforementioned reason, this study performed an analysis by focusing on the results of using AEB to avoid rear-end collision accidents from (1).

2. Occurrence status for recent rear-end collision accidents

Before analyzing the results from AEB, we will take a look at the occurrence status for recent rear-end collision accidents. Fig. 2 shows trends in all rear-end collision accidents and rear-end collision accidents involving private passenger cars between the years of 2008 and 2017. Such accidents were gradually trending upwards up through 2013 solely for kei-passenger cars, but since 2014 the number of accidents has been on a downward trajectory for small- and medium-sized passenger cars, and likewise for all parties.

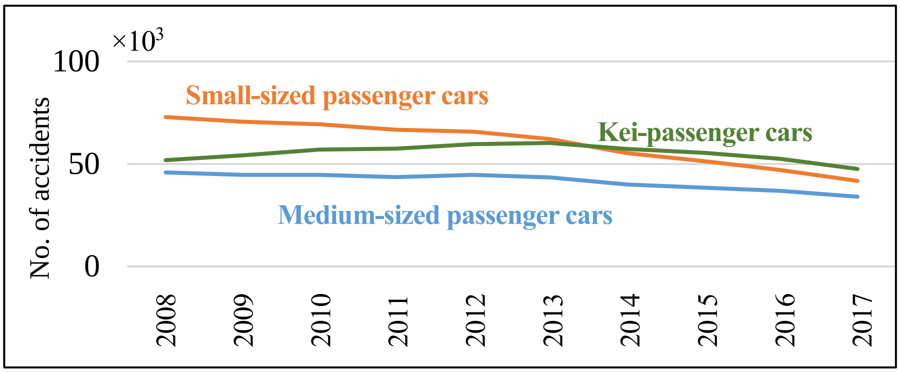

Fig. 2. Number of rear-end collision casualty accidents by primary party

Fig. 3 shows trends in the number of vehicles owned as of the end of each year for each party, with the number of medium-sized and kei-passenger cars owned continuing to increase. Yet despite this, the downward trend in the number of rear-end collision accidents for all parties has continued since 2014, as can be seen from Fig. 2. This is thought to be a manifestation of the results from the dissemination of AEB. Fig. 4 shows the results found by dividing the number of accidents from Fig. 2 by the number of vehicles owned from Fig. 3, while Fig. 5 shows the results obtained by standardizing the number of accidents from Fig. 4 using the year 2008 as the baseline. According to Fig. 4, while the number of accidents in and of themselves differ for each of the parties, they all exhibit similar trends. Moreover, Fig. 5 indicates a number of commonalities shared among them, like the fact that the downward trend in rear-end collision accidents has remained largely the same since 2008, and that the downward trend has become more pronounced since 2013 / 2014. From this, it can be surmised that the results of AEB began to become manifest starting from around 2013 / 2014 in relation to each of the parties.

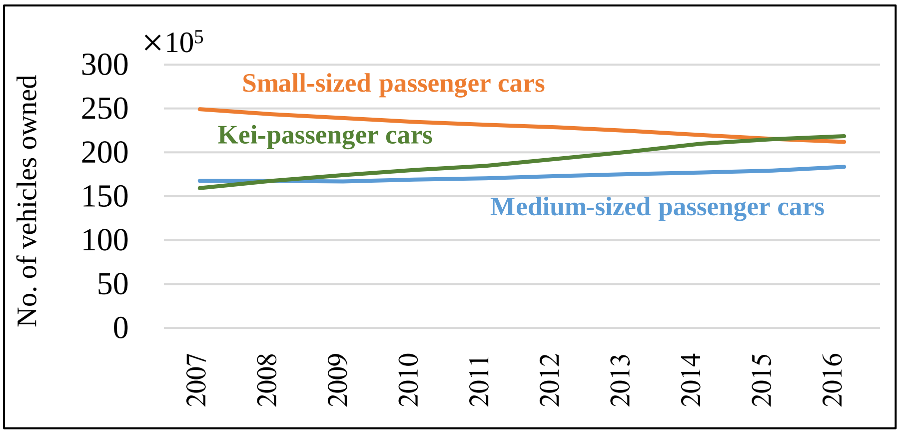

Fig. 3. Trends in the number of vehicles owned as of the end of each year

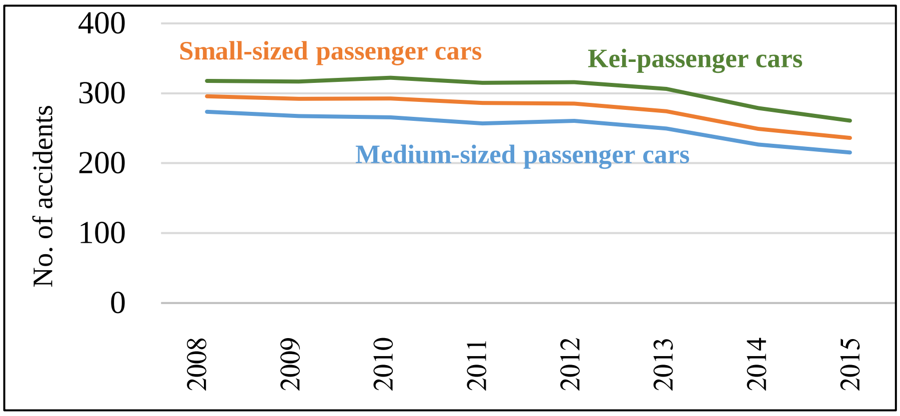

Fig. 4. Number of rear-end collision casualty accidents per 100,000 vehicles owned

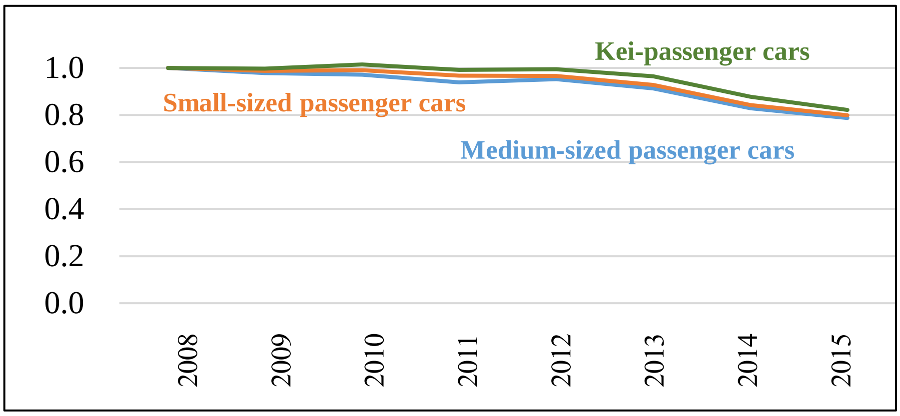

Fig. 5. Number of rear-end collision casualty accidents per the number of vehicles owned standardized with the year 2000 as the baseline

3. Analysis of the reduction results for rear-end collision casualty accidents via AEB

(1) Number of registered vehicles by whether or not they are equipped with AEB

The number of registered vehicles as of the end of each year between 2015 – 2017 by whether or not they are equipped with AEB is shown in Table 1, while a graph of the trends in this number is shown in Fig. 6. For the subsequent analysis, the number of accidents per 100,000 vehicles will be calculated by whether or not they are equipped with AEB, but in doing so the median number of vehicles from the beginning and end of the years will be used instead of the number of vehicles from just the end of the year. The reason for this is that, if we take the number of vehicles being driven in February as an example, then the figure for this that should be used would be one found by adding the number of vehicles newly registered in January to the number from the end of the previous year, and so therefore it is no longer appropriate to use the number from the end of the year. The annual median numbers of vehicles from 2016 and 2017 are displayed in Fig. 6.

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

		End of 2015	End of 2016	End of 2017
Without AEB	Medium-sized passenger cars	150,220	371,207	526,412
	Small-sized passenger cars	181,198	432,929	625,244
	Kei-passenger cars	311,322	676,274	949,862
With AEB	Medium-sized passenger cars	241,631	898,707	1,806,397
	Small-sized passenger cars	188,673	628,198	1,417,246
	Kei-passenger cars	576,631	1,341,345	2,287,164

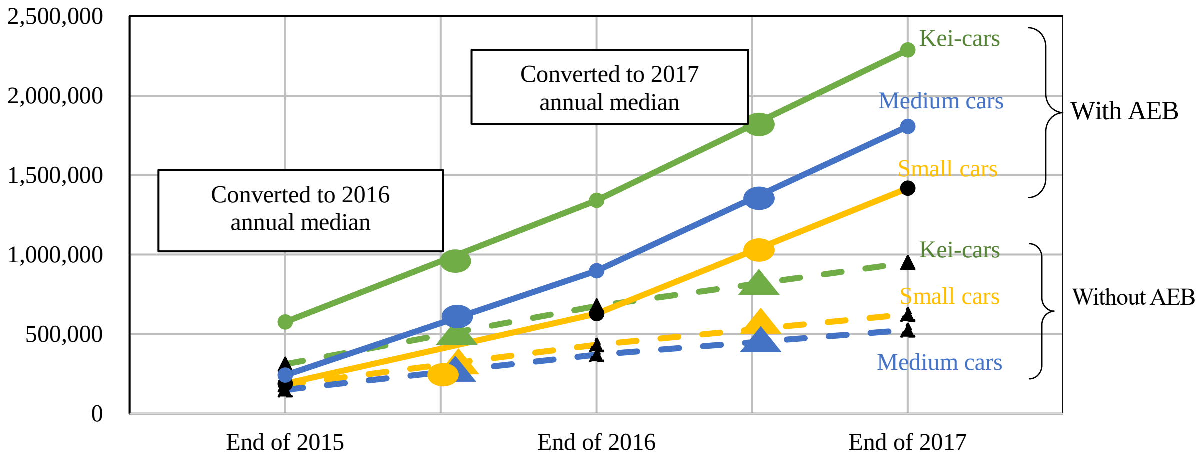

Fig. 6.　Trends in the number of vehicles owned by whether or not they are equipped with AEB and by party, and the number converted to an annual median

Table 2 shows the aggregate values for the annual median number of vehicles for 2016 and 2017 calculated from Table 1. These numbers will be used for the subsequent analysis.

Table 2. Number of registered vehicles from 2016 and 2017 used for the analysis

	AEB	
	Equipped	Not equipped
Medium-sized passenger cars	709,523	1,922,721
Small-sized passenger cars	836,150	1,431,158
Kei-passenger cars	1,306,866	2,773,243
Total	2,852,539	6,127,122

(2)　Results of reducing rear-end collision accidents by primary party

The results of calculating the number of rear-end collision casualty accidents per 100,000 vehicles by medium-sized / small-sized / kei- passenger cars and by whether or not they have AEB are shown in Fig. 7. The “**” symbols listed within the figure indicate results for which a “significance test” was performed to see whether the conclusion that having AEB equipped reduced accidents can be trusted in a statistical sense. The “*” symbol indicates significance via a significance level of 5%, while "**" indicates significance via a significance level of 1%. By way of example, significance via a significance level of 1% means that reliable results can be obtained 99 times out of 100. However, caution is required regarding the fact that this does not mean that the figures for the results of reducing accidents are reliable The actual reduction rate could potentially be larger or smaller than the calculated figures, but this proves that the results indicating that AEB reduces rear-end collision accidents are reliable.

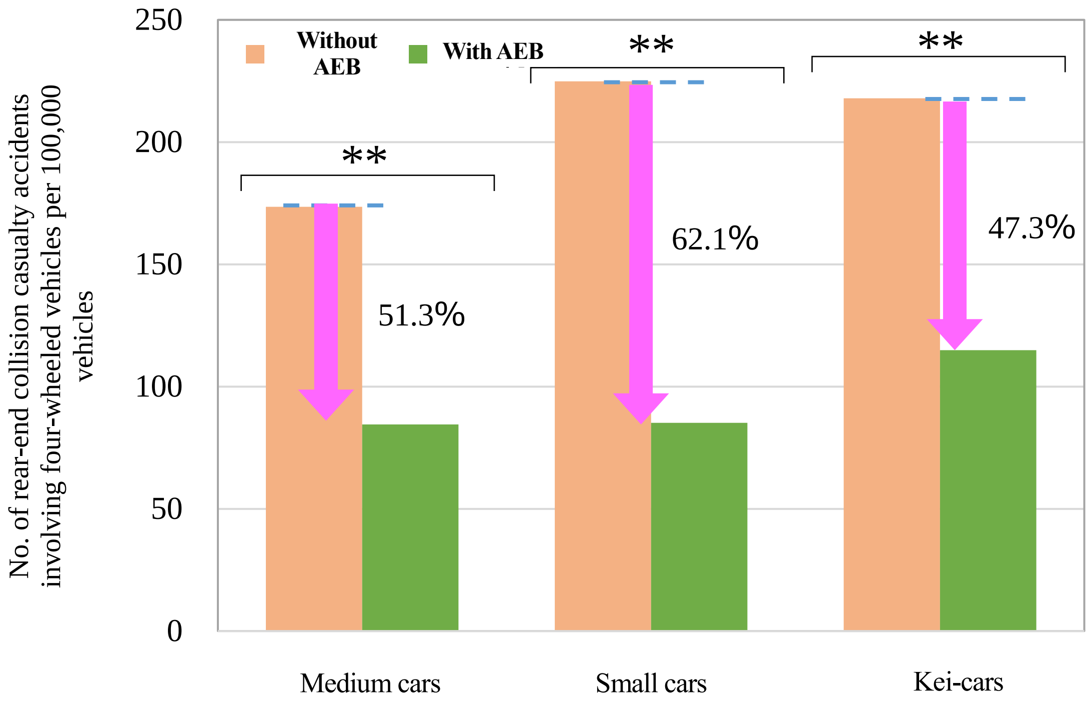

Fig. 7. Reduction results for rear-end collision accidents by party

We can see from Fig. 7 that results have been achieved whereby roughly half of the rear-end collision accidents could be avoided by equipping vehicles with AEB. What is more, while the reduction results differ by party, since the figures themselves do not serve as suitably reliable indicators (as was touched on in the statistics listed above), it would not be appropriate to discuss this difference. However, the parties can be thought of as being affected by differences in the driving characteristics of each user group. As such, the results found from surveying the distribution of danger perception speeds and driver ages by party are shown in Fig. 8 and Fig. 9 as reference. From the results we can see that for danger perception speeds there is a bulge in the medium speed range in the order of medium-sized passenger cars ⇒ small-sized passenger cars ⇒ kei-passenger cars, while similarly for driver age this bulges among the young age range in the same order. In general, an increase in speed proves a disadvantage for applying the brakes, and the risk of accidents is thought to be high among younger drivers due to their relative lack of driving experience. Therefore, the conclusion could be drawn that it would be more difficult to obtain the results of AEB with kei-passenger cars, with their broad medium speed range for danger perception speed and large number of young drivers, given their elevated risk of rear-end collision accidents. Yet in actuality, results were obtained for these that compare favorably to those from medium- / small-sized passenger cars, so presumably the results are impacted by a number of other factors aside from speed and driver age.

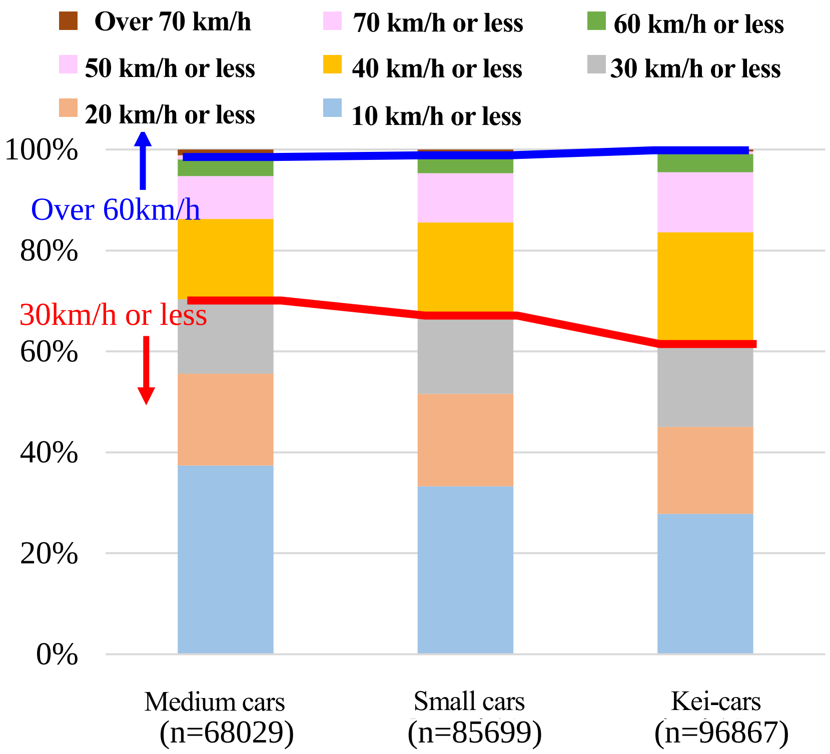

Fig. 8. Distribution by danger perception speed by party (disregarding secondary party classifications)

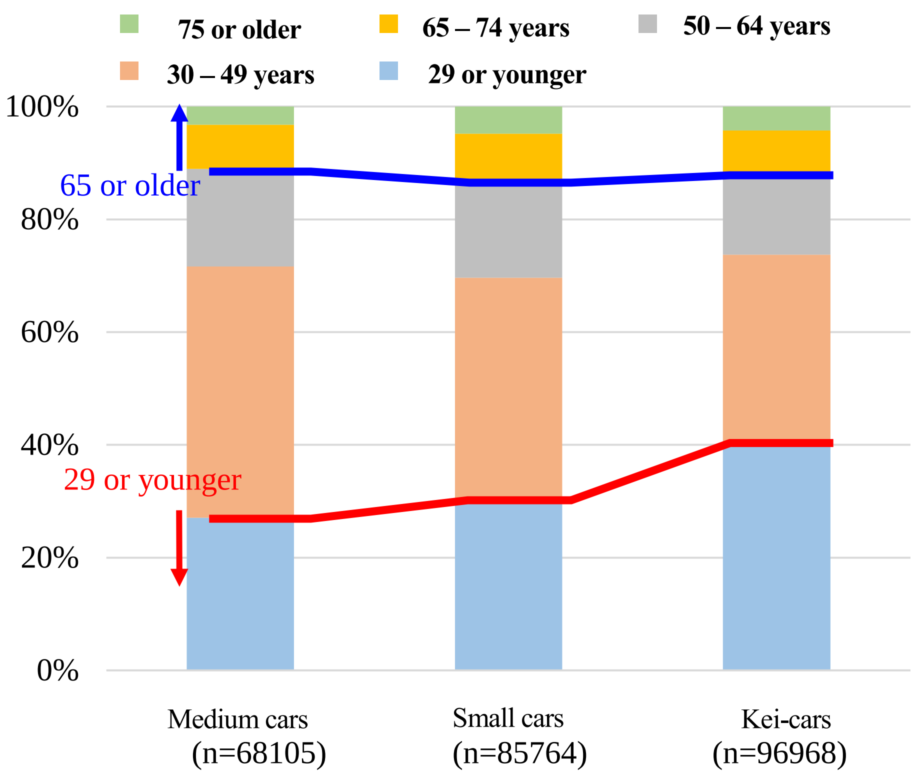

Fig. 9. Distribution of driver age groups by party (disregarding secondary party classifications)

(3) Rear-end collision accident reduction results by the danger perception speeds of the primary party

Next, the results from AEB by the danger perception speeds of the primary party are shown in Fig. 10. The reason for the large number of accidents per number of vehicles when danger perception speeds are low is because rear-end collision accidents often occur at low speeds. This figure reveals that rear-end collision accident reduction results can be obtained through the use of AEB in the low – medium speed ranges. However, in many cases significant results could not be obtained for the high speed range in excess of 60km/h. This is believed to be because as the traveling speed reaches high speeds, the number of cases increase in which AEB is effective at decelerating, but collisions still occur because it is unable to bring the vehicle to a stop immediately ahead of the other vehicle. Presumably AEB could offer damage mitigation results in such cases, but as was explained in the beginning, this study is unable to explore such results.

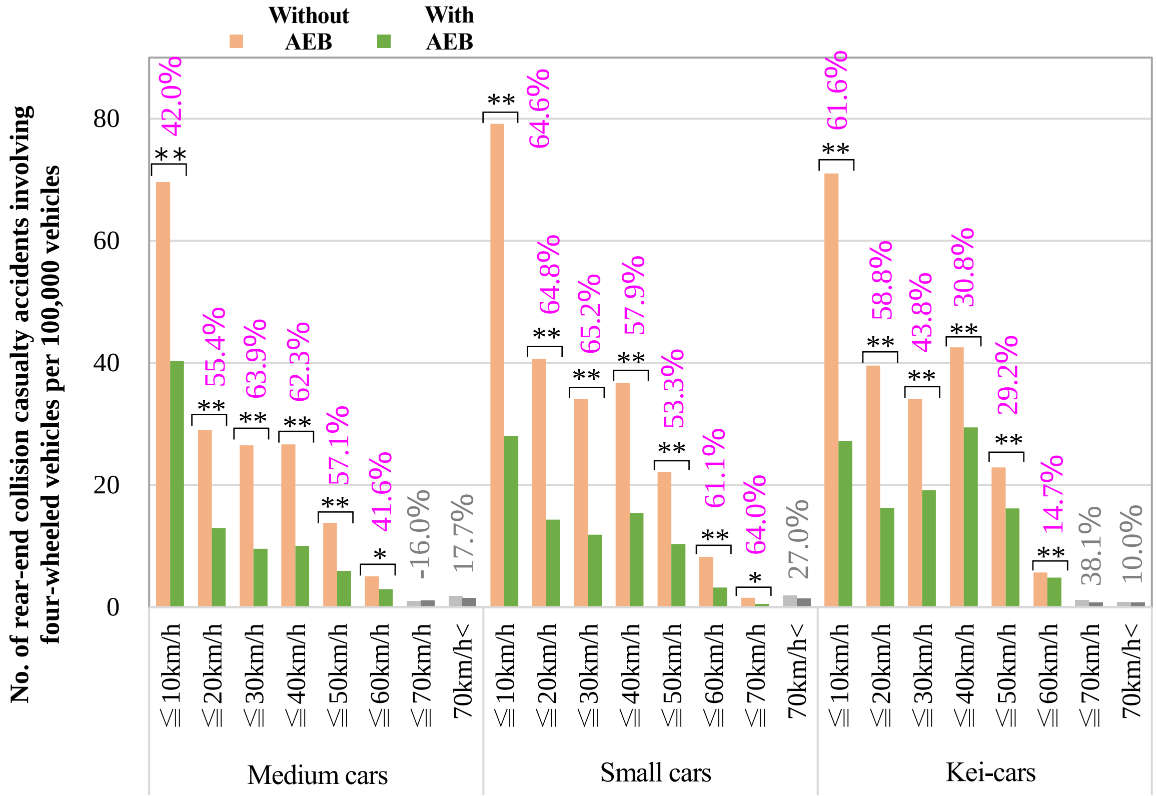

Fig. 10. Rear-end collision accident reduction results by danger perception speed

(4) Rear-end collision accident reduction results by daytime / nighttime

Since it is anticipated that AEB's performance in detecting leading vehicles will be affected by the surrounding environment, the results of analyses for both daytime and nighttime are shown in Fig. 11. The results indicate that AEB is effective at reducing rear-end collision accidents in both the daytime and nighttime, but conversely affirmed a trend whereby said reduction results are smaller at nighttime compared with during the daytime. Since the surrounding environment is dark at nighttime, this affects the AEB's detection performance when it comes to leading vehicles, on top of which traveling speeds are higher at nighttime than in the daytime. As a result, this is thought to be affected by the fact that there are numerous cases for which the results of AEB cannot be adequately obtained, as affirmed in Fig. 10. The reason for the lower number of accidents per 100,000 vehicles at nighttime versus the daytime is because the number of rear-end collision accidents itself that occur at night is lower.

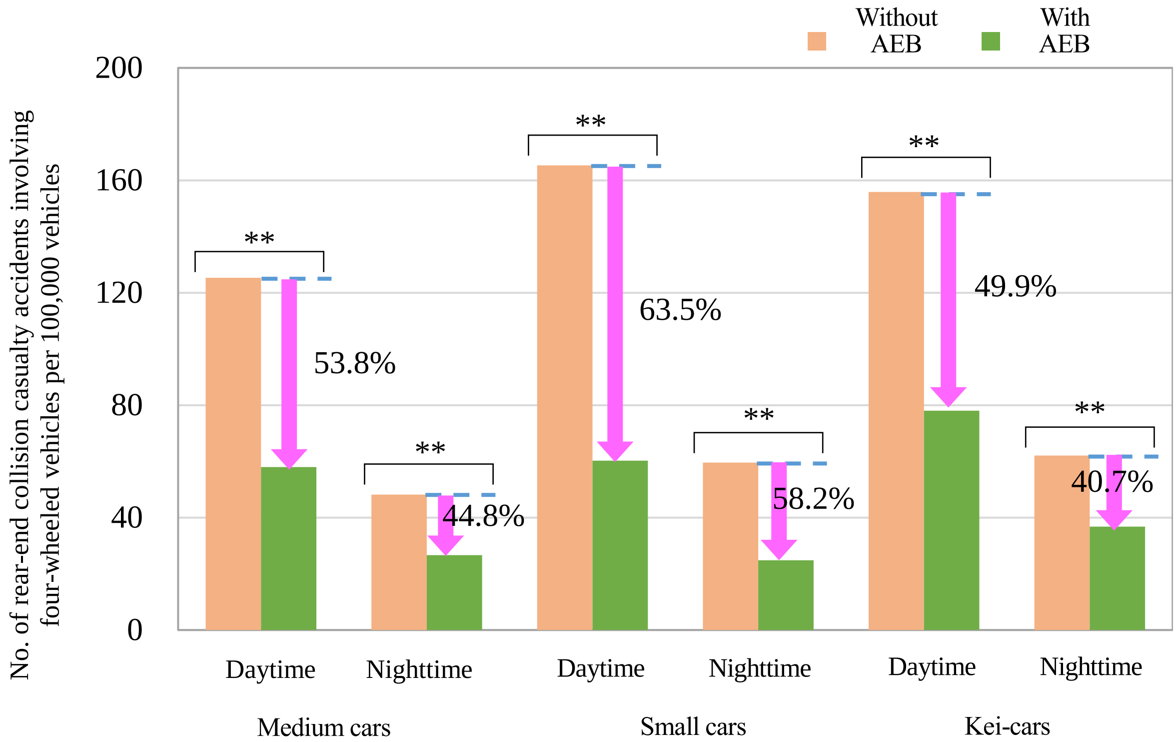

Fig. 11. Rear-end collision accident reduction results during the daytime and nighttime

(5) Rear-end collision accidents reduction results by age of the primary party

The latest analysis results have been announced at the 22nd ITARDA Seminar held in 2019, so please refer to the following address.

https://www.itarda.or.jp/presentation/22

(6) Estimated results for a scenario in which the AEB has achieved 100% penetration

The rear-end collision accident reduction results were estimated for a hypothetical scenario in which it was envisioned that AEB had achieved 100% penetration in 2017. The following equation was used to perform the calculation.

Estimated number of residual rear-end collision accidents when AEB is equipped on 100% of vehicles =

(Total number of rear-end collision accidents from 2017 − Number of rear-end collision accidents involving primary parties driving AEB-equipped vehicles from 2017)

× (1 − AEB reduction results) + (Number of rear-end collision accidents involving primary parties driving AEB-equipped vehicles from 2017)

The number of rear-end collision accidents that occurred in 2017, the number of these that involved vehicles equipped with AEB, and the calculated figures for the AEB reduction results recently calculated are enumerated in Table 5.

Table 5. Number of rear-end collision accidents from 2017 and calculations of the reduction results from AEB

2017 casualty accidents	No. of rear-end collision accidents	No. of accidents where the primary party had an AEB-equipped vehicle	Accident reduction results from AEB
Medium-sized passenger cars	32,633	1,102	51.3%
Small-sized passenger cars	40,242	864	62.1%
Kei-passenger cars	46,043	2,064	47.3%

The number of rear-end collision accidents reduced and residual accidents found from Table 5 and the calculation equation are shown in Fig. 13.

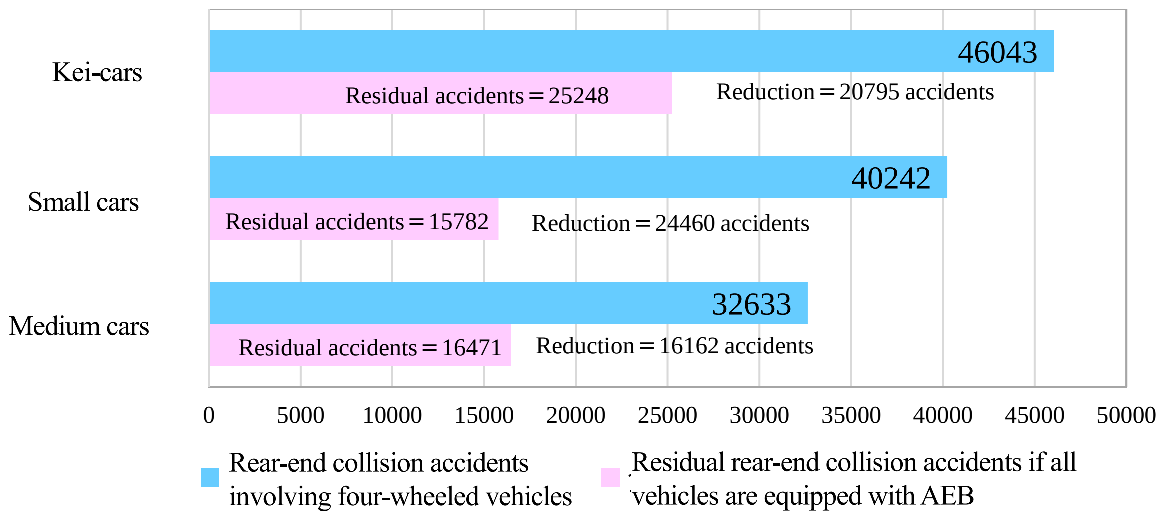

Fig. 13. Estimated results for the rear-end collision accident reduction results for 2017

It has been estimated that 61,417 rear-end collision accidents were reduced for medium-, small-sized and kei-passenger cars combined. This is equivalent to a 52% reduction in rear-end collision accidents, and a 13% reduction in the total number of 472,165 casualty accidents from 2017. Yet on the other hand, 57,501 rear-end collision accidents with four-wheeled vehicles still occurred, which were presumably accidents that occurred under conditions where AEB tends to not be fully effective.

4. Conditions where the AEB tends to not be effective

Through the analysis thus far, it has been confirmed that there are conditions under which AEB is effective at reducing rear-end collision accidents. Yet at the same time the fact was cleared that it is still unable to prevent many rear-end collision accidents via current AEB systems.. In a questionnaire on AEB carried out by the Japan Automobile Federation, responses indicating an awareness that AEB entailed "automatic braking" and "collision-free vehicles" accounted for 97.3%. Unfortunately, on the other hand this also laid bare the fact that nearly one out of every two people (45.2%) were under the misapprehension that the device was "a device that would brake automatically to avoid collisions," which is to say they placed too much reliance in its abilities. Presumably, designations such as "automatic braking" and "collision-free vehicles" fostered this sense of overconfidence in the device. For this reason, the Automobile Fair Trade Council decided to apply guidelines banning the use of the designation "automatic braking" in commercials and internet videos by auto makers and dealerships starting from January 1, 2019. The hope is that this impression that AEB is a device that automatically stops the vehicle is one that will be dispelled in the future. But it is not enough to just dispel this impression. Drivers must be provided with an accurate understanding of AEB's function. As such, it will also be important to carry out awareness-raising activities that inform people of the conditions in which rear-end collision accidents occur even when AEB is equipped. Based on this perspective, on April 20, 2018 the Ministry of Land, Infrastructure, Transport and Tourism issued a press release cautioning people not to be overconfident in the device's abilities, and also released a video to raise awareness of the matter over the internet.[1)] This video introduced examples involving slippery road surfaces and steep downhills as cases where the AEB tends to not be effective.

Fig. 14. Scenarios where the AEB tends to not be effective
(Left: Slippery road surface; Right: Steep downhill)

In addition, as part of an explanation on AEB the National Agency for Automotive Safety & Victims' Aid raised the following examples as cases where the device does not fully fulfill its functions.[2)]

(1) At night or when it is raining

(2) When the windows are dirty

(3) When objects placed on top of the dashboard are reflected in the window

(4) When there are objects in front of the detection unit blocking it

(5) When maintenance has not been adequately carried out by specialty shops to maintain its accuracy

These various conditions can be broadly classified into the following three categories.

- Factors leading to a deterioration in the braking force

  (tire wear; dampness, snow cover, and frozen sections; steep downhills; a drop in tire pressure, etc.)
- Factors leading to a deterioration in the device's detection performance

  (darkness, reflected light, dense fog, dirt on the cameras / receivers, misalignment of the sensors, etc.)
- Objects that are difficult to confirm visually

  (trucks with protruding load-carrying trays, extremely small objects, etc.)

Extensive awareness-raising should be carried out in order to inform people that various conditions like those mentioned above can produce situations in which the AEB tends to not be effective, and therefore it is important that drivers personally ensure safe driving without relying on such devices.

5. Conclusion

This study was able to confirm that AEB offer extensive reduction results for rear-end collision accidents. Yet at the same time, it also affirmed that it is still difficult even for AEB-equipped vehicles to prevent nearly half of these rear-end collision accidents. It has also brought to light the fact that the misapprehension (overreliance) that just having an AEB allows one to avoid accidents is widespread among users. When cases where the devices are unable to function satisfactorily are factored in, this points to a need for awareness-raising activities designed to provide users with accurate knowledge regarding the devices. Though this is not just limited to AEB, but could be said for the full range of other advanced safety devices that will hopefully continue to achieve widespread popularity in the future. As such, the hope is that the interested parties will undertake further awareness-raising activities.

References

1) 国土交通省自動車局審査・リコール課 「衝突被害軽減ブレーキは万能ではありません」
https://www.youtube.com/channel/UCwFJ6KstdbqM9P91828lu2g

2) （独法）自動車事故対策機構 予防安全性能アセスメント－衝突被害軽減制動制御装置（被害軽減ブレーキ）
http://www.nasva.go.jp/mamoru/active_safety_search/collision_avoidance_system.html