イタルダ インフォメーション
ITARDA INFORMATION
交通事故分析レポート No.133

Special feature

Analysis of the effects of collision damage mitigation brakes (Automatic Emergency Brakes: AEB) on kei sized passenger vehicles

~ Precautions that drivers must pay attention to when driving an AEB-equipped vehicle ~

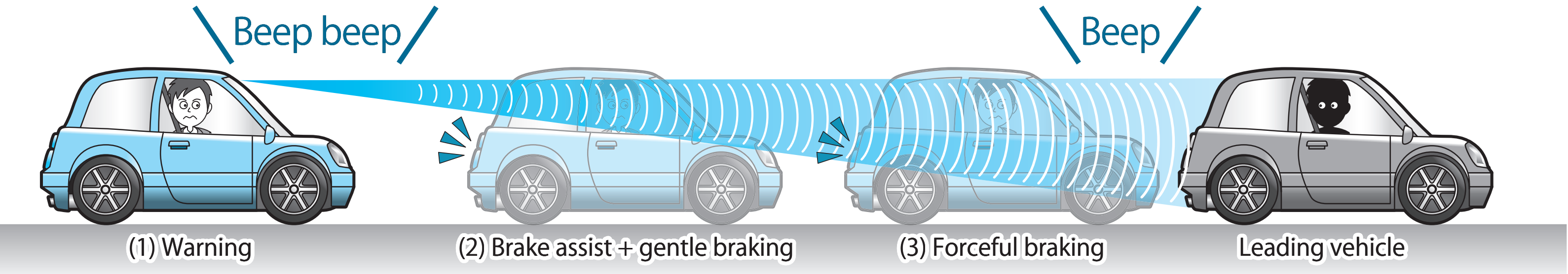

Fig. 1. Image of collision damage mitigation brakes (Automatic Emergency Brakes: AEB) activating

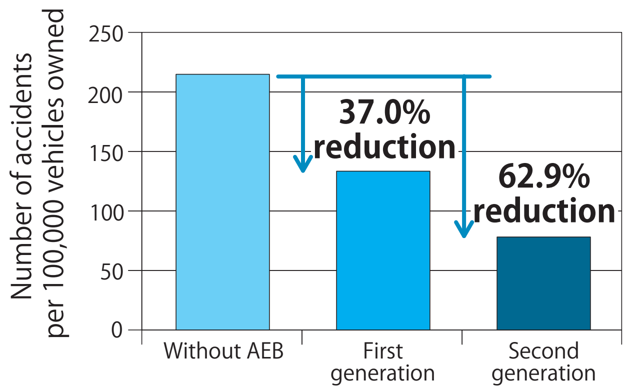

Fig. 2-1. Reduction effects on rear-end collision accidents involving four-wheel vehicle due to AEB
(2016 - 2018; primary party: kei sized passenger vehicle)

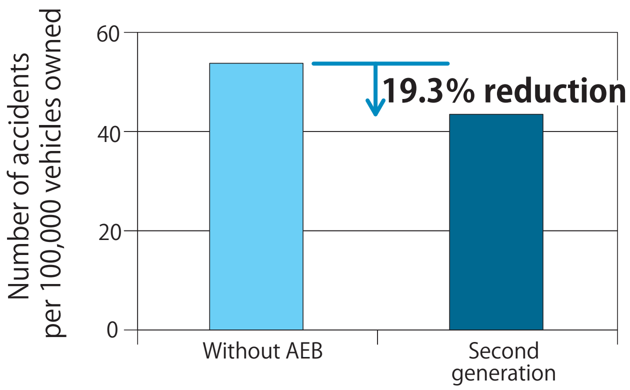

Fig. 2-2. Reduction effects on pedestrian-vehicle accidents due to AEB
(2016 - 2018; primary party: kei sized passenger vehicle)

1 Introduction

Collision damage mitigation brakes (Automatic Emergency Brakes: AEB) are driving assist systems that have the aim of avoiding traffic accidents or mitigating the damage when traffic accidents do occur by supporting drivers in applying the brakes in response to obstacles up ahead.
An image of an AEB activating is shown in Fig. 1 on the front cover. Sensors on the vehicle (cameras, radar, etc.) detect leading vehicles, pedestrians, and so forth and, when the system determines that there is a risk that the vehicle will collide with these if it continues on its present course, it initially emits a warning in order to urge the driver to apply the brakes (Fig. 1-(1)). In addition, to assist the driver with the force needed to apply the brakes, the system will increase the braking pressure and begin gently applying the brakes (Fig. 1-(2)). If the driver fails to subsequently apply the brakes and the system determines that the risk of a collision has risen, it will then forcefully apply the brakes (Fig. 1-(3)).
Fig. 3 shows a breakdown by type of accident for accidents in which a four-wheel vehicle served as the primary party over the five-year period from 2014 to 2018. This reveals that the rear-end collision accidents involving four-wheel vehicles and pedestrian-vehicle accidents that serve as the main target accident types that activate the current type of AEB account for 47% of all accidents, and suggest that the number of accidents caused by four-wheel vehicles can be greatly influenced by the effects from AEB. In addition, recently AEB that can respond to accidents from head-on collisions between four-wheel vehicles, collisions between a vehicle turning right and a vehicle going straight on, and bicyclists have begun to be practically implemented, with the thinking being that even more advanced and sophisticated AEB will be developed and disseminated in the future.

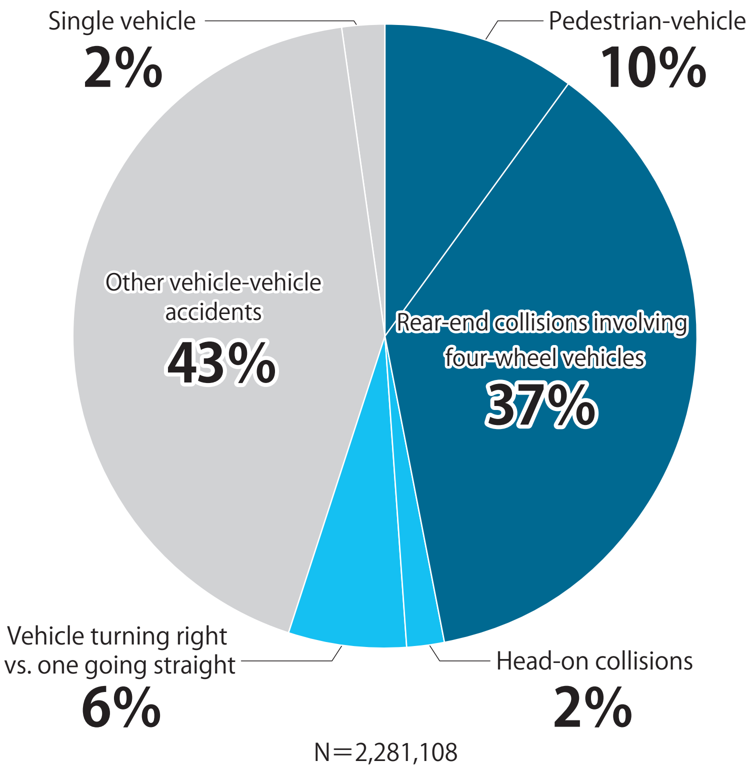

Fig. 3. Status of traffic accidents by type of accident (2014 - 2018; primary party: four-wheel vehicle; excluding accidents involving trains)

This issue of ITARDA Information will introduce readers to the results of analyses concerning the effects of AEB on kei sized passenger vehicles, as ITARDA possesses information on AEB systems from over an extended period of time, with a focus on the rear-end collision accidents involving four-wheel vehicles and pedestrian-vehicle accidents that serve as the main target accident types that activate the current type of AEB. It will also consider points that drivers must pay attention to when driving an AEB-equipped vehicle.
For this analysis, the AEB were divided up into different generations based on their functionality, as indicated in Table 1. The dissemination of AEB broadly proceeded in order from medium sized passenger vehicles on to small and then kei sized vehicles. However, since their functionality can be divided up as shown in Table 1 irrespective of the type or model of vehicle, the assumption could be made that results similar to those from this analysis arose with small and medium sized passenger vehicles as well.

Table 1. Features of each generation of AEB

AEB	Examples of the structure of sensors used for the AEB	Functionality	
		Target (type of accident)	Activation speed (km/h)
First generation	Laser radar	Rear section of four-wheel vehicles (rear-end collisions involving four-wheel vehicles)	5～30(*)
	Milliwave radar		5～80(*)
Second generation	Milliwave radar + Monocular camera / Stereo camera, etc.	Rear section of four-wheel vehicles (rear-end collisions involving four-wheel vehicles) Pedestrians (pedestrian-vehicle accidents)	5～100(*)

(*) Representative activation speeds are listed

Regarding the activation of the AEB shown in Fig. 1, since there is no way to separate out cases where the driver applied the brakes in response to a warning at stages (1) or (2) from cases where the brakes were automatically applied by the system at stage (3), the decision was made to lump these together for the accident reduction effects shown here. In addition, since the focus here is casualty accidents, there is a lack of data for ascertaining whether the decrease in accidents was because the AEB made it possible to avoid a collision, or because while a collision could not be avoided, the accident ended up as one that only involved property damage. As such, the decision was made to exclude this point from the analysis.

2 Thinking behind the analysis of the effects of AEB on kei sized passenger vehicles

For the analysis of the effects of AEB, the tendency of accidents to occur (number of accidents per 100,000 vehicles owned) in both cases where vehicle were equipped with an AEB and cases where they were not equipped with one were compared by focusing on casualty accidents caused by kei sized passenger vehicles throughout Japan in order to determine the macro accident reduction effects. The aggregation conditions for the targeted accidents, number of accidents broken down by whether the vehicle had an AEB equipped or not, and number of vehicles owned in the middle of the year are shown in Table 2.

Table 2. Accident aggregation conditions, number of accidents, and number of vehicles owned

Accident year	2016 - 2018				
Primary party	Kei sized passenger vehicle(*1)				
Type of accident	Rear-end collisions involving four-wheel vehicles			Pedestrian-vehicle accidents(*2)	
AEB system	Without AEB	First generation	Second generation	Without AEB	Second generation
No. of accidents	14,495	9,692	2,506	3,663	1,376
No. of vehicles owned in the middle of the year for the three-year period from 2016 - 2018	6,807,420	7,221,576	3,169,883	6,807,420	3,169,883

(*1) Data on vehicle models with AEB set as a standard or optional feature that went on sale in or after January 2006 was aggregated.
(*2) The first generation of AEB systems did not activate in response to pedestrians, so data for these regarding pedestrian-vehicle accidents was not aggregated.

3 Characteristics of the effects of AEB

Fig. 2-1 and 2 from the front cover show the number of accidents per 100,000 vehicles owned for rear-end collision accidents involving four-wheel vehicles and pedestrian-vehicle accidents where a kei sized four-wheel vehicle served as the primary party over the three-year period from 2016 - 2018 by whether the vehicles had AEB systems equipped in order to confirm the accident reduction effects of AEB. An accident reduction effect of around 60% was seen for rear-end collision accidents involving four-wheel vehicles, and a similar effect of around 20% was seen for pedestrian-vehicle accidents. Moreover, the accident reduction rate was lower with pedestrian-vehicle accidents compared to rear-end collisions involving four-wheel vehicles. The reason for this is that as opposed to the former, where the analysis was narrowed down to focus on accident conditions where AEB was more prone to activating from among vehicle-vehicle accidents, the latter involved a wide range of different pedestrian locations and directions of motion, making it difficult to narrow down the accident conditions. Detailed analysis results for pedestrian-vehicle accidents will be explained later on.

<Explanation of how to view the graph analyzing the effects of AEB>

- The numbers listed on the graph indicate the rate of reduction in the number of accidents per 100,000 vehicles owned for vehicles equipped with AEB systems and those without them.
- The blue lines in the graph indicate where the difference in the number of accidents per 100,000 vehicles owned for vehicles equipped with AEB systems and those without them has a 99% or greater probability of being significant in a statistical sense (clear). Cases where this is not clear are displayed in gray.

■ Rear-end collisions involving four-wheel vehicles

The accident reduction effects for rear-end collisions involving four-wheel vehicles is shown in Fig. 4 broken down by daytime / nighttime. Both first and second generation AEB systems clearly reduced accidents compared with vehicles without them, and this effect is even more pronounced with second generation systems as opposed to first generation systems in both the daytime and nighttime.

Fig. 5 shows the accident reduction effect for rear-end collisions involving four-wheel vehicles by the danger perception speed of the driver of the primary party vehicle. Both first and second generation systems proved to be effective in line with their activation speeds, with first generation systems mainly activating in the speed range of 0-30km/h and second generation systems activating in speed ranges from 0-30km/h, up to 60km/h, and 61km/h and above. The first generation systems on kei sized passenger vehicles all used laser radar that activates in low speed ranges, but some of these demonstrated partial effectiveness in speed ranges faster than their activation speeds.

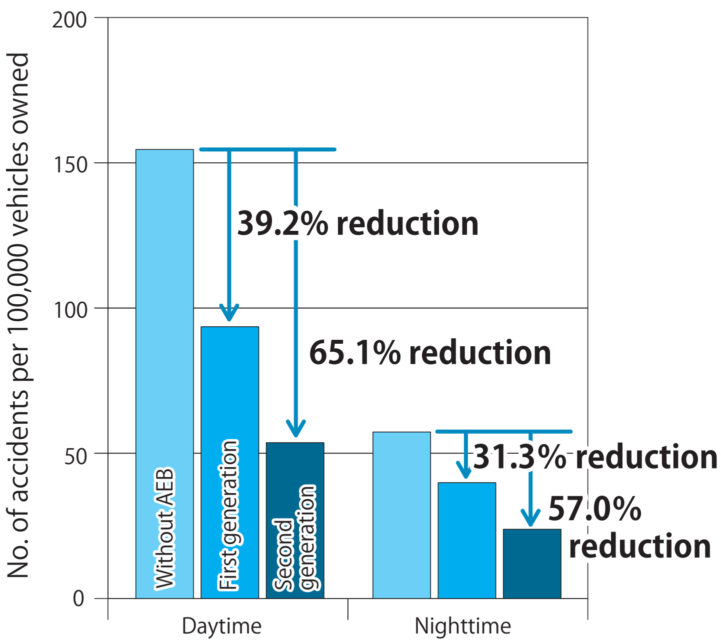

Fig. 4. Accident reduction effect for rear-end collision accidents involving four-wheel vehicles due to AEB in the daytime / nighttime
(2016 - 2018; primary party: kei sized passenger vehicle)

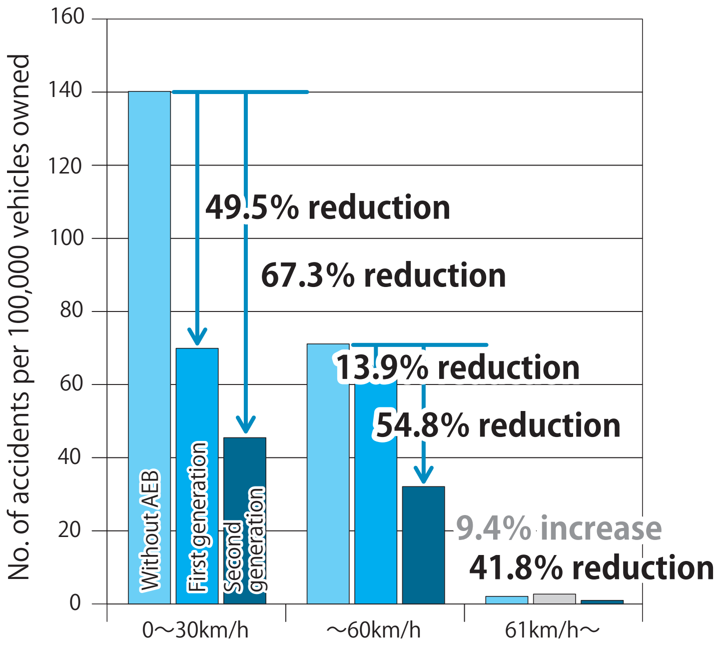

Fig. 5. Accident reduction effect for rear-end collision accidents involving four-wheel vehicles due to AEB by danger perception speed of the primary party
(2016 - 2018; primary party: kei sized passenger vehicle)

■ Pedestrian-vehicle accidents

The accident reduction effects for pedestrian-vehicle accidents is shown in Fig. 6 broken down by daytime / nighttime. Clear effects were observed in both the daytime and nighttime. Since only a limited number of vehicle models are equipped with AEB suited to detecting pedestrians at nighttime from among the targeted kei sized passenger vehicles, the thinking is that it is possible that other advanced safety devices aside from AEB, such as auto hi-beams that activate at nighttime, have contributed to reducing accidents as well. Hereafter, the focus will be placed on the effects of AEB, and so only accidents that occurred during the daytime will be included.

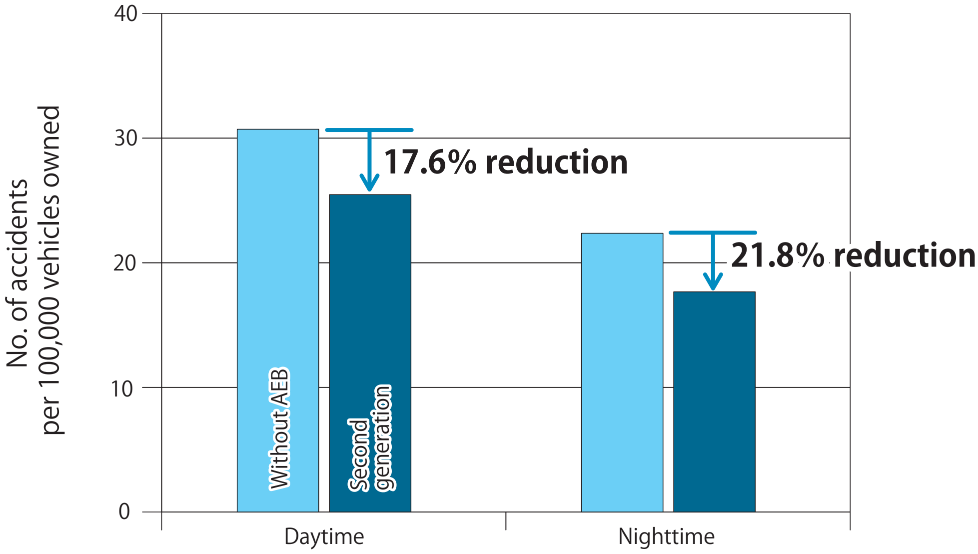

Fig. 5. Accident reduction effect for rear-end collision accidents involving four-wheel vehicles due to AEB by danger perception speed of the primary party

(2016 - 2018; primary party: kei sized passenger vehicle)

Data related to pedestrian-vehicle accidents has been aggregated without restrictions on the accident conditions more so than with rear-end collisions involving four-wheel vehicles, and so the results of this will be introduced by narrowing down the accident conditions to a greater extent. Fig. 7 shows the accident reduction effects of AEB for pedestrian-vehicle accidents by type of movement of the primary party's vehicle. Accidents that occurred when the primary party's vehicle was going straight or turning right accounted for a large share of these, regardless of whether or not the vehicle was equipped with AEB. Yet conversely, this reveals that the accident reduction effects of AEB mainly became manifest only when the vehicle was going straight. In addition, no effects were observed when the vehicle was turning either left or right. The reason for this is thought to lie in the fact that the AEB system judged that situations in which the driver cut the steering wheel sharply constituted a type of evasive action on their part, and therefore it did not activate.

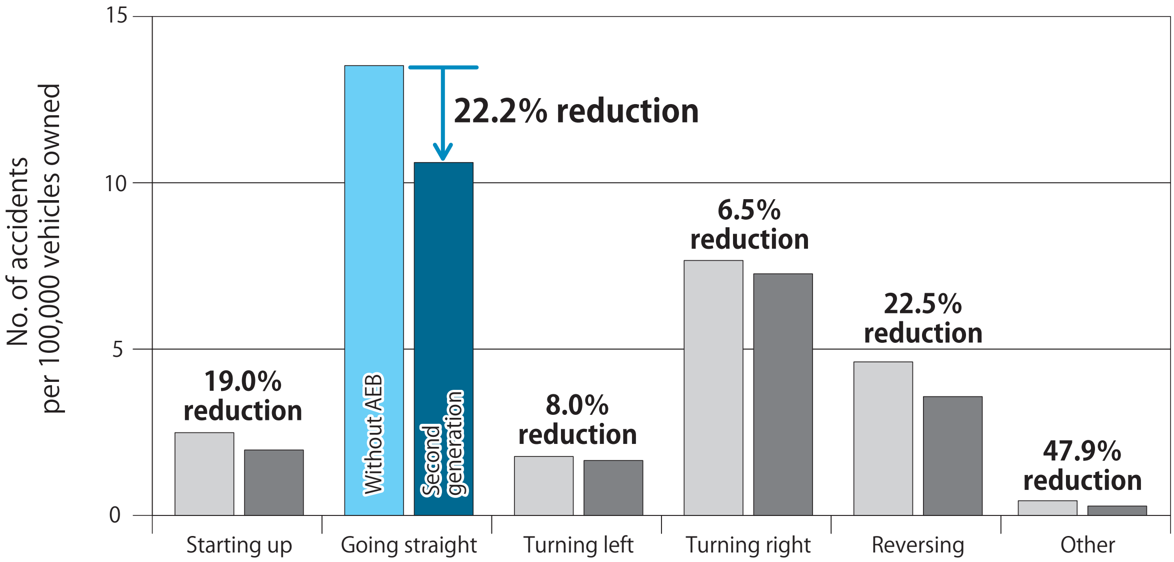

Fig. 7. Pedestrian-vehicle accident reduction effects due to AEB by the type of movement of the primary party

(2016 - 2018; primary party: kei sized passenger vehicle; daytime)

Additionally, with regard to accidents that occurred when the primary party's vehicle was going straight, the accident reduction effects of AEB will be introduced by the different human factors of the primary party driver. Fig. 8 shows the accident reduction effects for human factors that account for a large share of the whole (failure to pay attention forward, failure to confirm safety factors*) and the total for all cases where the vehicle was going straight. A clear reduction was seen with accidents caused by a failure to pay attention forward. AEB is believed to cut down on accidents that had previously occurred when the driver failed to notice the pedestrian when the pedestrian was within the forward field of vision of the driver, which corresponds to the detection range of the AEB sensors. Yet on the other hand, no clear reduction was observed with accidents caused by a failure to confirm safety factors. This is thought to be because the AEB either cannot detect pedestrians or is delayed in detecting them in situations where said pedestrians move from outside the sensor's detection range to inside this range, like when they suddenly rush out, and thus this is not conducive to reducing accidents.

(*) Failure to confirm safety factors: This refers to cases where the driver caused an accident because they either failed to detect the other party or were delayed in detecting them because they did not make every possible effort to check for confirmation by decelerating to a speed where they could make said confirmation (going slow, temporarily stopping).

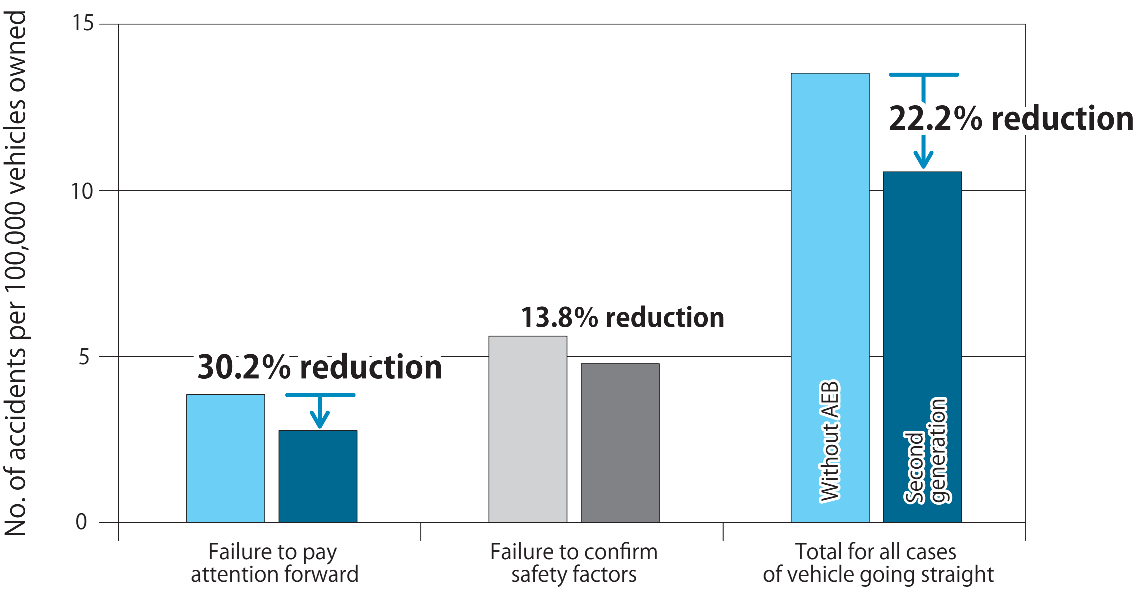

Fig. 8. Pedestrian-vehicle accident reduction effects due to AEB by human factor when the primary party was going straight
(2016 - 2018; primary party: kei sized passenger vehicle; daytime)

4 Why do accidents still occur even on vehicles equipped with AEB?

While the performance of AEB systems has been improving from the first generation to the second, they cannot completely eliminate accidents. Let's consider the reasons for this in detail.
We can presume that the accidents involving vehicles equipped with AEB include accidents that occurred in conditions that exceeded the inherent functionality of the AEB system. Both the first and second generation systems have preset objects that activate the AEB and speed ranges for this. Naturally, the assumption is that they will not prove effective in conditions that deviate from these settings.
What is more, even under conditions in which the AEB should function there is the possibility that the AEB may not activate normally as a result of factors like the weather, the maintenance status of the vehicle, or the shape of the object detected. The Ministry of Land, Infrastructure, Transport and Tourism[2)] and National Agency for Automotive Safety and Victims' Aid[3)] have listed examples of these which, when broadly categorized, can be classified as follows (see Fig. 9).

(1) Factors that lead to a reduction in braking force
Tire wear; dampness, snow cover, or frozen surfaces; steep downhills; a drop in tire air pressure, etc.
(2) Factors that lead to reduced detection capabilities of the system
Darkness, back-light, fog, dirt on the windshield / sensor receivers, misalignment of the sensor direction, etc.
(3) Objects that are difficult to sight visually
Trucks with protruding load platforms, extremely small objects, etc.
Pedestrians walking in a group, pedestrians holding umbrellas, etc.

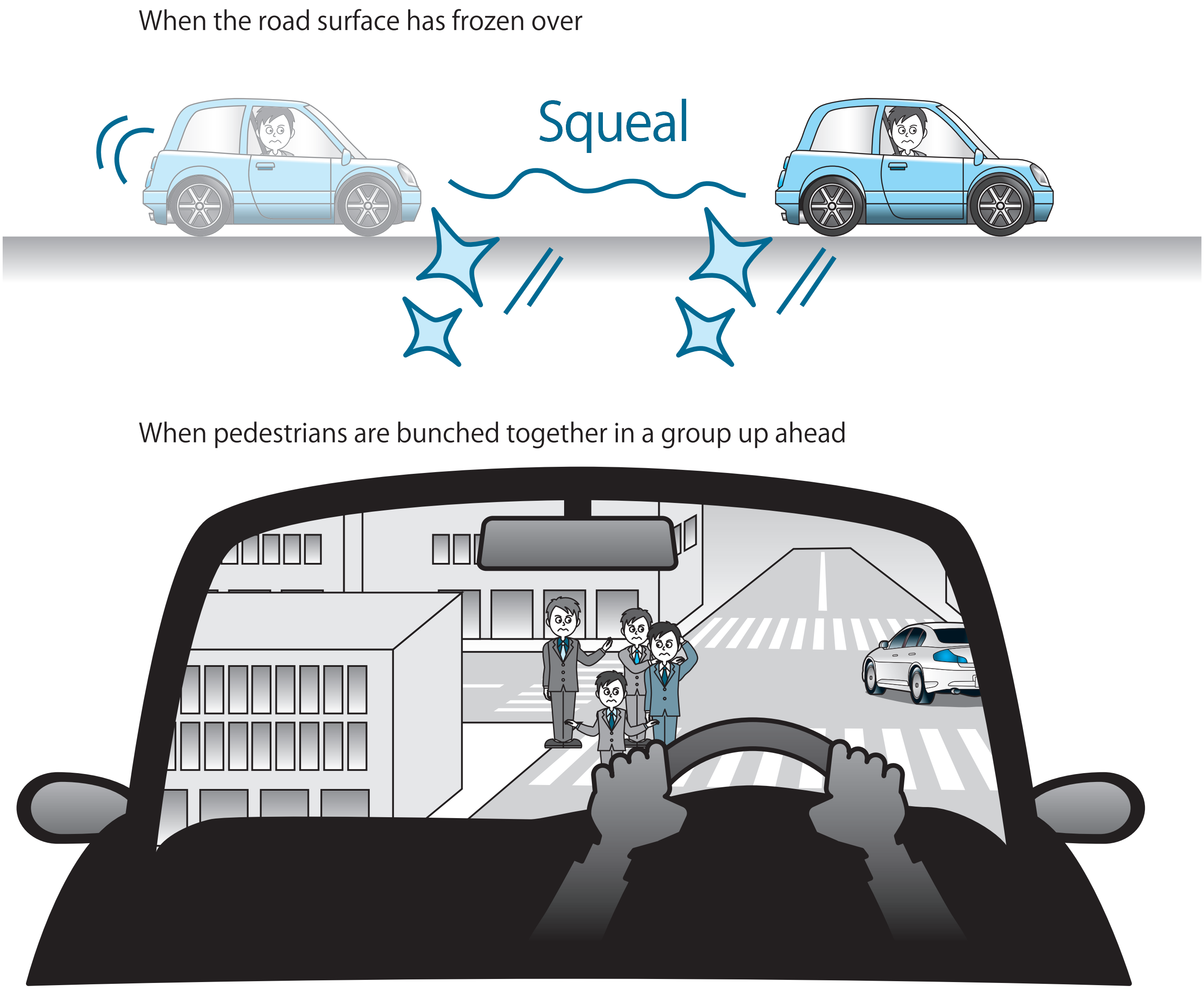

Fig. 9. Examples of factors that can negatively impact AEB activation

Moreover, accidents that could not be avoided even by a vehicle equipped with AEB include some accidents where the braking distance was no longer sufficient to avoid said accident as of when the AEB detected the object. Specific examples of this that could be mentioned include rear-end collision accidents involving four-wheel vehicles where the vehicle caused a rear-end collision with another vehicle parked in a location with poor visibility, such as on a steep curve, as well as pedestrian-vehicle accidents where a pedestrian crossing from a blind spot suddenly rushed out. AEB sensors are nothing more than a stand-in for a person's eyes; they cannot predict the movements of other people occupying blind spots. Therefore, in such cases it is essential for the driver to predict danger and respond by curbing their speed, for example.

5 Conclusion

Collision damage mitigation brakes (Automatic Emergency Brakes: AEB) have the following characteristics and limitations.

- **Accident reduction effect characteristics for kei sized passenger vehicles of AEB**

  Rear-end collisions involving four-wheel vehicles:

  Said effects were observed with accidents in the same speed range as the AEB's activation speed ranges (first generation: 0 - 30km/h; second generation: 0 - 30km/h, up to 60km/h, and 61km/h and above) in both the daytime and nighttime.

  Pedestrian-vehicle accidents:

  AEB reduced accidents in both the daytime and nighttime, though the thinking is that it is possible that other advanced safety devices, such as auto hi-beams, had an effect on this as well at nighttime. As for the daytime, effects were seen in situations where the vehicle was going straight, particularly when the driver failed to see a pedestrian up ahead.

- **The number of rear-end collisions involving four-wheel vehicles and pedestrian-vehicle accidents cannot be completely eliminated, even with AEB-equipped vehicles. The thinking is that this is because such accidents include accidents that occurred in conditions that exceeded the AEB's functionality, accidents involving factors that negatively impacted the activation of the AEB, accidents where the braking distance was no longer sufficient to avoid said accident as of when the AEB detected the object, and so forth.**

  Based on the above, precautions that drivers must pay attention to when driving an AEB-equipped vehicle will be summarized below.

- **AEB has shown effects at reducing accidents to a certain extent, but at present they work best under certain limited conditions. As such, they should be thought of as nothing more than systems for assisting with driving, and drivers should refrain relying on them too much when driving.**

- **Drivers must have a thorough understanding of the functionality and activation conditions of AEB in order to obtain their benefits.**

  Since the AEB's functionality and activation conditions differ on each vehicle type and model, drivers should gain a thorough understanding of the AEB on the vehicle that they drive. Ways of doing this include checking the manufacturer's homepage and their owner's manual, inquiring with their vehicle's dealership, and so forth. It is important that they confirm the following points in particular.

  ・Objects that activate it (vehicles, pedestrians, etc.)
  ・Activation speed range
  ・Conditions that can negatively impact activation (darkness, back-light, fog, etc.; said conditions can vary depending on the types of cameras / sensors)

- **Drivers should get in the habit of performing the following routine inspections and maintenance to ensure that their AEB can perform as intended.**

  ・Confirm the extent of wear on the tires and properly regulate the air pressure in their tires (to counter decreased braking force)
  ・Remove dirt from the front windshield and sensor receivers (to counter decreased detection capabilities) However, should the camera lenses get dirty, cleaning them could potentially result in damage to the lenses. So drivers should consult with their vehicle's dealership or the like rather than cleaning these themselves.

Moving forward, AEB with even greater functionality is expected to be disseminated in order to cut down on accidents as much as possible. The expectation is that the functionality and activation conditions of the AEB systems introduced in this issue will be improved upon in the future.

(Naoya Kondo)

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