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Analysis of Compatibility Issues in Frontal Collision Accidents Between Vehicles

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1. Introduction

Discussions have started on whether MPDB[*1] frontal collision tests (Fig. 1)—which evaluate compatibility in frontal collisions between vehicles of different weights or sizes and were adopted for vehicle assessments in Europe from January of 2020—should be adopted domestically in Japan. Because vehicle types and road environments differ between Europe and Japan, it is necessary to discuss the possibility of adoption and determine conditions by first considering the types of accidents that occur in Japan.

In research performed jointly with the Japan Automobile Manufacturers Association (JAMA) in 2018 and 2019, road traffic accident integrated data (hereinafter, "macro data") and accident investigation data (hereinafter, "micro data") were used to analyze frontal collisions of vehicles with different weights and sizes in order to assess characteristics and trends.

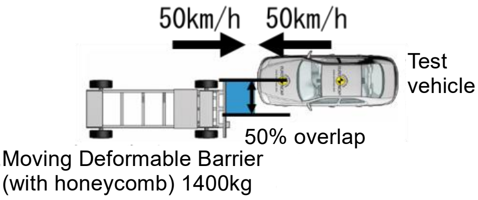


Fig. 1 - Compatibility evaluation tests in Europe

*1) **M**obile **P**rogressive **D**eformable **B**arrier

2. Analysis subjects

There are two types of frontal collisions between vehicles—those that take place between vehicles of the same weight and size, and those between vehicles with different weights and/or sizes. Although accidents between vehicles of the same weight and size are covered by fixed-wall collision tests performed by JNCAP[*2], evaluation methods for accidents between vehicles with different weights and/or sizes have yet to take shape in Japan. The goal of compatibility is to ensure the protection performance of the driver's own vehicle, while simultaneously reducing any damage caused to the opposing vehicle. For this reason, it is important to suppress the aggressiveness (harmfulness) of heavy and large vehicles, while improving protection levels provided to light and small vehicles. Because compatibility is determined by factors such as vehicle weight difference, speed difference, collision energy distribution, force interaction at the front of the vehicle, vehicle body strength, and passenger tolerances, variables from macro data such as vehicle weight, speed, passenger attributes, as well as variables from micro data such as injuries/points of contact, bumper height, and dashboard intrusion amounts, were extracted and subjected to analysis[*3]. Conditions for data extraction are as shown in Table 1.

Table 1. - Main data extraction conditions

Macro & Micro data	Type of accident/Area of collision	Vehicle-to-vehicle frontal collision/Vehicle front
	Parties concerned and injuries	Death/serious injury/slight injury of primary and secondary drivers (wearing seat belts)
	Vehicle types and applications	Kei, small, and medium-sized (passenger) vehicles
	Vehicle weight	Unladen vehicle weight (topped-off fluids, excluding tools and spare tires)
Macro data	Year of accident (year of survey)	2008-2017
	Year first registered	Two groups: 2001-2007 / 2008-2017
Micro data	Year of accident (year of survey)	2005-2017
	Year first registered	2005-2017

*2) Japan New Car Assessment Program

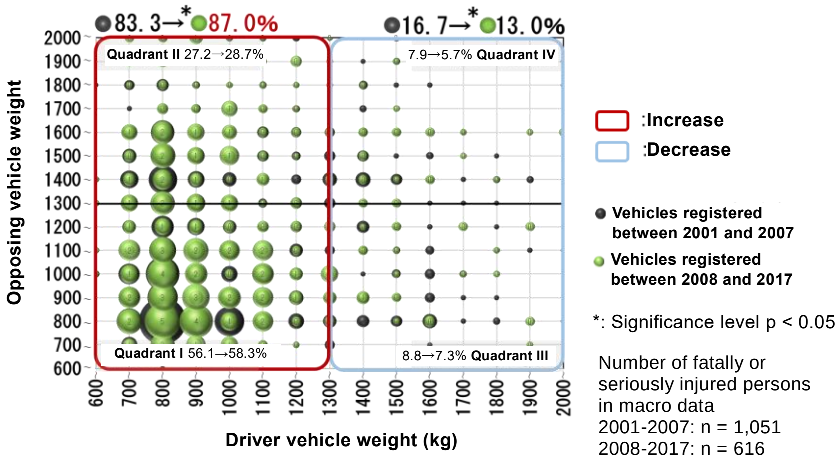
*3) This document shows excerpts of analysis results mainly from the results of joint research and from the viewpoint of vehicle weight.

3. Analysis using macro data

3-1. Changes in distribution for the number of fatally or seriously injured drivers

Figure 2 shows the distribution of composition rates for the number of fatally or seriously injured drivers in their own vehicles during vehicle-to-vehicle frontal collision accidents. In this figure, both the horizontal axis (driver's own vehicle) and vertical axis (opposing vehicle) plot vehicle weights in 100 kg increments (e.g., 600~: from 600 kg to less than 700 kg). The plot size indicates the ratio size. Also, the figure has been split into four quadrants for the sake of convenience, with the Quadrant I showing driver vehicles between 600 to less than 1,300 kg and opposing vehicles between 600 to less than 1,300 kg, Quadrant II showing driver vehicles between 600 to less than 1,300 kg and opposing vehicles of 1,300 kg or more, Quadrant III showing driver vehicles of 1,300 kg or more and opposing vehicles between 600 to less than 1,300 kg, and Quadrant IV showing driver vehicle of 1,300 kg or more and opposing vehicles of 1,300 kg or more. 600 kg is roughly the lower limit for passenger cars in the Japanese domestic market, while 1,300 kg is the midpoint of the 600 and 2,000 kg range that makes up the large majority of vehicles in the Japanese domestic market. From Figure 2, it can be seen that the ratio of registered driver vehicles weighing from 600 to less than 1,300 kg increased from 83.3% in 2001-2007 to 87.0% in 2008-2017. In other words, the distribution for the number of fatally or seriously injured persons shifted to Quadrants I and II, which are made up of driver vehicles lighter than 1,300 kg.

When separating individuals into the age groups of "65 and older" and "younger than 65" (Fig. 3), it can be seen that the rate for the number of fatally or seriously injured persons made up of individuals aged 65 or older in vehicles registered between 2008 and 2017 increased from 19.3% to 25.5%, while the rate for individuals younger than 65 decreased. This means that the distribution for the number of fatally or seriously injured drivers in vehicles registered between 2008 and 2017, particularly the number of fatally or seriously injured elderly drivers, shifted to Quadrants I and II, which have lighter vehicle weights than vehicles registered in 2001 to 2007. Accordingly, in order to reduce numbers of fatally or seriously injured persons in vehicle-to-vehicle frontal collision accidents, efforts that focus on protecting lightweight vehicles and elderly drivers are needed.



Values inside the plot are the composition rate (%) of vehicles registered between 2008 and 2017

Composition rates:

Numbers after the decimal point are hidden

Composition rate subtotals:

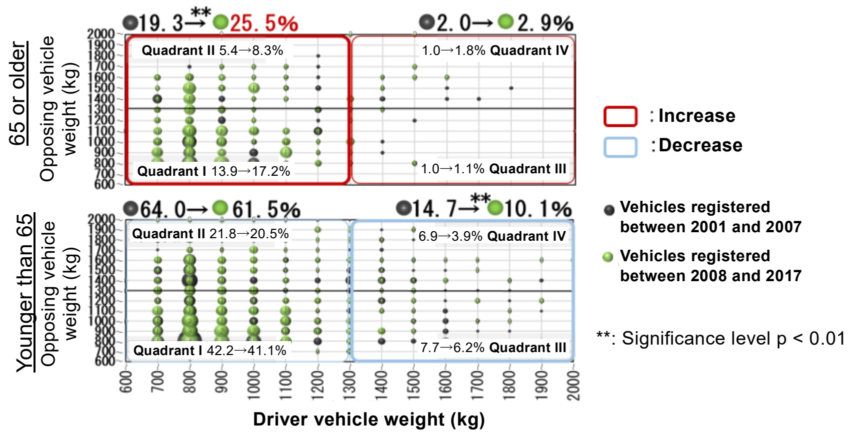
Numbers after the second number following the decimal point are rounded up

(survey years 2008-2017)

Fig. 2 - Composition rates for numbers of fatally or seriously injured drivers during vehicle-to-vehicle frontal collision accidents

Number of fatally or seriously injured persons in macro data
[2001 to 2007] 65 or older: n = 224, Younger than 65: n = 827
[2008 to 2017] 65 or older: n = 175, Younger than 65: n = 441

Values inside the plot are the composition rate (%) of vehicles registered between 2008 and 2017
Composition rates:
Numbers after the decimal point are hidden
Composition rate subtotals:
Numbers after the second number following the decimal point are rounded up



(survey years 2008-2017)

Fig. 3 - Composition rates for numbers of fatally or seriously injured drivers during vehicle-to-vehicle frontal collision accidents by age group

3-2. Changes in numbers of fatally or seriously injured persons and fatality/serious injury rates per 100,000 drivers in their own vehicles

Figure 4 shows the distribution for the number of fatally or seriously injured persons and fatality/serious injury rates*4 per 100,000 vehicles, with effects from the number of registered vehicles being excluded from the number of fatally or seriously injured drivers in their own vehicles. To facilitate comparison, 100 kg increments are not used. Instead, “from 600 to less than 1,300 kg” and “1,300 kg or more” have each been compiled into their own separate quadrants.

Although the number of fatally or seriously injured persons per 100,000 vehicles registered between 2008 and 2017 is decreasing more than that for vehicles registered between 2001 and 2007 in each quadrant, both groups of registered vehicles are at their highest level for numbers of fatally or seriously injured persons in Quadrant I, which means some issues regarding accidents between lightweight vehicles remain unresolved. This is possibly due to factors such as effects from the distribution of elderly drivers or the high encounter rate between drivers of lightweight vehicles.

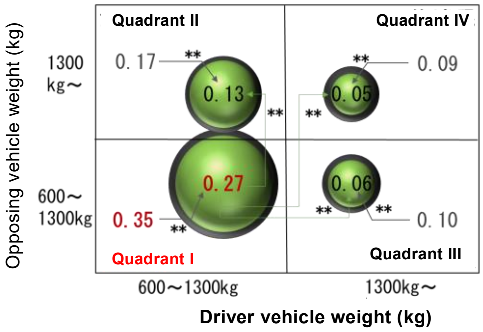
Furthermore, the fatality/serious injury rate for drivers in vehicles registered between 2008 and 2017 is higher than that of vehicles registered between 2001 and 2007 in Quadrants I and II. This is possibly due to factors such as effects from the distribution of elderly drivers shifting to Quadrants I and II. Quadrant II is particularly high, which means that fatality/serious injury rates are high in accidents between a lightweight vehicle (driver vehicle) and a heavy vehicle (opposing vehicle) and indicates that some compatibility issues also exist domestically in Japan.

From the above, it is apparent that efforts are necessary that address measures for reducing numbers of fatally or seriously injured persons in accidents between lightweight vehicles as shown in Quadrant I, as well as measures for reducing fatality/serious injury rates for accidents between lightweight vehicles (driver vehicles) and heavy vehicles (opposing vehicles) as shown in Quadrant II.

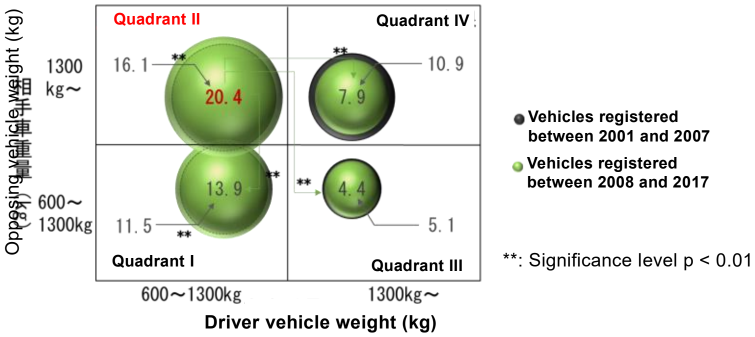
Number of fatally or seriously injured persons in macro data
[2001 to 2007] n = 1,051, Number of registered vehicles between 600 and 1,300 kg: n = 166,758,729, 1,300 or more: n = 91,172,529
[2008 to 2017] n = 616, Number of registered vehicles between 600 and 1,300 kg: n = 131,821,684, 1,300 or more: n = 70,825,281

Macro data
[2001 to 2007] Number of fatally or seriously injured persons: n = 1,051, Casualty numbers: n = 9,487
[2008 to 2017] Number of fatally or seriously injured persons: n = 616, Casualty numbers: n = 4,925

Number of fatally or seriously injured persons per 100,000 vehicles



Fatality/serious injury rate



(survey years 2008-2017)

Values outside the plots represent vehicles registered between 2001 and 2007, while values inside the plots represent vehicles registered between 2008 and 2017

Fig. 4 - Numbers of fatally or seriously injured persons and fatality/serious injury rates per 100,000 drivers in their own vehicles during vehicle-to-vehicle frontal collision accidents

*4) Fatality/serious injury rate = Number of fatally or seriously injured persons ÷ (Fatalities + Serious injuries + Slight injuries) × 100

3-3. Are measures possible that address both Quadrant I and Quadrant II?

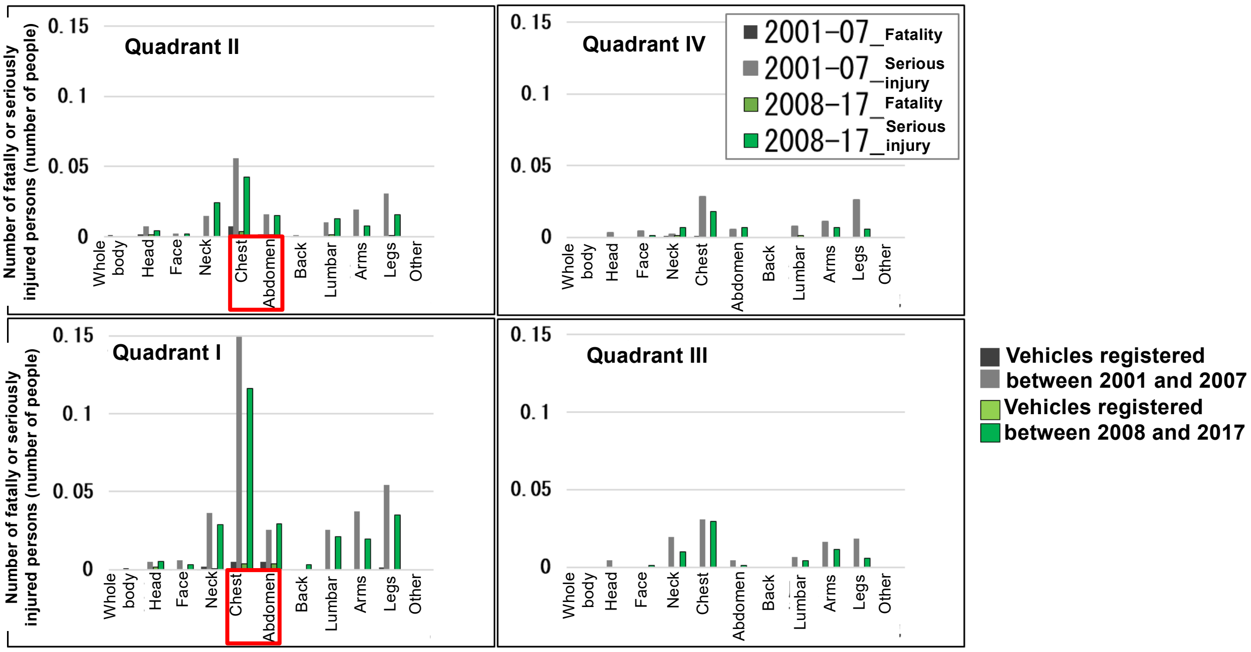
We will now look at measures for addressing the number of fatally or seriously injured persons (Quadrant I) and measures for addressing fatality/serious injury rates (Quadrant II). In the case of Quadrant I—which shows fatality/serious injuries in collisions between lightweight vehicles—there were many cases of injuries being caused to the chest or abdomen due to restraining force applied by the seat belt. In order to reduce numbers of fatally or seriously injured persons, it is necessary to decrease the amount of load being applied to the chest and abdomen by keeping driver restraining force as low as possible. However, as a measure to address collisions between lightweight vehicles (driver vehicles) and heavy vehicles (opposing vehicles) as shown in Quadrant II, it is necessary to reinforce lightweight vehicle bodies and increase driver restraining force in order to suppress cabin deformation in lightweight vehicles so that interference to driver steering can be prevented. Although it is necessary to consider how to implement measures that address both numbers of fatally or seriously injured persons (Quadrant I) and fatality/serious injury rates (Quadrant II), measures for lightweight vehicles are contradictory as described above, and not easy to achieve.

Conversely, although measures that minimize the harmfulness of heavy vehicle frames by weakening them are conceivable, there are concerns that simply weakening the bumper beams or frame could result in serious damage to heavy vehicles (passenger cars) in the event of a collision with a heavy-duty truck or a structure such as a wall. In response to these concerns, we will continue joint research on compatibility this year and analyze accidents to observe the harmfulness of heavy vehicles. We will make efforts in cooperation with JAMA to achieve both measures that address both issues by minimizing such harmfulness.

3-4. Distribution of parts of the body where drivers in their own vehicles sustained injuries

Figure 5 shows a distribution of parts of the body where drivers in their own vehicles sustained injuries for each quadrant. In both Quadrants I and II, drivers sustained torso injuries, such as to the chest and abdomen. These injuries are considered to be an issue particularly providing protection to elderly people who have lower levels of impact resistance.

(survey years 2008-2017)



Macro data [2001 to 2007] Numbers of fatally or seriously injured persons: n = 1,051
[2008 to 2017] Numbers of fatally or seriously injured persons: n = 616

Fig. 5 - Numbers of fatally or seriously injured persons per 100,000 vehicles by parts of the body where drivers in their own vehicles sustained injuries

4. Analysis using micro data

4-1. Details of injuries, points of contact, and extent of injuries sustained by drivers in their own vehicles

Figure 6 shows a distribution for the number of AIS2+ injuries sustained by drivers in their own vehicles in a fatal/serious injury accident by injury, points of contact, and extent of injuries*5. From Figure 6, it can be observed that when the driver vehicle is lighter than the opposing vehicle, the driver’s chest is injured by the seat belt, while the abdomen is injured by both the seat belt and steering wheel, with bone fractures and visceral injuries being the most common type of injury sustained. As one of indicator of compatibility evaluations, it may be effective to emphasize chest and abdomen evaluations while by considering the point of contact and the extent of injuries.

*5) Where the results of micro data are analyzed, it is necessary to pay attention to any impact low amounts of data may have on the accuracy of results.

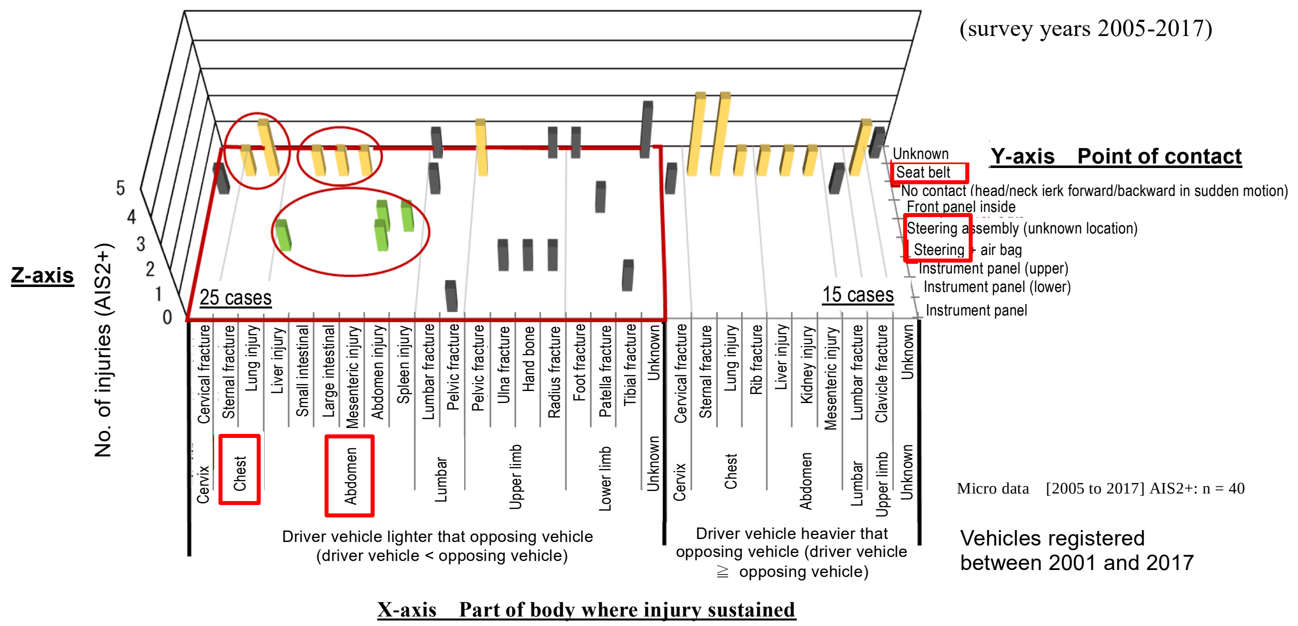


Fig. 6 - Number of injuries sustained by drivers in fatal and serious injury accidents during vehicle-to-vehicle frontal collisions by injury and point of contact

4-2. Impact of bumper height differences between vehicles

Figures 7-1 and 7-2 show the relationship that differences in vehicle front bumper height[*6] share with numbers of injuries sustained by drivers in their own vehicles and dashboard intrusion amounts. When differences between bumper heights are small (between -50 to less than 50 mm), dashboard intrusion amounts will also be lower, resulting in fewer injuries with a severity of AIS2+. It is conceivable that effectively matching bumper heights would improve vehicle-vehicle load transmission and minimize vehicle body deformation, in turn resulting in lower numbers of AIS2+ injuries. Although it is apparent that evaluations of bumper height matching may be effective, joint research performed this year will seek to ascertain whether that is in fact the case.

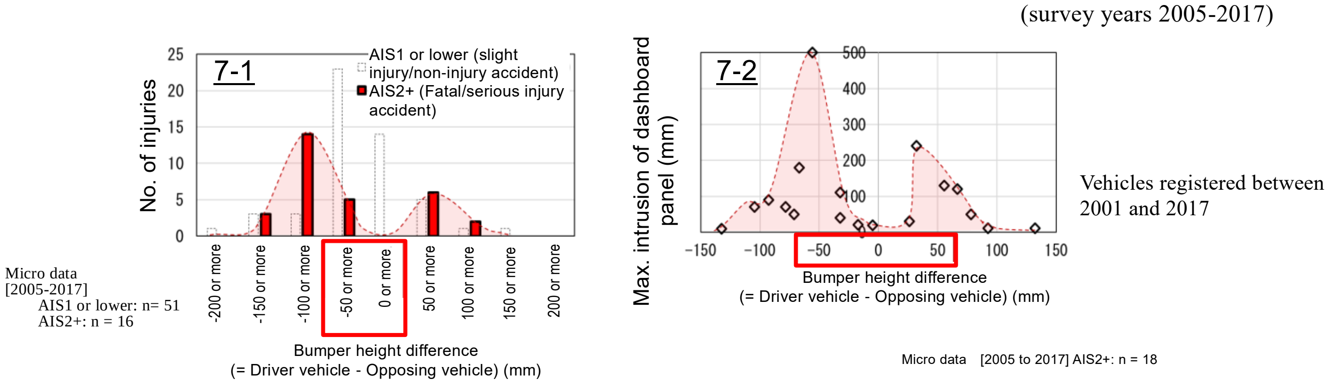


Fig. 7 - Numbers of injuries sustained by drivers in their own vehicles/dashboard intrusion amounts in vehicle-to-vehicle frontal collision accidents by bumper height difference

*6) Bumper height difference = Driver vehicle bumper height - Opposing vehicle bumper height

5. Conclusion

In regards to vehicle-to-vehicle frontal collision accidents:

(1) It was confirmed that fatality/serious injury rates are high and that compatibility is an issue for the Japanese market when considering measures to address collisions between lightweight vehicles (driver vehicles) and heavy vehicles (opposing vehicles). There are also high levels of chest and abdominal injuries being sustained, and the protection of elderly drivers is of particular concern in Japan with its significantly aged population.

(2) On the other hand, it is necessary to continue studying measures aimed at addressing the conventional issue of perennially high numbers of fatally or seriously injured persons due to chest and abdominal injuries in accidents between lightweight vehicles.

(3) Because measures for addressing issues (1) and (2) facing lightweight vehicles are contradictory, in the future it will also be necessary to analyze accidents to observe the harmfulness of heavy vehicles (passenger cars) in order to achieve measures that address both of these issues, including from the viewpoint of minimizing harmfulness.

(4) Furthermore, in order to standardize compatibility in the future, it may be effective to emphasize chest and abdomen evaluations by considering the points of contact and the extent of injuries, or to use indicators such as evaluations of bumper height matching. We will continue our joint research to ascertain whether this is in fact the case.