Hironori Chaya, Toyota Motor Corporation

Aiming to realize a society with zero traffic accidents where everyone can move safely and confidently

Toyota Motor Corporation continues to evolve and improve the performance of technologies that support safe driving in order to realize its ultimate goal of zero fatalities and injuries in traffic accidents. We interviewed Hironori Chaya from Advanced Mobility System Development Division about his efforts to estimate the benefit of Collision Damage Mitigation Brakes (also known as Automated Emergency Brake, AEB) using CarMaker, as well as his vision for future evolutions and improvements in simulation technology.

To achieve the ultimate goal of zero fatalities and injuries in traffic accidents, Toyota Motor Corporation is continuing to evolve and improve the performance of technologies that support safe driving. Could you explain this in more detail?

Automobiles are convenient vehicles that allow us to move freely. To continue enjoying safely and confidently driving a car in future, we are constantly engaged in research and development toward our mission of reducing traffic accidents to zero fatalities and injuries for everyone - including vehicle passengers, pedestrians, and all other road users.

Zero fatalities and injuries from traffic accidents is the ultimate goal of everyone involved in the automotive industry. To achieve this goal, we must not only develop safer vehicles, we must also conduct educational activities for drivers and all other road users.

It is also essential to improve the traffic environment and infrastructure, including traffic signals and roads. In addition to promoting this three-pronged effort, we believe it is important to pursue improved safety measures by applying what we have learned from traffic and accident data to our product development. Based on the Integrated Safety Management Concept*, Toyota aims to minimize the risk of accidents by linking individual safety technologies and systems, and providing appropriate support according to the respective driving conditions.

Mr. Chaya's interview took place at Toyota Technical Center Main Building.

What are your responsibilities within your department, Mr. Chaya? Please describe your tasks and what roles you play.

Our mission is to create sustainable mobility/service technologies that enrich people's lives.

My team is developing technologies to realize a society where there are no traffic accidents and where everyone can move safely and confidently by understanding effectiveness of advanced safety features and brushing them up through human research and simulation technology.

What do you enjoy most about using CarMaker to develop AEB technology?

First, the use of simulation allows the target traffic accident scene to be reproduced as many times as necessary under different conditions. While repeated experiments in the laboratory may yield slightly different results due to variability in real-world confounding factors, simulation is not subject to variability, no matter how many times it is repeated. This property makes it possible to precisely study the effects of changing only certain conditions.

We use this to predict the effectiveness of the Collision Damage Mitigation Brakes . With CarMaker, we can simulate everything from sensing to AEB activation to understand whether a collision with a pedestrian will occur. We can predict the effectiveness of AEB by comparing it to emergency braking by a human driver. It can also examine AEB's operation under various conditions, such as the speed and angle of pedestrians and vehicles. In this way, we are trying to estimate the actual effect of AEB under more realistic conditions..

**Toyota's approach to safety technology and vehicle development with the ultimate aim of realizing a "vehicle that does not cause accidents". In addition to the coordination of individual safety technologies and systems installed in vehicles, it includes coordination with road infrastructure (vehicle-to-infrastructure) and the utilization of information obtained from other vehicles (vehicle-to-vehicle) to provide optimal driving support according to driving conditions.*

What kind of traffic accident cases have you simulated?

According to the National Police Agency's annual report, pedestrians account for about 40% of traffic accident fatalities in Japan. More than half of these accidents occur while crossing the road, whether or not they are at a crosswalk.

When a pedestrian unexpectedly crosses a road without traffic lights or crosswalks, approaching vehicles may not be able to stop in front of the pedestrian even if the driver is paying full attention. In this study, we assumed a scenario where a vehicle traveling on a straight road (without a traffic light or crosswalk) is presented with a pedestrian who suddenly emerges from the far side of a vehicle stoppedon the roadside ahead.

What kind of simulation environment did you build to simulate this pedestrian crossing accident?

The aforementioned simulation scenario was created in CarMaker's "Scenario Editor". The brake control was performed via MATLAB®/Simulink ®. The braking characteristics of the simulation were compared with those of an in-house test of emergency braking when a pedestrian dummy ran out into a dry road under sunny conditions. We determined that the reproducibility of the simulation was sufficient for this study.

Without AEB, braking operation by the driver (human) is simulated. We assume that the driver is concentrating on driving and immediately detects the pedestrian when it enters his/her field of view. The deceleration profile of the vehicle is varied under the same conditions, based on the assumption that the braking operation (after the pedestrian is detected) will vary depending on the driver's psychological state and physical condition, as well as individual differences and repetition.

With AEB, the system enters standby mode when a pedestrian enters the AEB sensor's field of view, and when the Time to Collision (TTC) falls below a threshold value, AEB is immediately activated and the vehicle decelerates according to a predetermined profile.

Please tell us more about the evaluation using the environment you created.

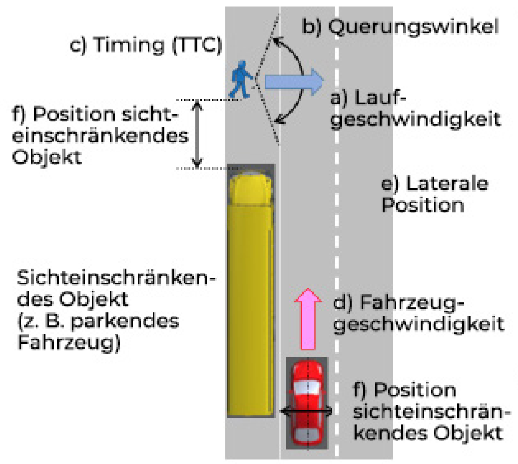
A total of 17,000 cases of simulation conditions were created by varying six parameters, including vehicle and pedestrian movements, with probability distributions.

The six parameters specifically refer to pedestrian crossing conditions (walking speed, crossing angle, and walking start timing), vehicle movements (travel speed and width position in the lane), and stopped vehicle (bus) positions on the side of the road. L.H.S. (Latin Hypercube Sampling) was used to combine the parameters.

The simulations were run using CarMaker's "Test Manager" function. 17,000 simulation cases were run with AEB not activated (hereafter referred to as "without AEB") and 17,000 simulation cases were run with AEB activated (hereafter referred to as "with AEB").

The simulation results could be classified into three categories: (A) collisions avoided with and without AEB, (B) collisions avoided with AEB but not avoided without AEB, and (C) collisions occurred with and without AEB.

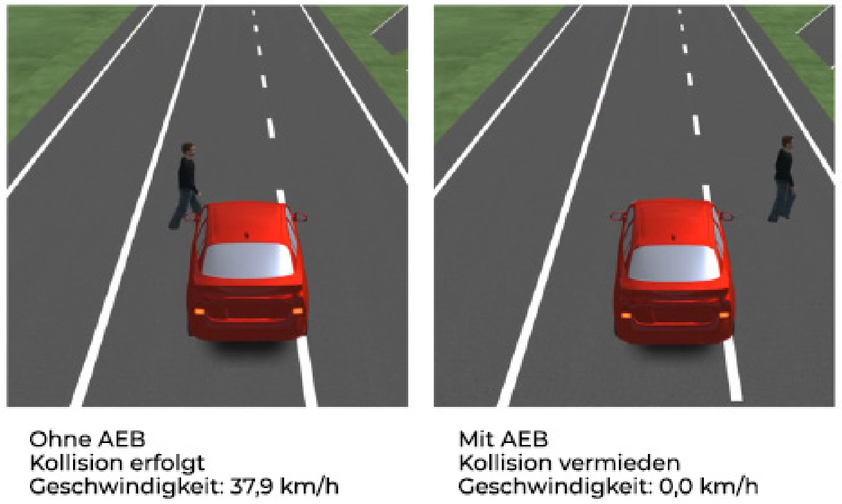
The collision avoidance effect with AEB was calculated as (B)/{(B)+(C)}. Here, (B) and (C) denote the number of collisions, respectively.



Parameter			Bereich (±3 σ)	Verteilung
Fußgänger	a	Lauf-geschwindigkeit	2,9 bis 7,2 km/h	Gaußsche Verteilung
	b	Querungswinkel	-70 bis +70 Grad	Gaußsche Verteilung
	c	Timing (TTC)	0,7 bis 10 Sek.	Logarithmische Normalverteilung
Fahrzeug	d	Fahrzeug-geschwindigkeit	10 bis 60 km/h	Gaußsche Verteilung
	e	Laterale Position	-0,8 bis +0,8 m	Gaußsche Verteilung
	f	Position sichteinschränk-endes Objekt	4 bis 24 m	Logarithmische Normalverteilung

Durch die Kombination von Parametern wurden vielfältige Bedingungen (ca. 17.000) für Querungsszenarien mit einem Fußgänger geschaffen.

Simulated scenario where pedestrian suddenly appears from behind the sight shield.



Example of results (B) in which collision occurred without AEB (left figure) but was avoided with AEB (right figure).

What were the evaluation results obtained from the simulations?

Calculated according to the above formula, the benefit of AEB in collision avoidance was estimated at 84%. This means that there was an 84% reduction in the probability of a collision when AEB was activated.

An example of classification (B) that collision occurred without AEB and did not occur with AEB is shown in the figure above. Without AEB (left figure), the driver recognized a pedestrian who appeared behind a stopped vehicle (bus) on the side of the road and braked suddenly, but the vehicle failed to achieve a full stop in front of the pedestrian. With AEB (right figure), the sensors detected the pedestrian, and the emergency brake was activated immediately, ensuring that the vehicle came to a complete stop in front of the pedestrian.

These two cases have the same conditions except for the presence of AEB.

What are some of the future challenges in improving simulation technology?

The results described above predict the effectiveness of the driver and AEB systems when they work ideally, i.e., the driver model does not look off the road or become distracted, and it reliably recognizes pedestrians in its field of vision. Also, the AEB model reliably detects pedestrians in the sensor's field of view and assumes that the AEB system's ECU calculations and brake actuators are activated at the same time they are detected, without any delay.

On the other hand, real-world drivers can make mistakes, and the AEB system has its own limits of operation. If these aspects can be brought closer to the actual, real-world conditions, it is inferred that the simulation results will be improved.

What is your outlook for the future?

In this study, we dealt with accidents with pedestrians while crossing the road, which account for the largest percentage of traffic accident fatalities in Japan.

In the future, we will continue to study accidents with motorcycles (which account for the second largest number of fatalities) and accidents with pedestrians and bicycles while turning right or left. We also plan to study the effects of differences in the driver's state of arousal which may affect action delays when the driver perceives, understands the situation, and takes an action.

We estimate that more than 100,000 cases will need to be simulated in order to predict the effects of the AEB system using similar ways as I explained above. We believe that functions such as CarMaker's HPC (High Performance Computing) will be very useful in efficiently performing such simulations. Through these studies, we hope to contribute to the creation of safer and more confident vehicles.

Thank you for this insightful interview, Mr. Chaya.