

# Research on a Brake Assist System with a Preview Function

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## ABSTRACT

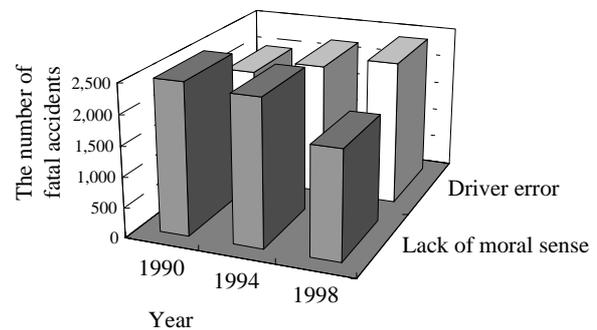
Traffic accidents in Japan claim some 10,000 precious lives every year, and there is seemingly no end to the problem. In an effort to overcome this situation, vehicle manufacturers have been pushing ahead with the development of a variety of advanced safety technologies. Joint public-private sector projects related to Intelligent Transport Systems (ITS) are also proceeding vigorously.

Most accidents can be attributed to driver error in recognition, judgment or vehicle operation. This paper presents an analysis of driver behavior characteristics in emergency situations that lead to an accident, focusing in particular on operation of the brake pedal. Based on the insights gained so far, we have developed a Brake Assist System with a Preview Function (BAP) designed to prevent accidents by helping drivers with braking actions.

Experimental results have confirmed that BAP is effective in reducing the impact speed and the frequency of accidents in emergency situations.

## ACCIDENT ANALYSIS

Figure 1 shows recent trends in the number of fatal accidents by types of violation. The number of accidents caused by drivers' pernicious behavior or lack of moral sense, such as disregarding traffic signals, drunken driving and excessive speed, has been decreasing year after year. On the other hand, the number of accidents caused by a slight error, such as operating mistakes, careless driving and distraction, has been increasing.



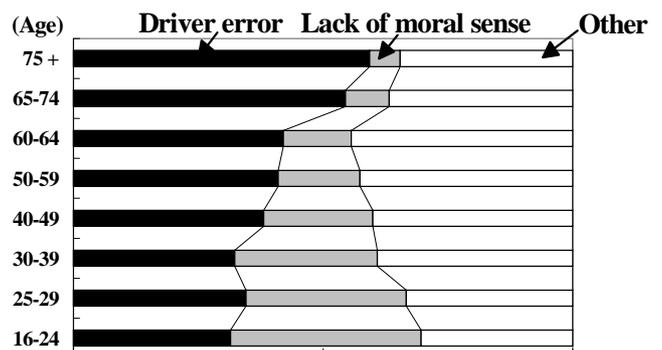
Source : National Police Agency, Japan

Fig 1. Trends in the number of fatal accidents by types of violation

Figure 2 shows the number of fatal accidents by types of violation for different age brackets. The percentage of accidents caused by a slight error, such as operating mistakes, careless driving and distraction, increases with increasing age. We can estimate that in the near future the ratio of these accidents will increase more as the population continues to grow older.

Fig 2. The number of fatal accidents by types of violation for different age bracket

Figure 3 shows recent trends in the ratio of traffic accidents by types. Rear-end and broadside collisions



are the two types of accidents which occur most frequently in Japan and have been steadily increasing in recent years. Since 1990, rear-end and broadside collisions have accounted for over 50% of all traffic accidents.

From the foregoing data, we can conclude that stepping up the development of technologies to assist drivers' recognition, judgment or vehicle operation under conditions with the potential for rear-end or broadside collisions will be a crucial factor in reducing the overall accident rate.

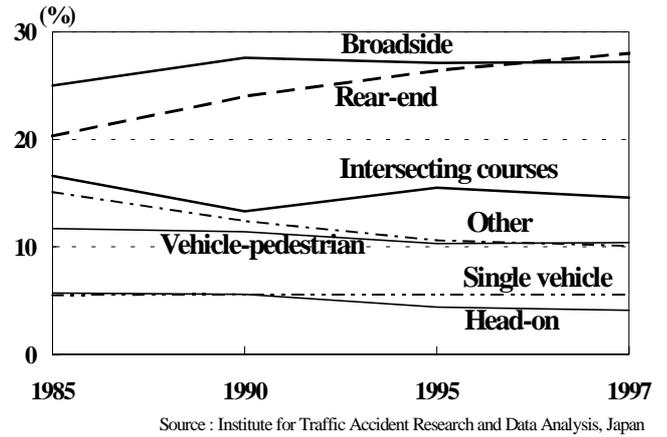


Fig 3. Trends in the ratio of traffic accidents by types

### ANALYSIS OF DRIVER BEHAVIOR

Knowing how drivers respond and brake in emergency situations is essential in order to analyze the fundamental causes of accidents and determine the direction for technology development. Using the driving simulator shown in Figure 4, a model was developed of an emergency situation where another vehicle suddenly comes out of a side street at an intersection and one's own vehicle runs into it broadside; measurements were made of drivers' behavior and responses (Figure 5).

To prevent the test subjects from predicting an emergency situation, they were first instructed to stop at or pass through a number of intersections. Following those dummy tasks and at a point when it was thought the subjects were accustomed to the driving simulator and might be apt to drive carelessly, a vehicle was presented from a side street. In order to focus on braking behavior, a vehicle was parked in the opposite lane so that the subjects could not avoid the collision simply by steering.



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Fig 4. Nissan Driving Simulator

Many subjects had depressed the accelerator pedal and accelerated the vehicle before the appearance of the other vehicle from the side street. After the other vehicle appeared and the subjects perceived the risk of a collision, histograms of their behavior show that they applied greater force to the footrest or gripped the steering wheel more strongly. After that, they soon released the accelerator pedal and pressed the brake pedal. (Figure 6)

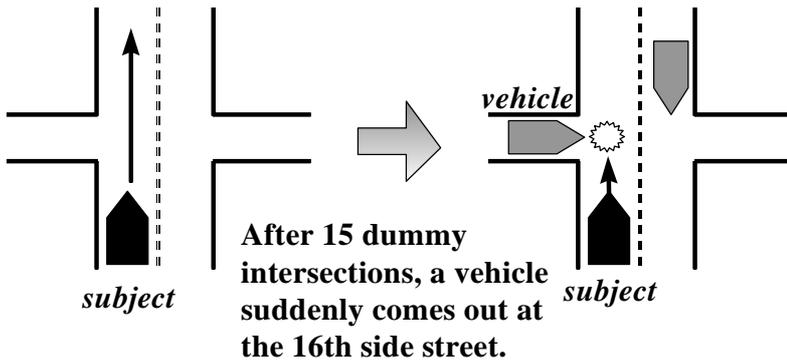


Fig 5. Simulated emergency situation

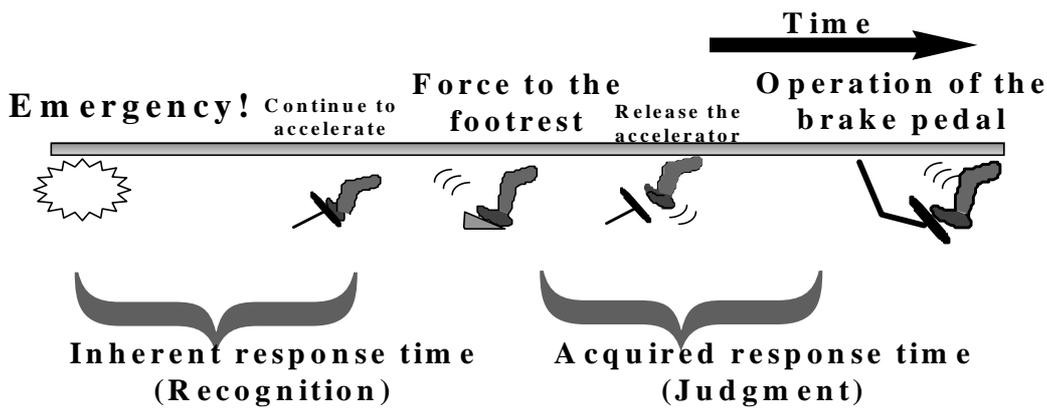


Fig 6. Time chart of drivers' responses and operations

Figure 7 shows that the inherent response time from a driver's perception of danger ahead to the application of force to the footrest or the steering wheel was approximately 0.62 second. The acquired response time from application of force to the footrest to operation of the brake pedal was 0.38 second, and the total response time was 1.00 second.

It was observed that some experienced subjects happened to be distracted when the danger arose ahead and were not able to avoid a collision. Little correlation is seen between the inherent response time and driving skill. However, the acquired response time shows little deviation and provides a criterion that readily indicates the difference in the driving skill of individual subjects.

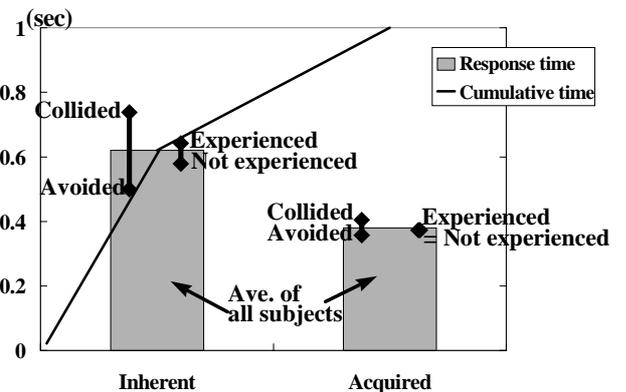


Fig 7. Response time of subjects

To summarize this analysis of driver behavior, technologies to assist drivers in recognizing a vehicle ahead by using radar sensors would be effective in reducing accidents for all drivers.

## OBJECTIVE OF BAP

In order to reduce accidents, it would be desirable for one's own vehicle to detect the headway distance reliably and to apply suitable braking force to avoid a collision. However, further development of accurate headway detection capabilities and reliable deceleration control is needed to commercialize such a system.

As the first step toward future automatic braking technology, we are currently developing an emergency braking aid system called the Brake Assist System with a Preview Function (BAP). This system provides minute braking force when the sensor detects danger ahead. This braking force closes the gap between the brake rotor and the brake pad to improve braking response when the driver presses the brake pedal and thereby reduces the stopping distance and the impact speed.

An overview of a prototype vehicle equipped with BAP is shown in Figure 8. It has a millimeter-wave radar sensor on the grille to detect the distance and relative speed of a vehicle ahead, a throttle angle sensor to measure accelerator pedal, control units, and a brake actuator to provide minute braking force.

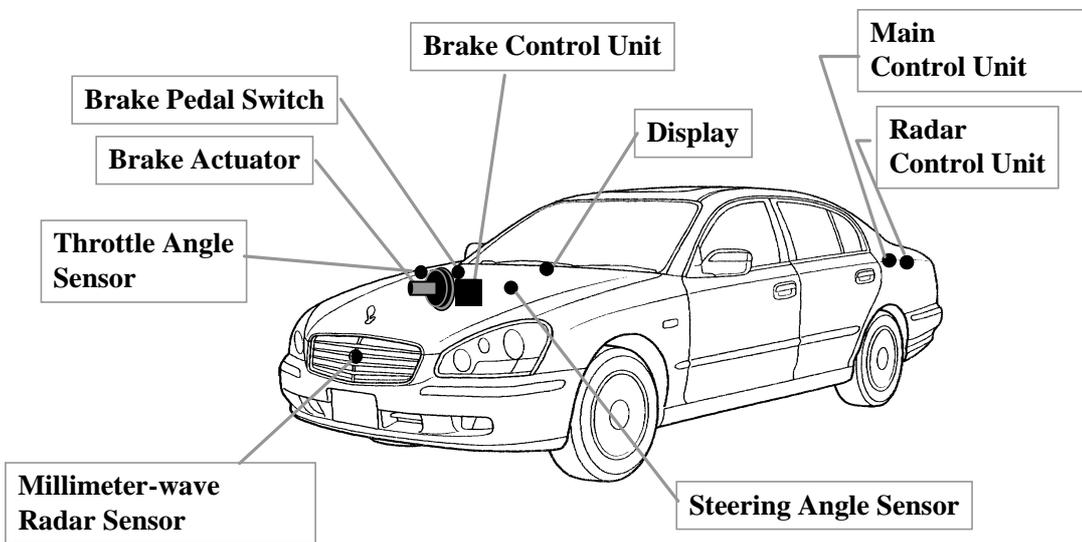


Fig 8. Overview of BAP-equipped vehicle

## CONTROL ALGORITHM

The target deceleration for stopping without colliding with the vehicle ahead,  $G_p$ , is calculated as follows:

$$G_p = (V_m^2 - V_f^2) / (2 * ds)$$

where  $V_f$  = velocity of the vehicle ahead

$V_m$  = velocity of the host vehicle

$ds$  = current distance between the two vehicles

Braking force begins to be provided when  $G_p$  exceeds a certain predetermined value, which is considered to indicate an emergency situation. A value of  $5.88 \text{ m/s}^2$  (0.6 G) was used in this research.

The supplied brake pressure  $P_t$  is determined by the manner in which the host vehicle approaches the vehicle ahead. In this research, greater brake pressure was supplied when the host vehicle accelerated or the return speed of the accelerator pedal was faster than usual while approaching the vehicle ahead.

$$P_t = f_1(A_m, V_m) * f_2(P_{dot}, V_m)$$

where  $A_m$  = host vehicle's acceleration

$P_{dot}$  = return speed of the accelerator

The system judges that the emergency situation has passed on the basis of one of the following conditions.

- when the driver operates the accelerator pedal
- when the driver operates the brake pedal
- when a certain interval of time has elapsed without any operation of the accelerator pedal or the brake pedal

### BENEFITS TO DRIVERS

The results of experiments conducted with the prototype vehicle show that the delay time from the operation of the brake pedal to the rise of the brake pressure was shortened by 100 msec with BAP (Figure 9).

Figure 10 shows the experimental results for the braking distance at an initial vehicle speed of 100 km/h. This test methods used was the "control braking method", which means that braking was done by an experienced driver. The distance was reduced by 3 meters or 6% with BAP.

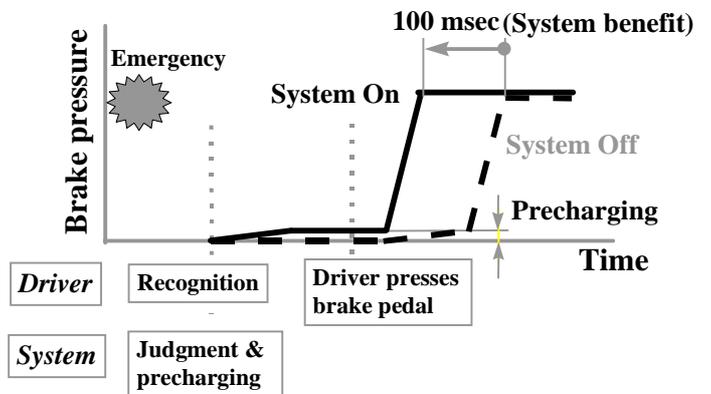


Fig 9. Comparison of brake pressure with system on and off

That would translate into a 5 km/h reduction in impact speed compared with conventional vehicles in the most frequent accident scenarios in Japan, in which a driver becomes aware of a obstacle at a forward distance of 20 meters when traveling at 50 km/h. The impact speed of a BAP-equipped vehicle would be 17 km/h, or 5 km/h less than that the 22-km/h impact speed of a vehicle without this system (Figure 11).

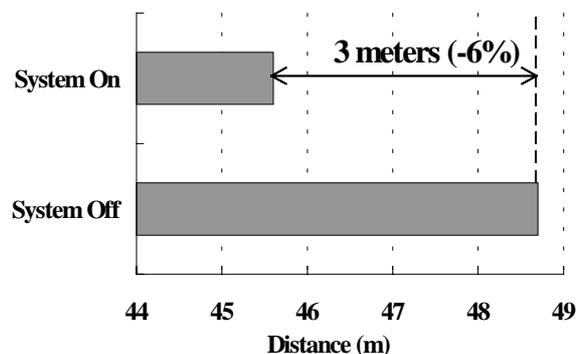


Fig 10. Comparison of stopping distance with system on and off

Figure 12 shows the correlation between the vehicle speed and the distance when the drivers recognize potential danger ahead. These data were collected in accident scene investigations or are based on statements given by drivers and other persons involved.

The curved line in the figure indicates the physical limit at which the vehicle can stop without a collision as a result of maximum deceleration. BAP would enlarge the collision avoidance area by the amount between the dashed line and the solid line.

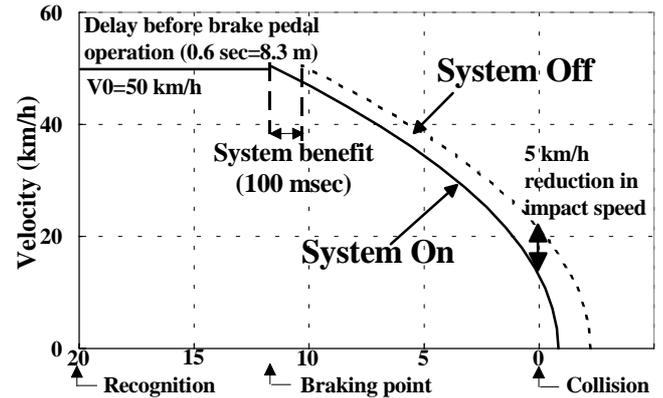


Fig 11. Comparison of impact speed with system on and off

In the accident database, 12 of 157 cases were in this expanded area, so it can be estimated that approximately 2% of the rear-end collisions might have been avoided. This estimation is premised on the assumption that the sensor for detecting the headway distance can recognize the driving environment without fail. In actuality, however, the sensor sometimes loses the vehicle ahead, so the actual collision avoidance rate might be smaller than 2%.

### LIMITATIONS OF BAP

We have confirmed that BAP would be helpful in reducing the impact speed or frequency of accidents. However, this system is only aimed at improving the braking response when the driver operates the brake pedal; it is not an automatic braking system. Accordingly, drivers must press the brake pedal firmly just as in ordinary driving.

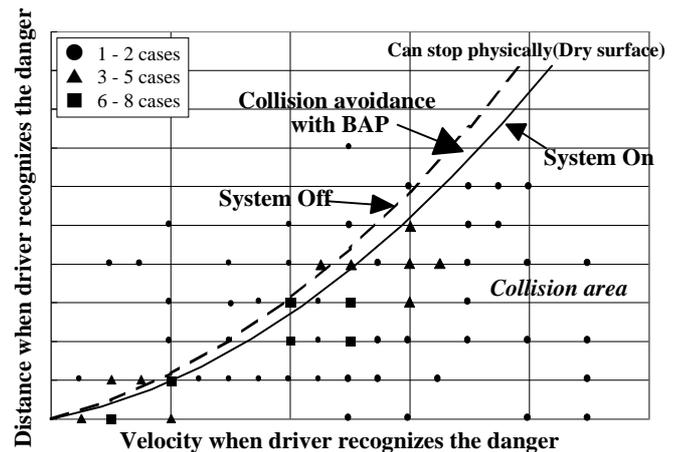


Fig 12. Estimation of collision avoidance

Although the performance of sensors for recognizing the driving environment has been improved significantly in recent years, sensors cannot detect, for example, objects that suddenly appear from crossroads or from behind some structures. It is expected that drivers will always try to drive carefully and not rely on the system excessively.

### CONCLUSION

- The results of experiments and accident database analyses revealed the behavior and response of drivers in emergency situations.
- A prototype of a Brake Assist System with a Preview Function (BAP) was built which incorporates sensor technology for detecting a vehicle ahead. A control algorithm for this system has been developed that is effective in compensating for a driver's inattention or misperception in an emergency situation.

- Sensors for detecting the external environment and actuators for controlling vehicle motions are being vigorously developed by many organizations for use in ITS or with advanced safety technologies. Such fundamental technologies will be used in this research to commercialize the next generation of BAP as quickly as possible with the aim of contributing to a reduction of fatal accidents.

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