Chapter 7
Technologies for safety improvement

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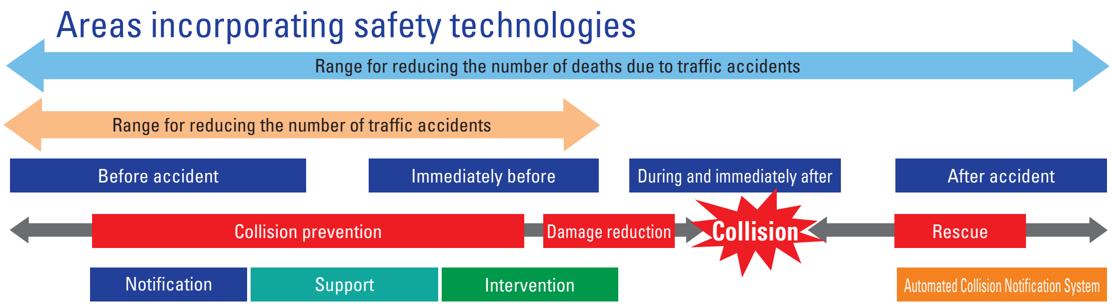
7.1 Passenger vehicles

This section categorizes by features various technologies for realizing the safety image presented in Chapter 6 and introduces the technologies with respect to each category of vehicle. We also describe the implementation timing for the devices shown in Fig. 1, mainly for passenger vehicles.



Active safety		Pre-collision safety	Passive safety	
Preventive Safety	Accident avoidance	Pre-collision safety	Injury reduction	Damage mitigation
ACC LKA AFS Multiview camera	ABS TRC ESC	CMBS E-pretensioner	Collision safety body Seatbelt/child seat Airbag system Pop-up hood Active headrest	Emergency alert system Energy-sensitive door unlock system

Figure 1. Areas incorporating safety technologies

7.1.1 Active safety

As of 2013, there are approximately 600,000 automobile accidents in Japan per year, and there is ongoing research and development and efforts to spread active safety technologies for preventing automobile accidents through the use of electronics and control technologies.

(1) Visibility enhancement technologies

Today we are seeing the practical use of high-luminosity discharge and LED headlights, which can improve forward visibility at sunset, at nighttime, and during inclement weather. There has also been increased implementation of adaptive front-lighting systems, which measure steering angle and vehicle speed to calculate the forward path of automobiles through turns in order to control the reflective mirrors of the headlight units, orienting them to better illuminate the path of travel.

Figure 2. Intelligent night vision system enhancing visibility of pedestrians[1)]

Indirect visibility is being improved as well. Installation of multiple cameras onto the car body allows display on monitors of traffic lanes at intersections with poor visibility, displays of the vehicle size superimposed on a rear-view image of the car when it is in reverse, and displays of the full area around the vehicle. Such fusions of video display with graphic image processing technologies allows for visibility enhancements of what is happening all around the vehicle.

Night vision systems to alert drivers of obstacles are also being developed (Fig. 2[1)]). Shining infrared light in the direction of travel during nighttime driving allows use of infrared cameras that can visualize and emphasize pedestrians or road conditions that would otherwise be difficult for the driver to see with the naked eye.

(2) Driving workload reduction technologies

While traditional cruise control systems maintain a constant speed on highways, adaptive cruise control (ACC) systems monitor conditions in front of the car by using millimeter-wave radar and stereographic cameras, and automatically adjust travelling speed to maintain a constant distance from other vehicles. ACC systems can be used not only to maintain speed on high-speed roadways, but also to provide proximity alerts and collision prevention in heavy traffic conditions on general use roads. Low-speed ACC systems in particular can be used in conjunction with collision mitigation braking systems to avoid or reduce low-speed collisions, and are looked to as a way of reducing the number of accidents at intersections, which account for the majority of traffic accidents.

Lane departure warning systems that use cameras and lane confirmation technologies are practical. In addition, intelligent driver assistance systems are being combined with car navigation systems. These can be used, for example, to notify or warn drivers of upcoming intersections at which a full stop is required.

(3) Vehicle dynamic performance technologies

When turning a steering wheel, if tire rotation is locked, then sufficient lateral force cannot be generated for yaw motion of the vehicle. For that reason almost all cars today have anti-lock braking systems (ABS) as standard equipment. ABS constantly monitors wheel rotation, and in cases where slippery road surfaces cause wheel locking during braking, briefly releases brake pressure to resolve the lock. By then raising brake pressure in a manner that prevents re-locking, braking can be performed in a manner that still permits steering wheel operation.

Electronic stability control systems have been required as a standard feature on all new automobiles since October 2012. These combine ABS with traction control systems, which prevent tire spinning during starts and acceleration, to provide active unified control of the force generated by each tire and thus prevent or reduce wobble and sideslip of vehicles. Integrating such systems with electronic power steering and others has also been promoted, which allows for overall improvements to vehicle dynamic performance, realizing better danger and accident avoidance in emergencies.

7.1.2 Passive safety

This section introduces technologies for minimizing damage to humans in the event of an accident.

(1) Collision damage mitigation technologies

The impact that is transmitted to occupants in a collision depends on the vehicle's momentum, which is the product of its mass and velocity. In the case of an extremely rigid vehicle body, the impact is immediately transmitted to the occupants, increasing the likelihood of serious injury. Engine compartments therefore have a "crumple zone" designed to deform and thereby absorb rather than transmit energy, reducing the amount passed on to occupants. In current methods of frame design, the amount of frame deformation in the time domain is calculated at the design stage, and design proceeds to ensure that the impact force delivered to occupants does not exceed a given critical danger value.

In vehicle-on-vehicle collisions, differences in the form of the colliding automobiles can result in impacts at different frame locations, sometimes significantly lowering the functioning of the crumple zone. The frames of light motor vehicles and standard class passenger cars are thus now designed to retain some degree of compatibility so that in the event of a collision, the frame of each can function as designed (Fig. 3[2)]).

Another recent technology for reducing the impact to passengers during a collision is emergency locking retractor seatbelts equipped with pretensioners and load limiters. When a collision is detected these seatbelts instantly retract any slack, and then

Figure 3. Schematic diagram of crash-compatible car bodies[2)]

the belt is fed out when a certain load is exceeded. Doing so can reduce injury to the chest.

Supplemental restraint system airbags have become standard equipment for both driver and passenger seats. In recent models collisions can be detected approximately 0.015 seconds after they occur. By varying the airbag inflation rate according to the speed of impact and constantly changing the airbag volume, passengers with various body types can be better protected. Side impact airbags that inflate in a curtain shape are also being increasingly deployed, and are effective toward reducing head and neck injuries.

(2) Pedestrian injury mitigation technologies

As a way of reducing injury to pedestrians in the event of a collision, automobile bumpers, fenders, and hoods are now being designed with space beneath them and are being manufactured with easily dented materials. Hood hinges are also being constructed so that when a strong force is applied to them they fold so as to absorb energy. Protrusions are being eliminated from car bodies to the extents possible to remove locations where a human body might get caught in a collision; this is one of the reasons why retractable headlights that pop up only when in use are no longer seen. Yet another safety feature is hoods that pop up at the moment a collision is detected, to produce a larger space beneath them.

7.2 Commercial vehicles

The forms of buses and large trucks are inherently different from those of passenger vehicles, due to the need to retain space for passengers and cargo. These vehicles are also operated in different ways, and so have unique safety features according to their characteristics.

Such vehicles are large, and truck beds or loaded cargo can create blind spots from the driver's seat, particularly to the rear and sides.[3)] These blind spots are being eliminated through the use of multiple mirrors as well as rear-facing cameras and sonar equipment that allow for confirmation of the status of areas of poor visibility. In recent years there have been trials of making the lower portion of passenger side door panel transparent, to improve side visibility.

Commercial vehicles remain in continuous operation for longer periods than do passenger vehicles, so equipment for monitoring driver attention is in practical use. As an example, certain systems use cameras to monitor the direction that drivers are facing and the status of their eyes, to ensure they are paying attention. Another system uses fuzzy logic to analyze the first 15 minutes of driving behavior, and from this can detect declines in driver attention from steering wheel operations and the like. In both cases, when driver inattention is detected a warning is sounded and displayed. An alarm can also be sounded when driver inattention is accompanied by weaving or failure to maintain lanes, and when this happens multiple times in sequence accidents can be prevented by decreasing the timing before which collision damage mitigation braking is applied.[4)]

With regards to vehicle dynamic performance, heavy-duty vehicles generally weigh more than passenger vehicles, and large loads on trucks can raise their center of gravity. This makes it easier for trucks to roll over or spin out in turns, leading to accidents. Today, in order to reduce such accidents, electronic stability control systems are being used in heavy-duty vehicles, just like in passenger vehicles.

Approximately 50% of accidents involving commercial trucks are rear-end collisions, and on highways the ratio reaches as high as 72%.[5] In an effort to reduce these accidents, implementation of collision mitigation braking systems is beginning to become mandatory for trucks. Trucks also tend to have a large clearance between their body and the road, leading to a submarine phenomenon at the time of collision with other categories of vehicles. Vehicle under-run protection devices are therefore currently mandatory, increasing compatibility with other automobiles as in the case of passenger vehicles.

In the future, we can expect to see more commercial vehicles adopting technologies from the ITS field, such as spacing maintenance systems (electronic horn system) using road-to-vehicle and vehicle-to-vehicle communications devices for comprehending conditions in the vicinity of operation. Also, these are expected to reduce the number of accidents involving other vehicles and to allow the formation of lines of trucks that automatically follow leader trucks, reducing fatigue in long-distance truck drivers.

7.3 Motorcycles

Motorcycles have two wheels, one in front of the other, and so must maintain balance at all times while in operation. Control operations are also more direct, such as by the rider directly changing steering angle or leaning the vehicle while in turns. There are some advanced systems that, for example, adjust engine output according to the vehicle attitude to prevent rear-tire skidding, but direct intervention through electronic stability control, such as that used in four-wheeled automobiles, is difficult.

One safety feature that accommodates these differences and is currently in practical use is an ABS system that uses electronic controls to link the front and rear wheel brakes. Motorcycles have a higher center of gravity than four-wheeled vehicles due to their shorter wheelbase and higher passenger-to-vehicle mass ratio. This results in a higher load transfer from the rear wheel to the front wheel under braking. Fig. 4 shows the resulting ideal braking force distribution curve for a motorcycle. Unlike the case in four-wheeled vehicles, when a motorcyclist applies sudden braking in excess of 0.5 G, the braking force on the front wheel must be increased and that on the rear wheel decreased. Attempts to apply single-input braking similar to that in

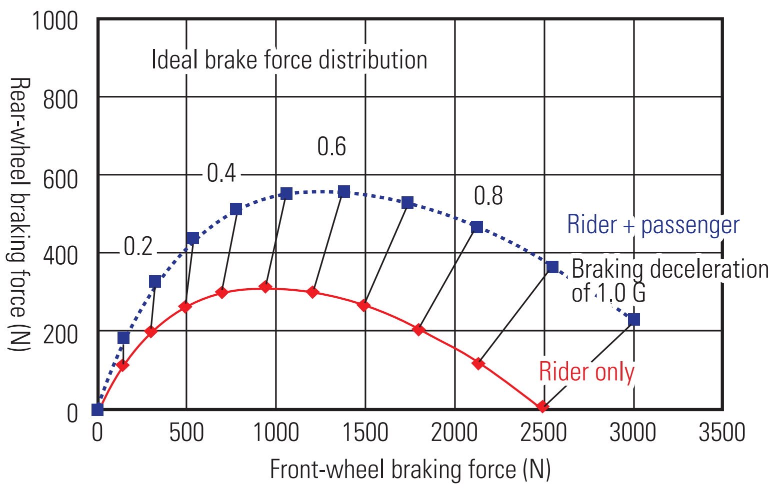


Figure 4. Ideal brake force distribution for motorcycle

automobiles result in complex apparatuses for rear-brake fluid pressure reduction, which is impractical for practical application given the motorcycle's limited mounting space. Most motorcycles thus have separate front and rear brake systems that riders themselves must operate independently in attempts to reproduce the ideal braking force distribution curve.

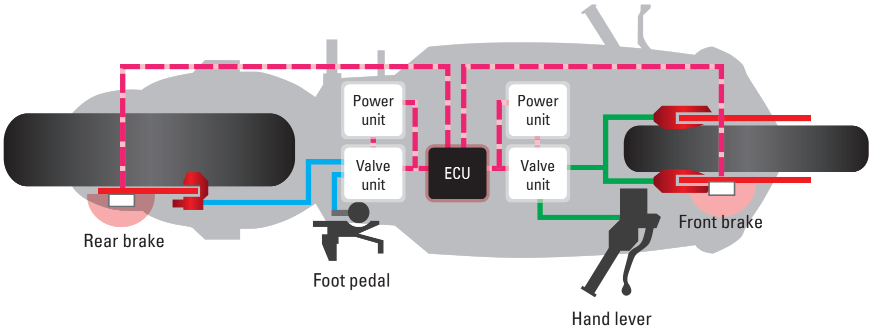


Figure 5. Diagram of electronically controlled combined ABS[6]

Electronic control of front and rear brakes coordinated through a by-wire can convert rider input to electronic signals, allowing computers to control both braking and the fine-grained activation of the ABS. This electronic control allows elimination of the ABS-dedicated equipment that was previously mounted on moving parts of the suspension, allowing use of standard parts.[6]

Another new technology is dual-clutch transmissions which reduce the shock caused by gear changes. This allows riders a larger margin of operation, and is expected to reduce the risk of accidents.[7]

Regarding passive safety, due to motorcycles' riding form and much smaller machine size, it is difficult to provide crumple zones like those seen in four-wheeled vehicles. However, through development of the ASV, some larger motorcycles now feature airbags. These airbags feature forms, sizes, and inflation methods particular to motorcycles, designed to accommodate the non-restrained seating of a rider.[8]

In recent years there riding jackets equipped with internally stored airbags have also been developed. These airbags automatically inflate when the rider becomes separated from the motorcycle due to a collision or rollover.

Motorcyclists on city streets frequently travel between lanes or along road shoulders to avoid traffic. As ITS becomes more widespread, road-to-vehicle and vehicle-to-vehicle communications devices like those described for automobiles are expected to decrease the number of accidents

Advanced Safety Vehicle and Driving Safety Support Systems (ASV/DSSS) to prevent left-turn accidents

[Purpose] To prevent left-turn accidents, information on hard-to-see vehicles is provided some distance back during left turns at an intersection with traffic signals.
[Expected benefits] Reduction in the number of left-turn accidents (accident prevention through provision of information regarding blind spot)

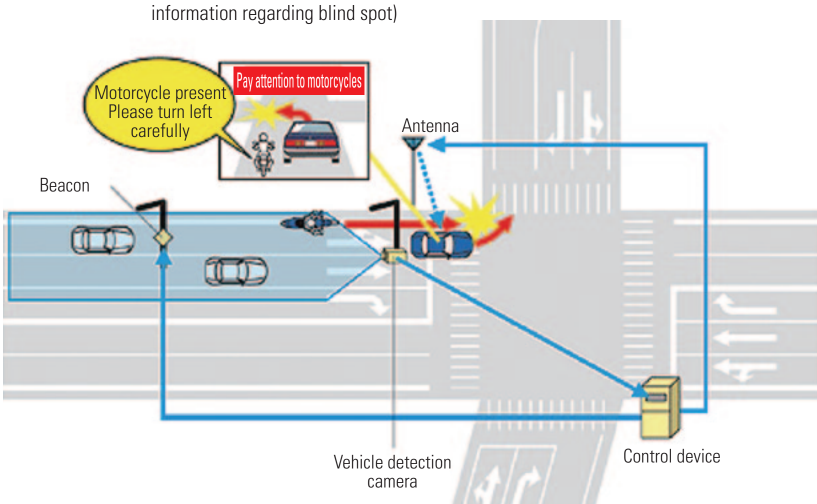


Figure 6. Vehicle-infrastructure cooperation under the intelligent transport system[9]

at intersections or involving cars turning in front of motorcycles, as such devices can alert other vehicles to their presence (Fig. 6[9]).

7.4 Other safety technologies

There have also been significant changes in tire technology. Run-flat tires (Fig. 7) have reinforced sidewalls that allow travel for some distance following a puncture. This allows vehicles to be operated without carrying a spare, reducing vehicle weight and thus fuel consumption.

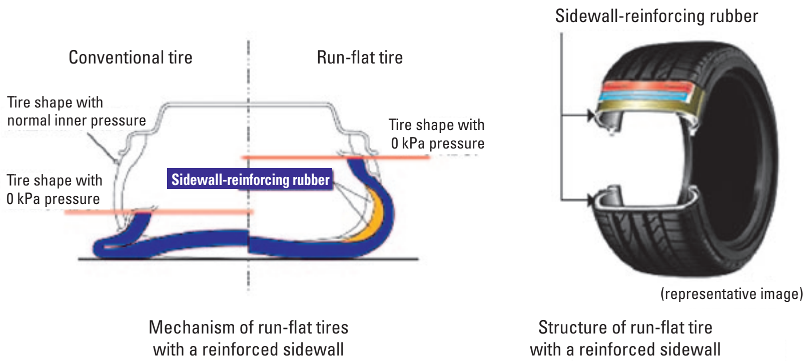


Figure 7. Structure of a run-flat tire[10]

Vehicle body component materials too are changing. While their use remains limited at present, we are starting to see the use of carbon fiber-reinforced plastic, in addition to the traditional ultra-tensile steel in consumer vehicles. This is expected to further reduce vehicle weight, improving running characteristics and decreasing fuel consumption. As body designs advance, assuming the increased use of such composite materials, freedom of design will allow increased safety over current mainstream body shapes.

Electric and hybrid vehicles are increasingly popular due to their environmentally friendly nature, but vehicles operating under electric power make much less sound than do those with an engine drive. This can result in pedestrians being unaware of their presence, increasing their involvement in accidents. Some such vehicles now issue an electronic sound when operating in electric mode, alerting those around them to their presence. Electric vehicles also contain high voltage components, so designs are now taking this in consideration to prevent accidental electrocution in the event of accidents.

As society continues to age, the rise of a new category of vehicles is becoming apparent: ultra-compact mobility devices with very small vehicle footprints and high maneuverability (Fig. 8[11]). These vehicles generally

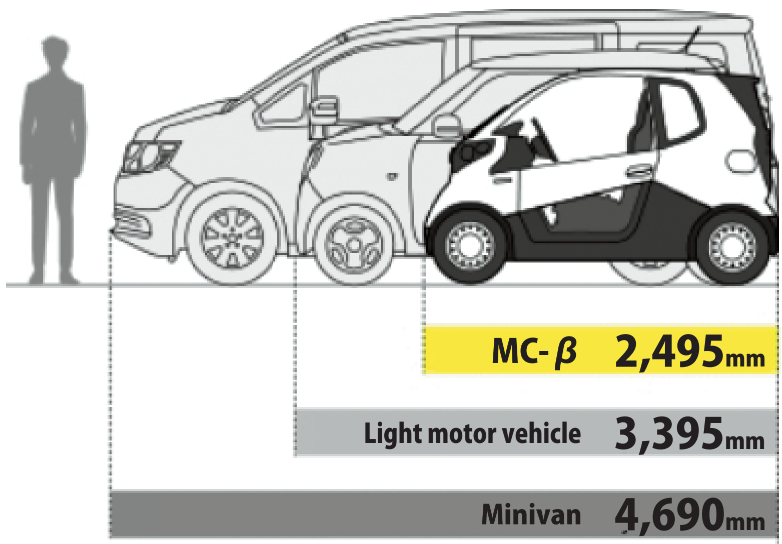


Figure 8. Size comparison of ultra-compact mobility devices[11]

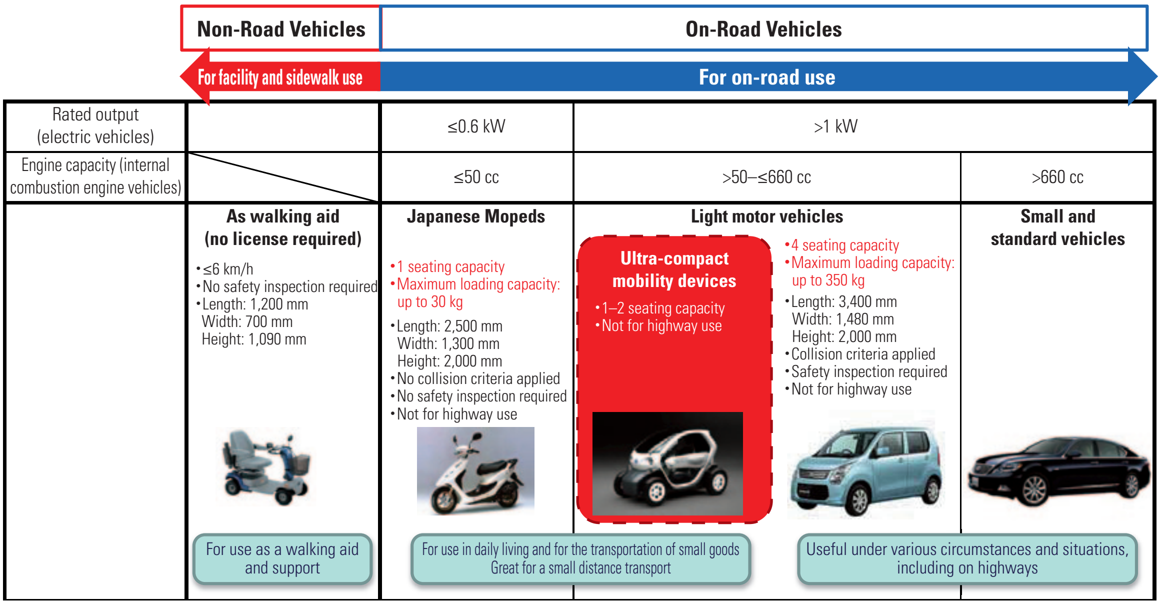


Figure 9. Ultra-compact mobility devices in comparison with conventional vehicles in Japan[12)]

allow only one or two occupants, and consume only about a sixth the energy of a standard vehicle (or about half that of an electric vehicle). They are generally intended for local travel near the home, excursions at tourist destinations or commercial areas, and small-scale delivery operations, but as they become more popular, more of these vehicles will likely be mixed in with general traffic, and there will be a need to confirm that they are differentiated and supplied with sufficient running space (Fig. 9[12)]).

As with motorcycles, these vehicles are very small, making it difficult to design them with crumple zones. However, as they become more prevalent there will be an increasing need for developing compact, cost-effective collision prevention devices to reduce the number of accidents that they become involved in.

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Practical application projects for reference

A study on the role and limitations of motorcycles as a means of urban transport in Southeast Asia: 156–159