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Topic: Integral safety

Abstract

In developed countries such as the USA or Europe, the risks of injury or fatality in traffic accidents have declined significantly in recent years. These reductions apply to both vehicle passengers and other involved persons. Much of this improvement has been attributable to progress in the field of passive safety, i.e., better protection of car occupants in situations where an accident is unavoidable. However, the marginal benefits resulting from additional efforts and expenditures in passive safety have begun to decrease; in other words, a classical "point of diminishing returns" has been reached. Increasing emphasis for achieving further significant improvements in vehicle safety will be placed on integral safety systems: Integral safety involves a concerted strategy of interlinking sensors and actuators of active and passive safety. The primary goal of this interlinking is optimization of performance and robustness of safety systems for occupants, but integral safety approaches can also achieve better protection of vulnerable road users than passive safety measures alone. In view of considerations such as reduction of CO2 and fuel consumption, there is another attractive benefit: integral safety can serve to reduce the steady weight increase of vehicles and thus provide an important contribution to the development of both sustainable and safe vehicles.

Abstract

In order to develop effective measures for mitigating the severity of traffic accidents or even completely avoiding them, it is essential to understand the mechanisms of accident events, including the processes and risks involved in traffic situations in which these accidents occur. A quantitative understanding of these processes and risks aids in assessing the potential effectiveness of vehicle safety measures. The automobile industry is faced with enormous challenges in discovering and implementing the most effective solutions. Assessment by legal authorities and/or consumer groups should concentrate on safety performance, not on specification of particular technologies or methodologies, and should encourage implementation of devices providing greatest safety benefits by mandating robust and standardized testing and assessment techniques that quantify and measure effectiveness independently of technological details.

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The term “Vision Zero” (Vision Zero Initiative 2011) today is a synonym for future targets in traffic safety. The vision is based on the idea of avoiding accidents completely, that is, zero accidents with zero injuries and zero fatalities. However, this goal cannot be achieved by a single technological leap, but requires a combination of strategies based on a profound understanding of accident processes. The generally accepted definition of passive safety includes all features and functions designed to protect victims of traffic accidents during and after the point of no return, that is, when the accident can no longer be avoided. Active safety on the other hand describes features and functions with the primary purpose of preventing such accidents or at least mitigating their severity. Integral safety is a rather new terminology that describes the combination of both active and passive safety and thus provides a cross-link between the situations before, during and after a possibly injurious collision. Below, this cross-link will be described in further detail. Trends in accident statistics indicate substantial progress in road safety during recent years in the USA, Japan, and the developed countries of Europe. The picture is more complicated in emerging countries such as India or China, which are outside the focus of this report: in these countries, rapidly growing motorization – coupled with a rather immature traffic infrastructure – produces a considerably different situation.

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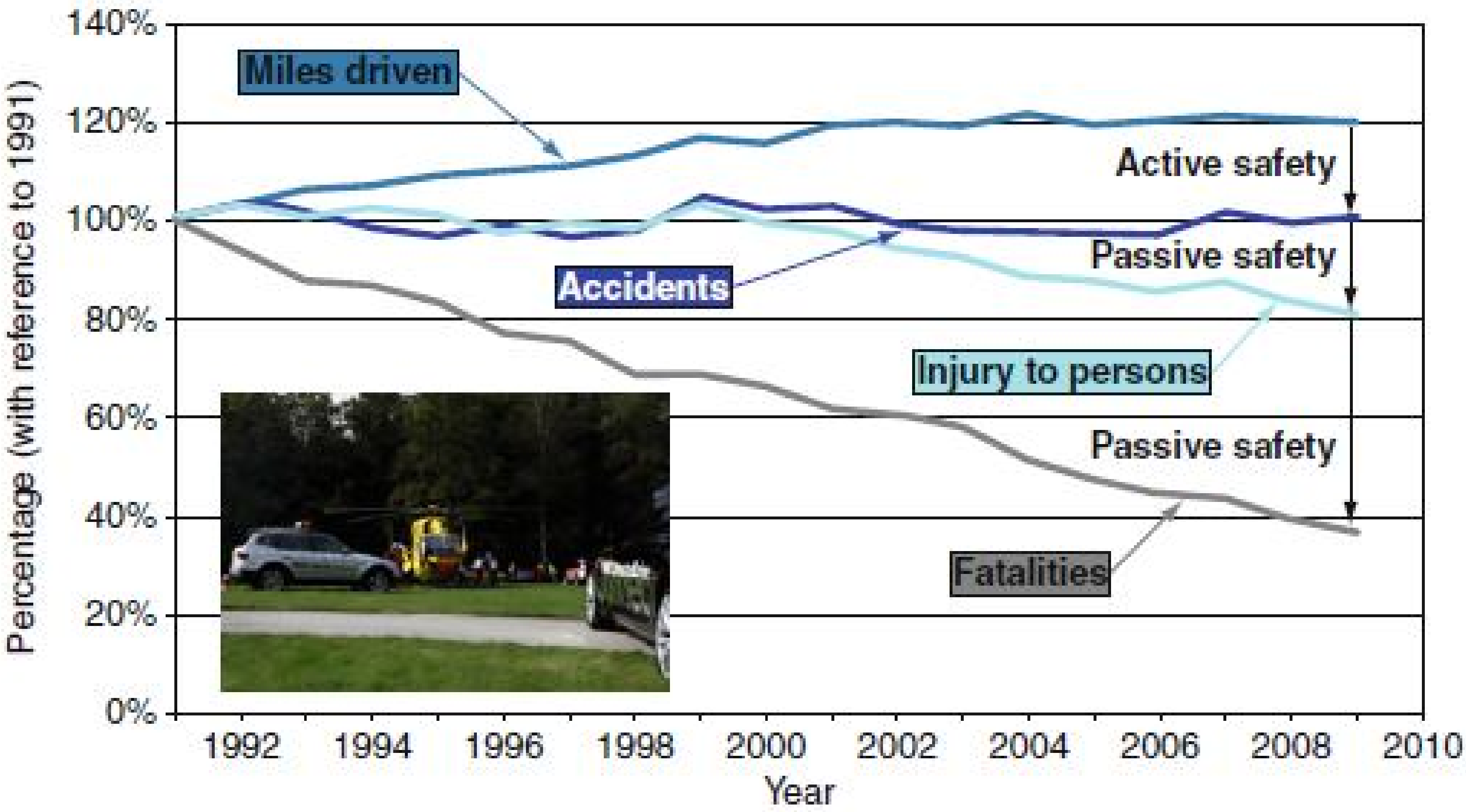
A large proportion of progress in “Western” traffic safety has been attributable to impressive developments in vehicle safety, especially in passive safety. Since the introduction of the three-point belt in 1960 – the most effective safety feature at that time in cars – the development of vehicle safety has been characterized by a sequence of milestones: safe passenger cells with energy absorbing crumble zones in the front end, air bags, child seats with standardized attachments, seatbelt pretensioners, and load limiters. Passenger protection by passive safety systems has attained a very high level during the past 30 years, with significant reductions in injuries, especially fatal injuries. With additional penetration of the market by modern vehicles, further improvements can be expected in the near future. Even though the miles driven have gone up significantly since the 1980s, the number of accidents has remained nearly steady during the last 20 years. The major reasons for this positive fact are improvements in traffic infrastructure, better education of the drivers, and last but not least better active safety performance of the vehicles, that is, better brakes, better suspension, vehicle stability systems, etc.



140%
120%
100%
80%
60%
40%
20%
0%
Percentage (with reference to 1991)
Miles driven
Active safety
Accidents
Passive safety
Injury to persons
Passive safety
Fatalities
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
Year

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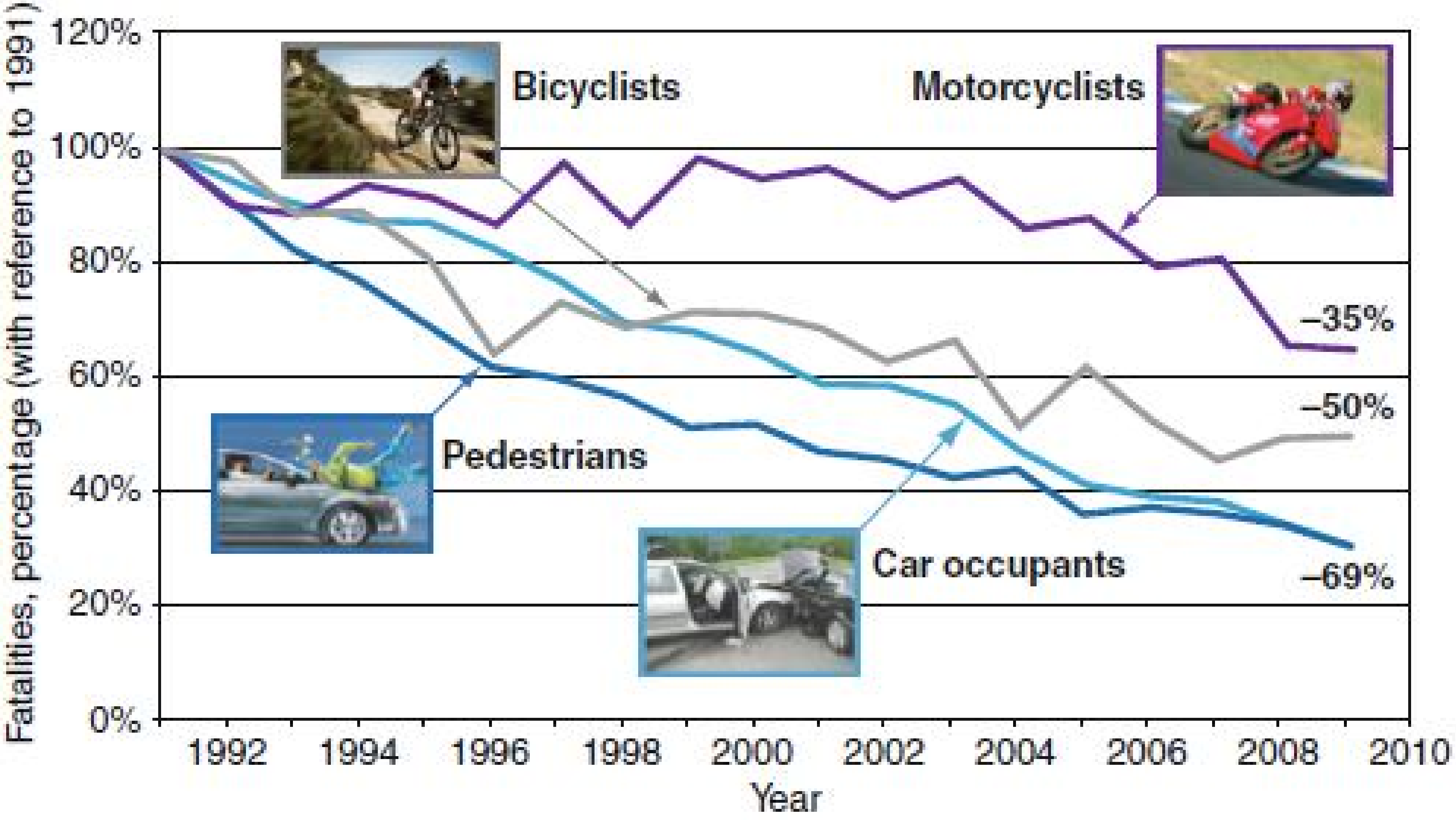
However, not all road users benefit equally from higher traffic safety. Car occupants are highly protected by passive safety features. Due to this fact, the number of fatalities has decreased significantly. Interestingly, the decrease in pedestrian fatalities has been comparable to the decrease in fatalities of car occupants, even though dedicated protection systems for pedestrians had low penetration during this period. Possible contributing factors in reduced pedestrian accident severity include better brakes and brake assistance systems. Note that the slope of the curve for pedestrians appears to have been less steep in recent years than for car occupants. Bicyclists and motorcyclists have registered weaker declines in fatalities; further efforts of vehicle manufacturers, infrastructure providers, as well as better training and supervision are essential for greater improvement. To continue these generally positive trends into the future, targeted measures in vehicle safety will be required. An intelligent combination of active and passive safety elements will contribute to further reductions of accidents, injuries, and fatalities.


Fatalities, percentage (with reference to 1991)
120%
100%
80%
60%
40%
20%
0%
Bicyclists
Motorcyclists
Pedestrians
Car occupants
–35%
–50%
–69%
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
Year

Introduction

Current ADAS (Advanced Driver Assistance Systems) offer the opportunity to evaluate the traffic environment with increasing reliability. Sensor-based systems detect and classify objects, track attributes such as distance and dynamic data, identify high-risk, critical driving situations and initiate suitable responses, such as warning the driver if there is sufficient time for him to avoid an accident by an appropriate controlled maneuver. (In pedestrian conflicts, a few precious tenths of a second delay in impact can suffice to allow a pedestrian to get out of harm's way.) If the traffic situation becomes even more critical and the driver has not yet initiated an intervention, automatic braking can reduce the impact speed and thus the kinetic energy of the collision. In addition to these measures, optimization of the postcrash phase has a strong potential for achieving further benefits: Medical studies of emergency and hospital care following an accident have shown that rapid rescue and intense, accident-specific care of the most severely injured persons in special trauma centers can significantly increase the survivability of severe car crashes. A prerequisite for delivering rapid, optimal emergency care is to identify risk of severe injury during (and immediately following) the crash using vehicle sensors and to communicate this risk to the call center automatically by an eCall. Thus, a holistic approach will be taken in the next generation of safety systems, integrating different systems and taking all phases of the accident into account: the precrash, the incrash, as well as the postcrash phases. Today a one-sided concentration on particular aspects of vehicle safety is no longer adequate for achieving further significant improvements. An integral safety approach combining and cross-linking all accident phases promises greater benefits.

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During the last few decades, passive safety systems have been intensively developed. Recently, the Insurance Institute for Highway Safety IIHS in the USA tested the crashworthiness of a 1959 Chevrolet Bel Air and compared it to a 2009 Chevrolet Malibu (IIHS 2011). One of the impressive results was to see the passenger compartment of the Bel Air collapse and trap the occupants, whereas the driver and passenger of the Malibu had a good chance of sustaining only mild injuries in an intact passenger compartment. Today a modern vehicle such as the BMW 5 series (Model year 2010+) satisfies the highest requirements in different test procedures worldwide. In the most prominent assessments, Euro-NCAP (European New Car Assessment Program) and US-NCAP, this car achieved the top rating of five stars. The load cases in these test procedures nearly completely represent real-life accidents, considering the impact speed of the vehicle. These tests together with >Fig. 27.3 illustrate the degree to which exploitation of the potential of passive safety has reached a plateau or a “point of diminishing returns”: Even extensive additional efforts in this area would provide only rather small further improvements. Not only do additional passive safety components fail to provide measurable additional injury reduction, they also worsen the vehicle weight ratio and thus are counterproductive for fuel economy and CO_2 reduction.

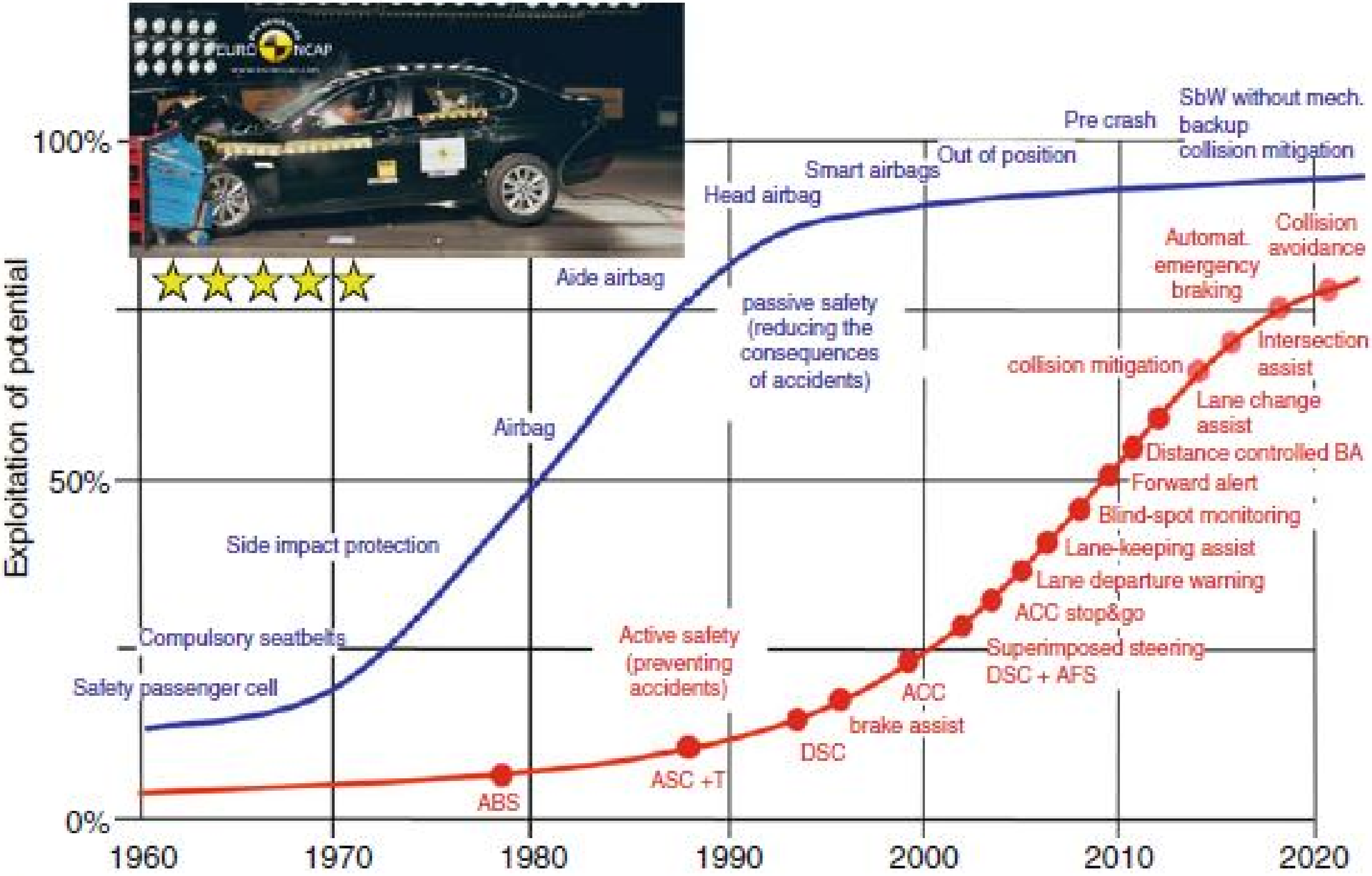

Fig. 27.3

Exploitation of potential of active and passive safety systems

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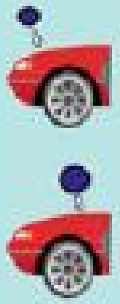
The protection of vulnerable road users such as pedestrians or bicyclists is probably the most difficult challenge in reducing severe injuries and fatalities. Up to now, regulatory as well as NGO safety assessments have defined testing procedures that focus solely on passive safety measures to address situations in which a pedestrian is struck by a vehicle: Human leg impactors or head forms are propelled onto the vehicles surface and accelerations, and forces or bending moments are measured; the car should absorb as much of the impact energy as possible by deformation (Euro-NCAP 2011). Considerable effort has been devoted to energy absorbing construction of the hood leading to elaborate front-end designs. However, in-depth studies have shown that head impact on the hood occurs in <6% of pedestrian accidents (>Fig. 27.4). Moreover, passive pedestrian protection only addresses the primary collision with the vehicle. Secondary collisions with the road surface or curb occur frequently and cannot be mitigated by this approach. Summarizing, current passive safety systems offer a high level of vehicle occupant protection in traffic accidents.

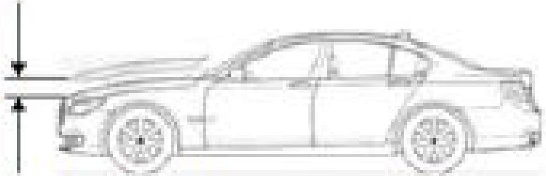
Example: head impact on hood:

Test:



2,5 kg / 40 km/h
HIC ≤ 1000

4,8 kg / 40 km/h
HIC ≤ 1000



Active hood can reduce head impact forces.

- Less than 6 % of the head impacts are on the hood
- Passive pedestrian protection only adresses the primary collision
- No influence on secondary collision (e.g. road surface, kerb)

Analysis of GIDAS* case studies → 920 events	100 % All passenger vehicle collisions with pedestrians → 710 events	24,8 % Head impact at passenger vehicle → 176 events	5,8 % Head impact on hood → 41 events

*GIDAS: German In Depth Accident Statistics

Fig. 27.4

Pedestrian protection – head impact on hood with only marginal benefit of passive safety systems

Limitations of Passive Safety Systems

Advanced restraint systems reduce forces on passengers sufficiently to avoid exceeding biomechanical limits even in severe collisions. At present, restraint systems need to be redesigned for increasingly restrictive legal and regulatory demands (e.g., new FMVSS 214, FMVSS 208 Ph. 2 und Ph.3, Euro NCAP and US NCAP Overall Rating). These demands require increasingly sophisticated adaptation in passenger restraint systems, which are tested by measurements on dummies in laboratory crash tests. At the same time, it is becoming more and more difficult to demonstrate that these additional efforts are effective in real accidents in the field: it appears that we are approaching a point of diminishing returns in passive safety systems. Of course, improvements in specific details are always possible, but great strides are not to be expected in the isolated development of passive safety systems. New approaches are needed (Kompass and Huber 2009).

The Approach of Integral Safety

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Functionalities in the area of active safety have considerable additional potential to improve vehicle safety. The increasing application of Advanced Driver Assistance Systems (ADAS) has set the stage for development of active safety systems. The penetration rate for ADAS has been steadily increasing, particularly in higher-valued vehicles, and significant growth in lower-priced vehicles is expected. Some accidents can be entirely prevented by active safety systems. However, even in cases where the accident is unavoidable, the mitigation effect in alerting the driver and thus potentially reducing the impact speed is beneficial per se. In the following, the mechanisms of collision mitigation and collision avoidance will be illustrated based on the example of pedestrian protection. In the foreseeable future, advanced driver assistance systems will contribute substantially to improvements in traffic safety by collision mitigation and the reduction of crash severity, as well as by warnings and assistance functionalities, which serve to enhance and augment the driver's own capabilities. The term integral safety as used here describes a holistic approach linking the fields of passive and active safety, which up until now have generally been treated as separate subjects. Active safety systems perform prediction and assessment of impending accidents and enable preparation and improved protection of the vehicle and the driver for the collision. In order to reduce the number of accident victims and the severity of injuries substantially during the next 10–20 years, the integral safety approach offers two key strategies.

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First, under certain conditions, active systems linked to the vehicle environment can allow an accident to be avoided entirely. Accident avoidance is clearly most effective for reducing deaths, injuries, and property damage. Second, linking passive and active safety can improve our ability to reduce the severity of accidents and their consequences by supporting optimization of passive safety processes. Considerable potential for progress exists in the development and implementation of active safety systems. To an increasing extent, these systems will be capable of preventing incipient accidents during their precrash phase; hence, instead of accepting crashes (including collision trajectories and kinematics) as given and trying only to manage the consequences, the new safety paradigm will address the accident situation beginning during the precrash phase and provide strategies designed to avoid the crash entirely or reduce relative collision speeds. Implementing this paradigm change will require meeting a number of technical challenges: Comprehensive knowledge of the vehicle's state, the driver's state, and the driving environment are required and must be provided reliably by sensors. If this data is available, the point of no return for an accident can be more accurately assessed, allowing improved adaptation of passive safety systems to the detailed accident situation. To achieve those benefits, a number of prerequisites need to be met.

The Approach of Integral Safety

Both detection hardware and algorithms have improved noticeably in recent years. Yet the reliability of sensor systems analyzing the vehicle's environment is still not on a par with so-called inertial sensors in the vehicle, which measure accelerations, speeds, or wheel rotation. Continuous improvements are necessary – and foreseeable – to further
optimize the ratio between necessary and unnecessary warnings or activations.

● Even with support by ADAS, the driver will continue to play an essential role in accident avoidance and mitigation; in some critical cases, integral safety systems will leave the final decision to the driver. Hence, increased acceptance of ADAS, better familiarity with functionalities, and improved adaptation by drivers would enhance the active safety performance of ADAS.

● Regulatory requirements and tests for such systems urgently need to be standardized and adapted to reflect field effectiveness: System development, specification, and optimization require enormous time and effort; lack of standardization or nonrepresentative tests create the risk to manufacturers that a system may not pass a specific test procedure, thus slowing down progress unnecessarily. This acute need has been clearly identified: Standardization groups, such as vFSS-Group (advanced Forward Looking Safety Systems) (vFSS 2011), consisting of partners from the automotive industry, NGOs, test institutes, insurance companies and legal authorities, are working together
to develop proposals for such requirements and test scenarios.

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The Approach of Integral Safety

By linking actuators and sensors of chassis control systems and driver assistance systems to passive safety systems, the concept of integral safety could mobilize unused potential for passenger protection. If a crash is unavoidable, the integral safety concept offers the opportunity to mitigate the consequences of the impending crash by targeted strategies: reduction of collision energy by braking, pretensioning restraint systems, triggering of active elements, etc. These strategies can be adapted to improve the effectiveness of airbags and seatbelts. The integral approach could also establish novel working principles for restraint systems and create new requirements on airbags and seatbelts, for example, ventilation, behavior during the ignition and expansion phases, etc. Figure illustrates the sequence of events relating to a crash: normal driving, the precrash phase, the crash itself, and the postcrash phase. Various systems are already available in premium vehicles that address safety throughout this entire chain of events and can protect passengers and other road users in the case of an unavoidable accident. Support of the driver by appropriate information begins during normal driving. Camera- or radar-based sensors detect objects and other vehicles in front of the car and support the driver in maintaining a safe distance or take over monotonous tasks such as stop-and-go driving in a jam, etc. In addition, even when these systems are not actively performing driver assistance, they can still monitor the traffic situation in front or around the vehicle in order to detect critical situations and get the driver back into the control loop. Thus, a driver whose attention has lapsed can be given optical and acoustic warnings in the case of an impending rear-end collision. In this way, the driver can react in time to avoid a collision. If he decides to execute an emergency braking maneuver, he will be effectively supported
by prefilled brakes.

Связывая приводы и датчики систем управления шасси и систем помощи водителю с системами пассивной безопасности, концепция интегральной безопасности может мобилизовать неиспользованный потенциал для защиты пассажиров. Если авария неизбежна, концепция комплексной безопасности предлагает возможность смягчить последствия надвигающегося столкновения с помощью целевых стратегий: снижение энергии столкновения за счет торможения, системы предварительного натяжения, срабатывание активных элементов и т. Д. Эти стратегии могут быть адаптированы для улучшения эффективность подушек безопасности и ремней безопасности. Интегральный подход может также установить новые принципы работы систем безопасности и создать новые требования к подушкам безопасности и ремням безопасности, например, вентиляции, поведению во время фаз зажигания и расширения и т. Д. На рисунке показана последовательность событий, связанных с аварией: нормальное вождение, Фаза до катастрофы, сама авария и фаза после аварии. В автомобилях премиум-класса уже доступны различные системы, которые обеспечивают безопасность во всей этой цепочке событий и могут защитить пассажиров и других участников дорожного движения в случае неизбежной аварии. Поддержка водителя соответствующей информацией начинается во время нормального вождения. Камерные или радиолокационные датчики обнаруживают объекты и другие транспортные средства перед автомобилем и помогают водителю поддерживать безопасное расстояние или выполнять монотонные задачи, такие как «остановка и движение» в пробке и т. Д. Кроме того, даже когда Эти системы не оказывают активной помощи водителю, они могут отслеживать ситуацию с движением впереди или вокруг автомобиля, чтобы обнаруживать критические ситуации и возвращать водителя в цепь управления. Таким образом, водителю, чье внимание отвлеклось, могут быть даны оптические и акустические предупреждения в случае надвигающегося столкновения сзади. Таким образом, водитель может вовремя среагировать, чтобы избежать столкновения. Если он решит выполнить экстренный тормозной маневр, он будет эффективно поддержан по предварительно заполненным тормозам.

The Approach of Integral Safety

If there is no driver response despite the warning, or if the response occurs too late, then a collision can no longer be avoided entirely. Nonetheless, even during this phase it is still possible for active safety systems to help decrease the crash severity and the resulting risk to passengers and other road users. There are already vehicles on the road that can brake automatically in case of an unavoidable collision. Seats can be moved into optimal position for passenger protection, and seatbelts can be pretensioned to remove slack prior to the crash.

During the crash itself, passive safety devices operate; these have already attained a high level of effectiveness. Even after the crash, vehicle-based systems lead to faster and more effective rescue and trauma care of accident victims. Sensors measure the severity, direction, and forces of the crash, count the passengers, and determine the risk of life-threatening injuries. The precise GPS coordinates of the vehicle as well as other accident data are transmitted to rescue headquarters, which can order emergency management services, arrange helicopter transport to an advanced trauma center, and initiate contact with the passengers. As shown in the previous section, the development of passive safety is approaching a point of diminishing returns. The limitations can be seen in the case of pedestrian protection.While current assessment procedures award a favorable pedestrian safety rating based on passive safety measures alone, their benefit for pedestrians in real-life accidents is expected to be marginal and may even be difficult to detect in future accident statistics. An integral safety approach appears more promising: even though it is unlikely that all collisions between automobiles and pedestrians can be avoided, the combination of avoidance of some collisions, reduction of impact velocities in many further collisions, and adequate passive safety promises far better results.

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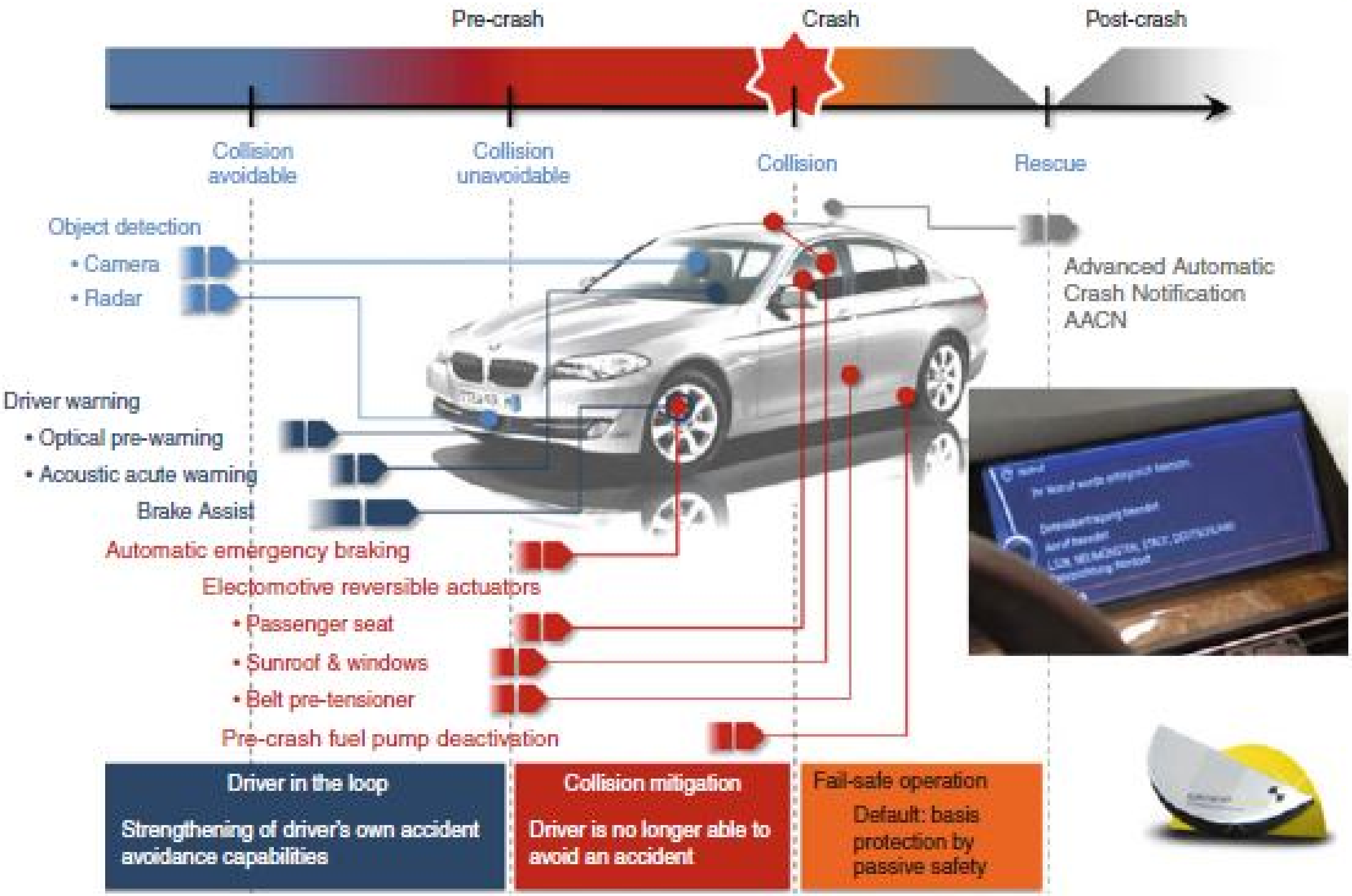

Fig. 27.5

Integral safety – maximum vehicle safety by teamwork of all functions

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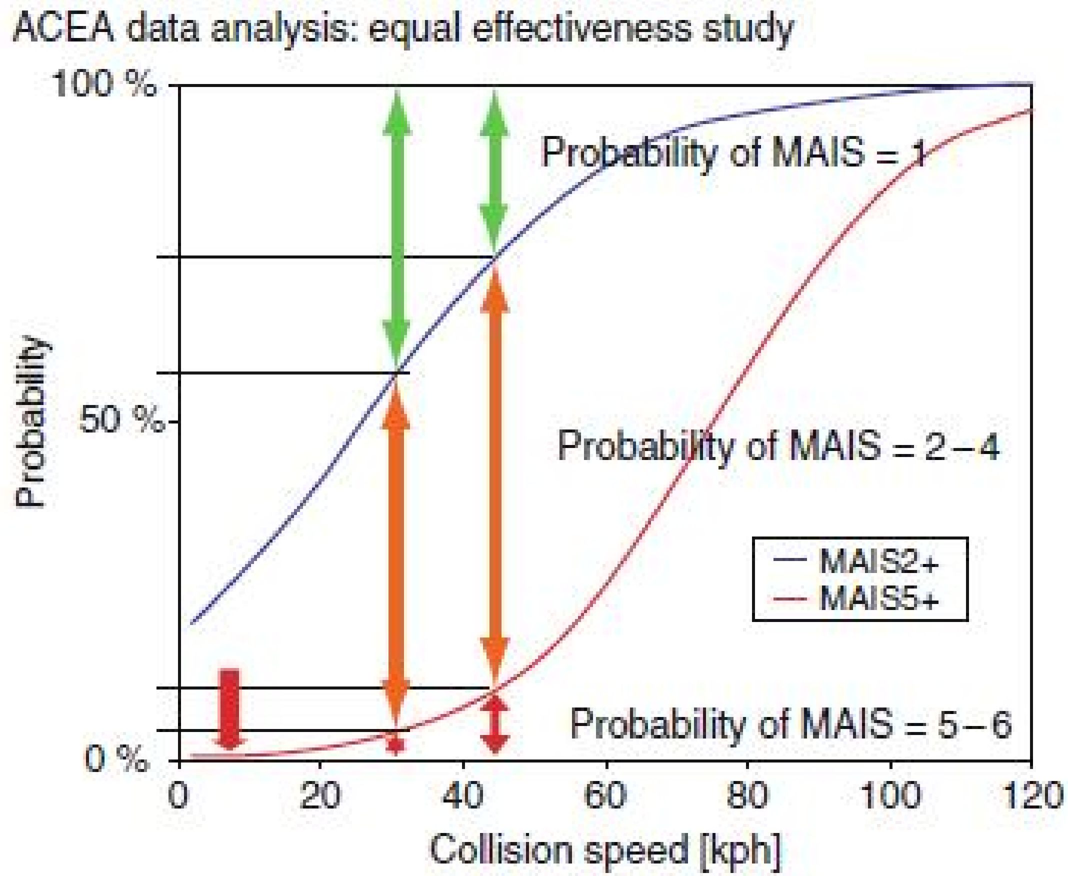
As seen previously in >Fig. 27.2, at least in certain countries pedestrians have benefited from safety measures comparably to well-protected vehicle occupants. One positive factor is the general improvement in traffic infrastructure including pedestrian friendly infrastructure, for instance in Europe. Clearly marked sidewalks, pedestrian crossings, bridges, or traffic lights provide evident benefits. A second positive factor is vehicle technology: efficient brake systems and tires enable modern vehicles to reach decelerations of more than 1 g. Brake assistants provide additional braking force so that even hesitant drivers can rapidly achieve high decelerations. A substantial number of accidents including those involving vulnerable road users have been avoided in this way. At the same time, this discussion illustrates that an integral safety approach promises considerably greater success in injury reduction. In pedestrian collisions, the collision speed has a strong influence on injury severity. If collision speeds can be reduced in a large percentage of accidents, the protective effect as a whole will exceed that possible by passive safety measures. >Figure 27.6 displays the so-called injury risk function for pedestrian accidents, that is, the dependence of injury risk (expressed in MAIS classes) on collision speed. A decrease of the collision speed from 45 to 30 km/h considerably reduces the probability of a MAIS 5–6 injury (the most severe). Integral safety seeks to attain a higher effectiveness than possible by passive measures alone by a holistic approach, combining different domains of development and utilizing communication among vehicles as well as connections between vehicles and their environment. However, the overall safety performance of the vehicle cannot be assessed by standard crash test procedures as carried out in the past. For example, protective preconditioning strategies affecting the vehicle or the passengers in case of a detected impending collision are ignored in such simple crash tests.



- Pedestrian detection by sensors.
- Increased driver awareness by warning.
- Reduction of impact speed by driver triggered emergency braking (Hydraulic Brake Assist).
- Reduction of impact speed by autonomous braking, when an impact is unavoidable.

Fig. 27.6

Pedestrian protection by impact mitigation by reduction of speed

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A method for including preconditioning systems in the assessment of safety performance by a crash test was demonstrated in a cooperative effort between BMW and Dekra (>Fig. 27.7). The test was performed on a specially prepared vehicle in which all systems operated autonomously. This test required substantial modifications compared to a stock vehicle, since special measures were needed to allow target detection by a radar sensor within the test hall. In addition, the test rig needed to be equipped with a mechanism for detecting the braking vehicle and exerting only the forces required to guide the vehicle along the planned trajectory without counteracting the vehicle's own braking acceleration. >Figure 27.8 summarizes the sequence and times of vehicle actions. Following the warnings to the dummy driver – who did not respond, as a real driver might have done – the vehicle braked automatically. This emergency braking led to a collision speed of 40 km/h instead of the 64 km/h collision speed that would have otherwise occurred. This decrease resulted in a substantial reduction of occupant loads. >Figure 27.9 summarizes the test results. Note that the development of such systems requires enormous effort. Because accidents in real traffic are complex occurrences, at present it is only possible to address particular accident scenarios by systems designed to avoid collisions or reduce their severity. Although the limited spectrum of scenarios that can be addressed is gradually expanding due to increasingly sophisticated and reliable measurement devices and sensors, passive safety measures will continue to play an essential role for some time to come. Integral vehicle safety comprises several stages. During the first stage, the goal is to keep the driver in the loop – or bring him back into the loop, if need be: for example, warning and evoking a reaction in case of a lapse of attention in a hazardous situation. During the next stage, the vehicle should support the responsive driver and appropriately focus or amplify his response in order to utilize the full potential of vehicle maneuvering, particularly braking .

Метод включения систем предварительной подготовки в оценку показателей безопасности при проведении краш-теста был продемонстрирован совместными усилиями BMW и Dekra (> рис. 27.7). Испытание проводилось на специально подготовленном транспортном средстве, в котором все системы работали автономно. Это испытание потребовало существенных модификаций по сравнению со стандартным транспортным средством, так как требовались специальные меры для обнаружения цели с помощью радиолокационного датчика в испытательном зале. Кроме того, испытательный стенд должен был быть оборудован механизмом обнаружения тормозного транспортного средства и приложения только усилий, необходимых для направления транспортного средства по запланированной траектории, без противодействия собственному ускорению торможения транспортного средства. > Рисунок 27.8 суммирует последовательность и время действий транспортного средства. Следуя предупреждениям для фиктивного водителя, который не ответил, как мог бы сделать настоящий водитель, автомобиль автоматически затормозил. Это экстренное торможение привело к скорости столкновения 40 км / ч вместо скорости столкновения 64 км / ч, которая в противном случае произошла бы. Это снижение привело к значительному снижению нагрузки на пассажиров. > Рисунок 27.9 суммирует результаты теста. Отметим, что разработка таких систем требует огромных усилий. Поскольку аварии в реальном трафике являются сложными событиями, в настоящее время можно рассматривать только отдельные сценарии аварий с помощью систем, предназначенных для предотвращения столкновений или уменьшения их серьезности. Хотя ограниченный спектр сценариев, которые могут быть рассмотрены, постепенно расширяется благодаря все более изощренным и надежным измерительным приборам и датчикам, пассивные меры безопасности будут продолжать играть важную роль в течение некоторого времени. Интегральная безопасность транспортного средства состоит из нескольких этапов. На первом этапе цель состоит в том, чтобы держать водителя в петле или, при необходимости, вернуть его в петлю: например, предупредить и вызвать реакцию в случае потери внимания в опасной ситуации. На следующем этапе транспортное средство должно поддерживать отзывчивого водителя и соответствующим образом фокусировать или усиливать его реакцию, чтобы использовать весь потенциал маневрирования транспортного средства, особенно торможения.

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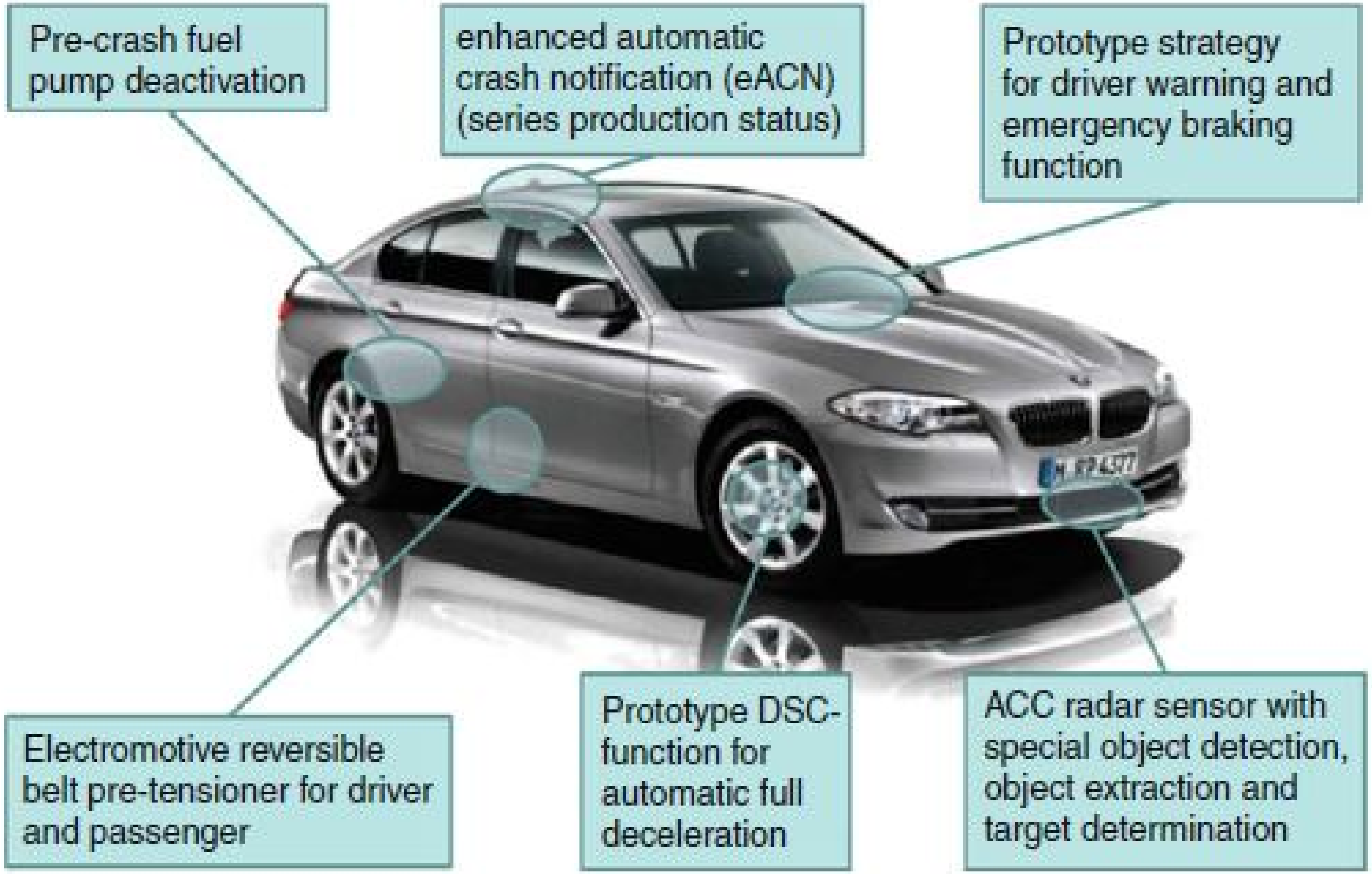

Fig. 27.7

Prototype test vehicle – similarities and changes to series production BMW 530d

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If (and only if) the driver fails to respond or responds far too late to avoid a collision, the vehicle can react automatically with the goal of reducing collision energy as well as preparing the vehicle and occupants for the crash in order to reduce the resulting occupant loads.
Passive safety operates in a fail-safe mode to protect the occupants or other road users. Immediately following an accident, emergency rescue services should be notified by a reliable, fast, targeted, informative, automatic electronic calling system, resulting in rapid transportation to an appropriate trauma center of victims whose lives are at stake. The development of integral safety concepts requires considerable effort. In order to make sure that all measures implemented in vehicles really achieve the highest possible safety benefits in real accidents, detailed analysis capable of predicting and optimizing these safety benefits prior to full-scale implementation are needed. Public authorities responsible for safety regulations and other agencies involved in assessing vehicle safety should define "holistic" goals and ratings: vehicle safety regulations and assessment should be oriented toward the effectiveness of a vehicle's safety systems, considered as a whole, in reducing mortality and injuries in the field. Ideally, it should be possible to define standards for predicting effectiveness.

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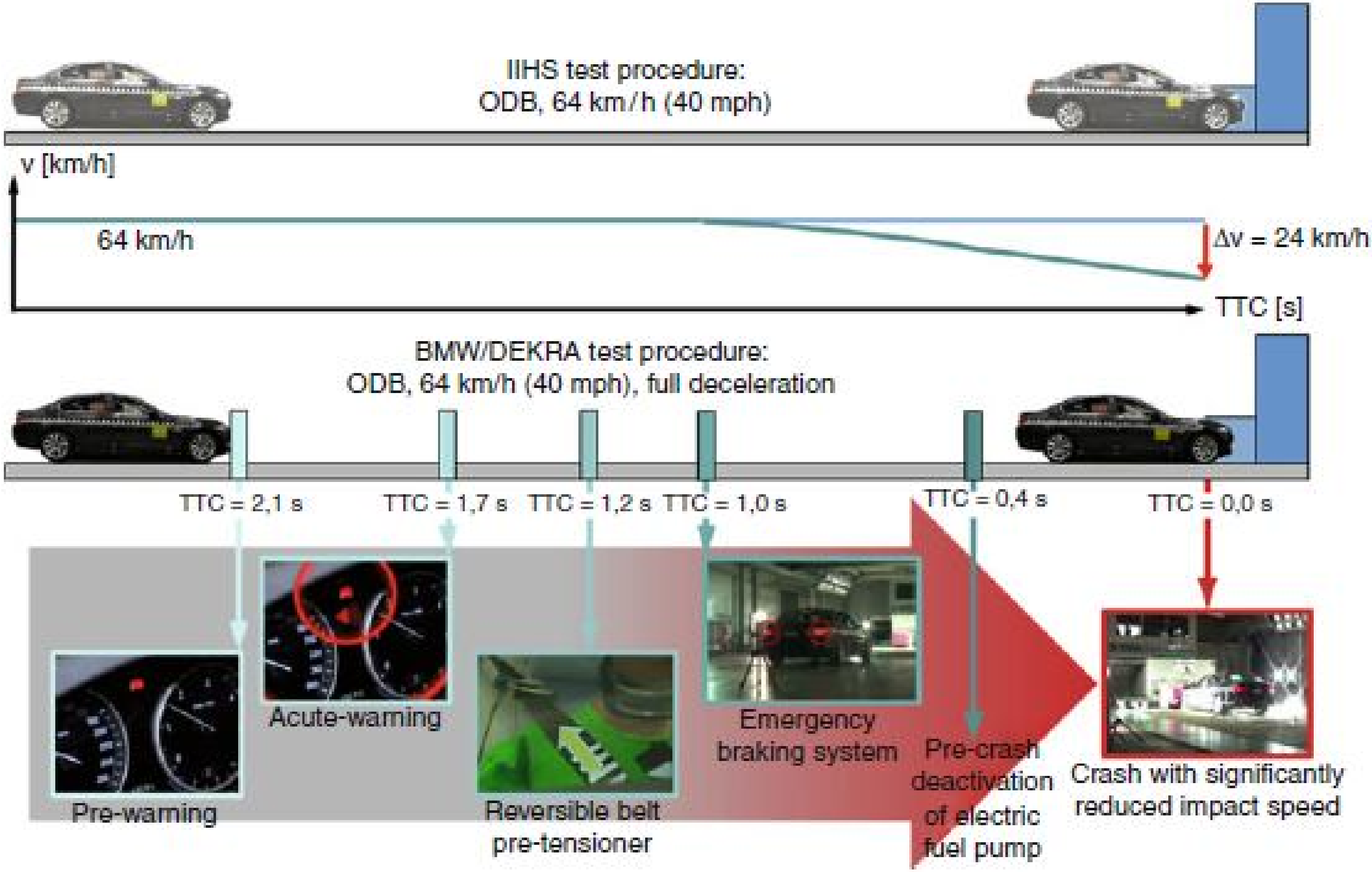

Fig. 27.8

Test overview – course of events compared to standard test

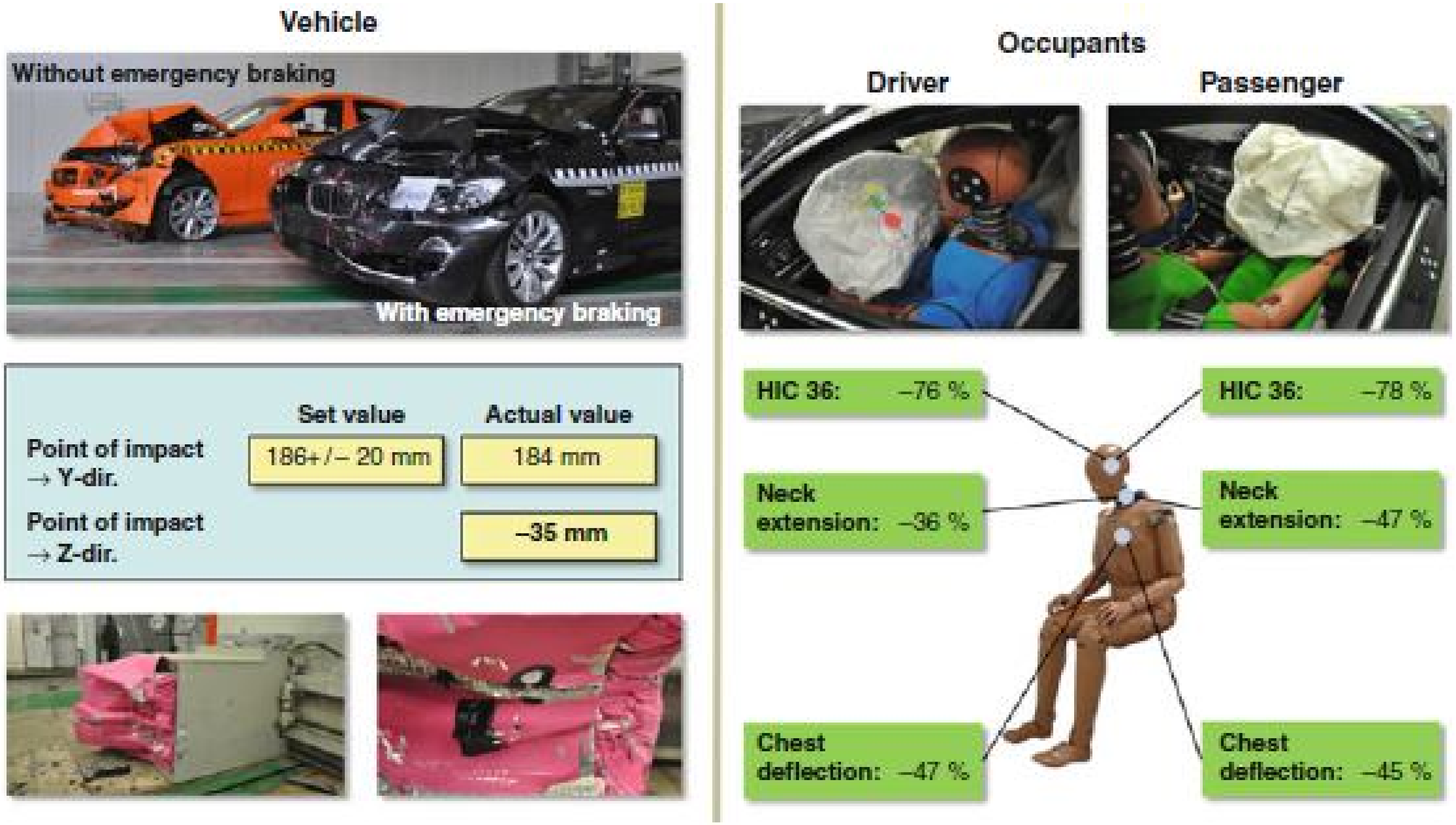

Fig. 27.9

Test results of crash test with emergency braking reaction of the test vehicle – significant reduction of occupant loads

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