

Active and Passive Safety at the BMW Group.

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1. Active and Passive Safety at the BMW Group. (Short Version).

“Supreme safety of the highest standard is a natural asset for the premium manufacturer. What makes our cars so unique is the overall approach we take in our safety concept” – states Klaus Kompass, BMW Group Director of Vehicle Safety, in describing the safety philosophy of the BMW Group.

The BMW Group's safety concepts are always based first and foremost on reality. Precisely this is why BMW Group experts in accident research examine a wide range of real-life accidents each year, interacting with biomechanics, doctors specialising in accident treatment and prevention, as well as traumatologists in Germany and the USA, and naturally sharing their experience with researchers and developers at BMW.

The knowledge gained in these processes goes directly into new concepts for active and passive safety, where the second aspect of the BMW Group's safety philosophy comes to bear: Safety, as seen by BMW, starts with sheer driving pleasure, that is long before a possible accident. For the best accident is an accident avoided right from the start – an accident that never happens. And, at the other end, the concept continues on a long way, only ending long after the accident as such has occurred.

The BMW Group has always attached great significance to safety in road traffic. To this day there is not one single safety system in production cars which the BMW Group has not examined or developed, in many cases taking on the role of a pioneer, as in the case of the head airbag.

An exceptional highlight of BMW's approach in this context is the integration of precise driving dynamics, specific support of the driver and optimum occupant protection within one overall package focusing on a very ambitious target: to ensure maximum safety all round and at all times.



BMW Group safety starts from the ground up on the car's suspension.

No statistics reveal the accidents which never happened. And indeed, we all experience incidents and situations even in normal road traffic which potentially might lead to an accident – whether it is misjudgment, unclear situations on the road, or adverse weather and ambient conditions.

In a BMW Group car the driver is able to take these situations in superior, relaxed style, a BMW or a MINI behaving the right way for the driver also under exceptional conditions and giving the driver all the benefits of his everyday motoring knowledge.

The objective of the chassis engineer in developing new chassis technology is to ensure safe and superior driving behaviour. For such superiority on the road creates the conditions required for relaxed motoring, smooth performance, and exemplary active safety. The driver remains in full control of his car, enjoying superior driving dynamics and safe motoring stability. And in the process he is supported by control systems handling particularly dynamic situations with ease and appropriate care.

Whenever the car reaches the limit, chassis control systems intervene actively to maintain the car's stability or to reinstate the stability required – also under adverse road conditions. DSC Dynamic Stability Control, for example, prevents the car from swerving out of control, for instance in an abrupt manoeuvre, by applying the brakes as required on individual wheels. BMW xDrive all-wheel-drive technology, in turn, likewise applies the brakes exactly as required and ensures a good balance of torque to avoid understeer right from the beginning and give the car safe and secure handling even in dynamic and fast bends. And other systems serving to enhance both steering precision and tracking stability are Dynamic Performance Control and Dynamic Drive.

The effects and contributions of these systems in enhancing safety increase to an overproportional extent when linked with one another. As an example, Active Steering in the new BMW 7 Series interacts with the car's DSC sensors. So that when applying the brakes with the wheels running on different surfaces, this intelligent technology prevents the car from swerving out of control by intervening appropriately in the steering.

The human factor – providing appropriate support and enhancing the driver's supremacy at the wheel.

Official statistics show that almost 99 per cent of all accidents are attributable to human error and false behaviour. So to prevent accidents right from the start, the first essential point is to assist the driver in the process of driving the car. Various driver assistance systems are used for this purpose and already make an important contribution to active safety, that is the avoidance of accidents, today. Such systems and concepts nevertheless still offer significant room for improvement and further development, while the various features and options supporting passive safety have already reached a high level.

Driver assistance systems relieve the driver of unpleasant chores and enhance his supremacy at the wheel by providing information, warnings, and help in taking the right decision.

Active Cruise Control with Stop & Go, referred to in brief as ACC Stop & Go, for example, not only maintains the desired distance from the vehicle ahead, but also controls the speed of the car in dense traffic all the way down to a standstill. And at the same time the system offers a proximity warning, optical and acoustic signals urging the driver to apply the brakes himself if, for example, the driver ahead is likewise braking very hard and slowing down very quickly. At the same time the vehicle itself is prepared for hard application of the brakes, again helping to keep the stopping distance short and, if everything works out, to avoid an accident.

ACC Stop & Go is only one of the many assistance systems the BMW Group offers its customers. Further examples are:

- Lane Change Warning giving the driver a visual and touch-stimulated warning of vehicles approaching in the driver's blind angle.
- Lane Departure Warning recognising unintentional deviation from the right lane and again giving the driver clear feedback via the steering wheel.

Other assistance systems help to improve the driver's perception and his overview of traffic conditions, offering him more information and allowing him to look further ahead. Among others, these systems include:

- The Speed Limit Indicator introduced for the first time ever in the BMW 7 Series and informing the driver at all times of the maximum speed allowed on the route he is currently taking.

- BMW's new Night Vision with detection of individual persons offering preventive pedestrian safety by recognising people up to a distance of 300 metres or almost 1,000 feet and warning the driver of dangerous situations. Considering that far more than 50 per cent of all fatal accidents involving pedestrians occur at night or in the dark (source: DESTATIS), such a safety system is particularly helpful.
- The Head-up Display providing information relevant to the driver in his direct line of vision. This minimises the need for the driver to take his eyes off the road and increases driving safety accordingly.
- Adaptive Headlights, variable light distribution, Bending Lights, adaptive headlight range control and the High-Beam Assistant offer a unique lights package ensuring optimum illumination of the road ahead at night, in fog and bad weather, without dazzling oncoming drivers.
- Like Park Distance Control, the back-up camera significantly facilitates the process of parking and manoeuvring.
- In the new BMW 7 Series the Safety Package is further enhanced by Side View enabling the driver to check out traffic crossing from the side in unclear crossings and road junctions.

Even with all these assistance and supporting systems, the most powerful element within the car remains the human being. And since practice makes perfect, as the old saying goes, the BMW Group also offers BMW and MINI Driver Training on virtually on levels.

When the worst comes to the worst, even the last millisecond counts.

Particularly the last few seconds prior to an inevitable collision may save lives, provided these brief instants are used properly. Precisely this is why the various features and elements of active and passive safety interact within the BMW Group's concept of integral safety, offering all their benefits and advantages shortly before an accident actually occurs. Assistance systems giving the driver the necessary information and warning prompt him to act the right way and in good time, the proximity warning, for example, telling him to apply the brakes. Dynamic Brake Control is activated at the same time in this process, chassis stability systems stabilising the car and helping to prevent a dangerous rollover.

The sensors fitted in the car, in turn, offer valuable information in order to pre-set the car's passive safety systems, the electric belt roll-up function, for example, serving to tighten the seat belts and thus ensure optimum restraint and safety right from the start.

The particular skill of the BMW Group's safety experts is to perfectly harmonise and match these processes to one another, in this way gaining decisive milliseconds in the interest of extra safety. The objective of all these features and technologies, finally, is to minimise accident severity to the greatest possible degree, if the accident cannot be avoided in the first place.

Passive safety means reducing the consequences of an accident to the greatest possible degree. A safe passenger cell, safe body structures with defined crash zones and optimised restraint systems are the basic elements within each safety concept. The development and use of an optimum passive safety concept is naturally of utmost significance to the BMW Group, three-point belts on all seats, six airbags featured as standard, and a strong body structure with specific deformation elements therefore forming part and parcel of all vehicle concepts today.

To prepare appropriately for the future in every respect, the BMW Group has consistently enhanced and renewed its testing facilities in recent years. All vehicles are tested and checked in crash testing and simulation systems not only for their full compliance with legal requirements, but also with the BMW Group's own and far more demanding internal standards: To ensure consistent safety on the road the world over.

This safety concept even continues beyond the actual occurrence of an accident, activation of the hazard warning flashers and the interior lights warning other road users and improving the chances of being rescued. The Safety Battery Terminal, for example, reduces the risk of fire. And depending on the car's features, the rescue headquarters are alarmed at the same time the automatic emergency call is sent out, receiving important information on the severity of the accident.

Implementing such a safety philosophy calls for the significant involvement of all parties concerned within the BMW Group. So the engineers are of course always very happy to receive mail such as this letter from the Ukraine stating right at the top: "Thank you, the whole BMW Team". This BMW customer, after surviving a head-on collision at high speed, even wrote BMW from the hospital: "I only survived because of your car – so let me express my heart-felt gratitude for such an outstanding achievement of engineering."

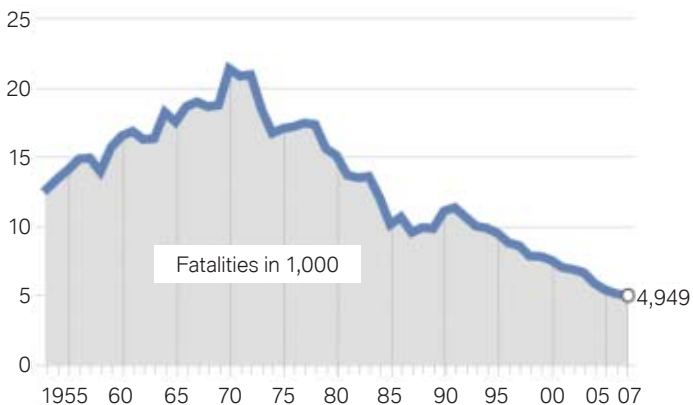
2. Active and Passive Safety at the BMW Group. (Long Version).

2.1 Introduction – Safety, an All-Round Concept.

Mobility without active and passive safety is inconceivable. Motorised road traffic – the first and foremost means of transport the world over in all leading nations – would never have become what it is today without a high level of safety. In 2007 the number of fatalities in German road traffic was lower than ever before, amounting to 4,949 according to the German Federal Office of Statistics. This trend has been continuing for a long time: From 1970 to 1990 the number of fatalities in road traffic in Germany dropped from 19,193 to 7,906, taking the territory of the former Federal Republic prior to re-unification. Then, just ten years later, the number of victims in the whole of Germany, now including the new German Länder in the East, dropped to an even lower level, with 7,503 people killed in road traffic.

The overall mileage covered by all motorists, on the other hand, has developed in exactly the opposite direction, increasing from 234.2 billion in 1970 to 458.2 billion kilometres 20 years later. And this trend has continued to this very day, with the number of fatalities in road traffic decreasing each year, while the overall mileage covered increased to approximately 700 billion kilometres last year.

Number of fatalities in road traffic Trend from 1953 to 2007



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In a nutshell, therefore, road traffic today is safer than ever before.

Safety in road traffic is first and foremost human safety. And precisely for this reason it is also a responsibility of the companies that give human beings the motorised mobility they enjoy so much – car makers. The BMW Group has always accepted and endorsed this responsibility. To this very day, every safety system available has been examined or even developed by BMW Group engineers often even taking on the role of the pioneer.

A few examples are the BMW 750i, the first German car with anti-spin control to enter the market in 1987. Just four years later xenon headlights made their world debut in BMW's flagship. As of 1997 head airbags in the BMW 7 Series have protected the driver and front passenger as another world-first achievement. And the BMW Group was also the pioneer of Active Steering introduced in series production in 2004.

BMW Group safety starts in normal traffic and does not end until long after an accident has occurred.

Safety is not a question of individual systems. On the contrary – safety is always a complete, all-round package. Precisely this is why the BMW Group's safety concept goes far beyond individual details and passive safety alone, with priority being clearly given to the avoidance of accidents right from the start. The intelligent network of all safety features within the car is referred to as Integral Safety, which in future will make a decisive contribution to the optimisation of safety in road traffic as a whole.

Today the BMW Group focuses first and foremost on active safety – the wide range of measures and technologies serving to prevent an accident right from the start. For while the features and technologies serving to enhance passive safety have now reached a high level, there is still a great potential for further development in active safety ensured above all by systems and technologies in support of the driver referred to as driver assistance systems.

Depending on their configuration and concept, such systems are able to support the driver while on the road, warning him of an imminent traffic conflict, helping him make the situation less dangerous or, if an accident is inevitable, enabling him to reduce the consequences of such an accident to the greatest possible extent.

As an example, ACC Active Cruise Control under normal conditions adapts the speed to a vehicle ahead. But once the driver of the vehicle ahead applies the brakes very hard, the BMW driver benefiting from ACC will be warned by optical and touch-sensitive signals.

At the same time the Proximity Warning reduces the Brake Assistant's release thresholds and activates the DSC brake standby function. Then, when the driver applies the brakes, the system immediately applies full brake power and thus minimises the car's stopping distance in order to prevent a collision or at least reduce its severity.

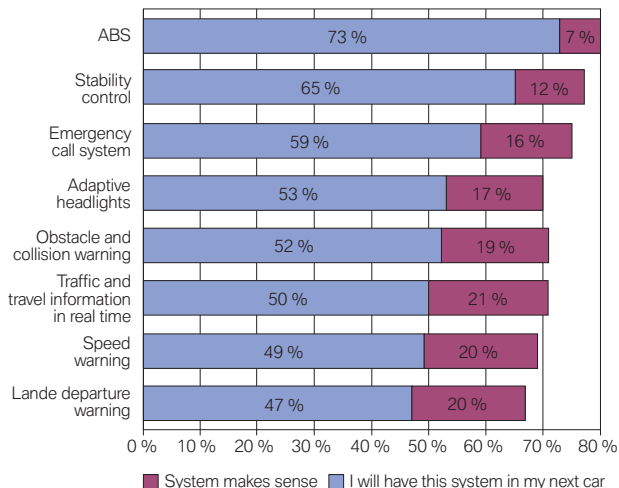
Assistance systems with shared functions: stabilising, manoeuvring, navigating.

The BMW Group divides Driver Assistance Systems in three categories: Systems for stabilising, manoeuvring and navigating the vehicle. Systems interacting actively in vehicle control – e.g. DSC Dynamic Stability Control or Dynamic Drive serve to stabilise the vehicle. Systems such as ACC Active Cruise Control or Lane Departure Warning support the driver in manoeuvring in specific situations.

Information systems such as the navigation system or the BMW ConnectedDrive telematics service offer useful but also safety-relevant functions such as enhanced traffic information or an automatic emergency call.

Providing systems of this calibre and with these features, BMW to a great extent already meets the demands made by the European Commission in a eurobarometer study on the "Use of Intelligent Systems in Vehicles" conducted on behalf of citizens in the EU. The study shows that a vast majority of EU citizens regard such assistance systems as useful and that most citizens would like to have systems of this kind in their next car.

European motorists wish to have the following assistance systems:



The big advantage of the BMW Group is the full coverage and support offered throughout the entire spectrum of motoring: Active Steering and Active Cruise Control with Stop & Go support the driver in everyday traffic. Systems such as the electric belt roll-up in the new BMW 7 Series, in turn, add to the passive safety when reaching the limits. Once the point of no return is reached, systems cut in in order to minimise the severity of an accident, tightening the seat belts and drying the disc brakes by moving up the brake pads in the interest of maximum stopping power.

Should the worst have come to the worst, passive safety systems offer ultimate protection, keeping the car safe – for example by activating the safety battery terminal and switching off the fuel pump.

Even after an accident, the BMW Group's safety concept still maintains its superior functions, with the hazard warning flashers switching on automatically to warn other motorists. At the same time the car's intelligent control switches on the interior lights and opens the central locking in order to improve rescue conditions. And depending on the car's level of equipment, an automatic emergency call function will alarm the rescue services and give them important information for an efficient rescue mission.

The starting point for developing the BMW Group's safety concept: analysis of accidents actually occurring in practice.

More than three decades ago the BMW Group already recognised the need to analyse accidents actually occurring in practice in order to enhance the safety features of BMW cars to an even higher standard. So as far as back as in 1976, BMW accident researchers started analysing accidents in and around Munich, soon extending their accident research to the whole of Bavaria.

The Bavarian police supported this project right from the start and to this day report severe accidents to the accident researchers whenever a BMW Group vehicle is involved. This ensures efficient evaluation of numerous severe accidents involving injuries and BMW Group vehicles each year, BMW's accident research specialists using the most modern equipment at the scene of such accidents to gain a clear picture of what has happened and establish precisely how the accident occurred and what its consequences are. Covering some 3,500 parameters in each accident, BMW's experts examine all relevant features and criteria from the actual development of the accident all the way to the final position of the vehicle.

In the so-called pre-crash phase BMW Group researchers examine two decisive positions in the accident scenario:

First, the so-called traffic conflict point where one of the parties involved in the accident took the – false – decision leading to the accident or failed to respond appropriately to a sudden challenge. Official statistics in Germany show that human error or false behaviour is responsible for nearly 99 per cent of all accidents. Only a small number of accidents, therefore, is attributable to technical deficiencies such as poorer maintenance – e.g. worn tyres or inadequate tyre pressure.

Second, the experts calculate the point of no return, that is the point beyond which the accident could no longer be avoided, but could still be reduced in its severity.

The knowledge acquired in this process then goes straight into research and development, ensuring the ongoing improvement of safety in BMW Group cars.

An important parameter in this context is the close cooperation of the BMW Group with Munich clinics such as the Ludwig Maximilian University Clinic in Grosshadern and the Schwabing Clinic where accident experts register and analyse the injuries suffered by occupants and subsequently download their results in coded form into the BMW Group's accident database.

This database, in turn, helps to provide precise information on the efficiency of the various safety systems featured in BMW cars, giving the BMW Group an objective and realistic basis for optimising and developing safety systems.

In 2006 the BMW Group expanded its accident research to the USA, upgrading its existing research partnership with the renowned William Lehman Injury Research Center (WLIRC) of the University of Miami/Jackson Memorial Medical Center by contributions made directly by the BMW Group in its multi-disciplinary accident research.

In the context of this cooperation BMW Group engineers cooperate with trauma experts in medical studies, teams of specialists conducting biomechanical accident analyses in order to determine the causes of injuries in road accidents even more precisely than before. The results of these examinations have already gone into BMW Group's latest production systems, one example being the Advanced Emergency Call Function.

Jeffrey Augenstein, Director of the WLIRC, on the cooperation: "Over the last few years, the organization that I have the privilege of directing, the William Lehman Injury Research Center, worked closely with BMW engineers and scientists to help to define the characteristics of the Advanced Automatic Collision Notification System that is now implemented in many BMW models. One major product of this effort was an algorithm that will help predict whether severe injuries occurred in a crash. Knowing not only the precise location of a crash but also the potential for life threatening injuries immediately will propel emergency services to the scene armed with the necessary life-saving tools. When fully implemented a trauma system based on Advanced Automatic Collision Notification will save thousands of lives.

BMW has taken a leadership position in this effort, and is due a tremendous amount of credit for spearheading this life-saving safety initiative. It has been my greatest professional pleasure and honor to have worked with the BMW team."

2.2 Active Safety – for Sheer Driving Pleasure.

The best accident is the accident that never happens. And the best safety a car maker can give the driver is active safety serving again to avoid an accident before it even occurs.

The BMW Group has been pursuing the principle of active safety consistently for many years and decades – simply because Sheer Driving Pleasure BMW style means a clear commitment. The agile drivetrain and suspension of all BMW Group vehicles, therefore, is not least an important element of active safety, fast and dynamic acceleration ensuring quick and safe overtaking processes as well as agile manoeuvring particularly in flowing traffic merging on to fast roads or motorways. The suspension and brakes of all BMW model series are acknowledged in each respective generation of new models as the benchmark and role model, the success of BMW Group cars in motorsport confirming the quality of active safety BMW-style under extreme racing conditions and the qualities of production-based BMW touring cars already being acknowledged as legendary.

Further features and components contributing to such superior driving safety are precise suspension control, driving control systems perfectly matched to one another, and driver assistance systems of the highest quality.

The chassis.

All BMW Group models are designed and built to give the driver genuine superiority even in an emergency, with the option to take a proactive response also in an emergency situation. The key to such successful accident prevention is that the car itself behaves the right way in an exceptional case, precisely as the driver would expect.

Conventional development of chassis components still practised by many manufacturers today is limited to components and features within or beneath the body of the car. But systems developed in this way have only a few or no interfaces and connections to the overall vehicle as such. BMW Group chassis development, in turn, has consistently grown in the course of time, becoming a genuine driving experience development, with BMW Group engineers focusing on everything that gives the car safe and superior behaviour on the road.

Precisely this foundation is ideal in creating exemplary driving qualities borne out by effortless motoring and supreme active safety. The driver is able to experience genuine driving dynamics through an optimum standard of control and driving stability, assistance and control systems helping him defuse accident-prone situations.

An important point is that active systems can only round off a consistently developed, sophisticated and appropriately designed overall chassis concept. Without this foundation, therefore, even the best driver support systems cannot develop their full effect.

An example is the multi-arm rear axle in the MINI, which is a genuine highlight in this segment appropriately conceived in its geometry to keep the wheels perfectly on the road at all times. A further point is that this multi-arm axle ensures very good use of the space available and helps to keep the luggage compartment extra-low with the dampers as far apart as possible. In all, the suspension and chassis of the MINI ensures a unique go-kart feeling combined with a high standard of all-round safety.

The fundamental philosophy applicable to all BMW Group cars is that the suspension is designed and set up to combine sportiness, comfort and safety in genuine style and with a perfectly balanced character. This gives the driver extremely precise driving behaviour, exceptionally good handling, and superior roll comfort at all times.

The only contact point to the road: the tyres.

The tyres of a car are the last link in the chain of transmitting power and ensuring active safety in the process. Here again the BMW Group has been conducting cutting-edge research for decades in pioneering the introduction of the runflat tyre, tyres with failsafe running qualities being introduced in the BMW 3 Series as early as in 1984.

Today's runflat tyres combine straightforward and easy handling qualities in everyday traffic with supreme safety against punctures or any other kind of deficiency. To ensure this high standard, both inner walls within the tyre are reinforced by special inserts preventing the damaged tyre from giving way or caving in under loss of pressure (which is why such tyres are also referred to as "self-supporting"). Indeed, modern runflat tyres offer these superior qualities even under extreme loads, for example on a serpentine route. And even when completely empty, such tyres enable the driver to continue on the road at a speed of up to 80 km/h or 50 mph, extended hump rims preventing the empty tyre from "jumping off" the rim through the hump sections

extending into the circumference of the tyre. The tyre therefore always remains in place, even when subject to a sudden loss of pressure in a fast and dynamic bend.

BMW Group cars are delivered to the customer with runflat tyres and come complete with a Tyre Defect Indicator recognising any loss of pressure through the higher speed of the tyre compared with the other wheels and informing the driver accordingly. This, in turn, is attributable to the simple fact that the circumference and roll radius of the tyre will change under a loss of air pressure, the speed of rotation increasing accordingly.

TPC Tyre Pressure Control permanently monitors the pressure and temperature inside all four tyres. Once all four tyres have been set to the right pressure, all the driver has to do is initialise the Tyre Pressure Control system, which then permanently monitors tyre pressure both at a standstill and when driving, regardless of road speed and the outside temperature. Once the pressure in one or several tyres drops below a certain tolerance level, the system will immediately inform the driver, thus helping to avoid tyre damage by driving too far on tyres with inadequate pressure – which is the main reason for a bursting tyre. Apart from an even higher standard of active safety, therefore, this also means greater all-round economy and motoring comfort.

Manoeuvring: the steering system.

Precise steering behaviour is elementary to superior safety and perfect handling, with the car responding spontaneously and precisely car to the driver's commands. Precision, in turn, calls for clearly tangible feedback and adequate return forces giving the driver a direct feeling of road and driving conditions. This applies to the steering with both hydraulic and electro-mechanical power assistance, both of which are designed to give the driver essential feedback from the road while suppressing any undesired or unwanted adverse effects.

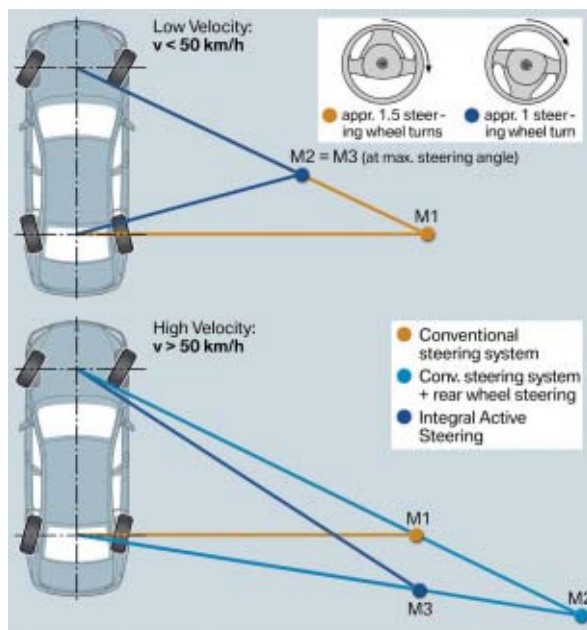
Today the BMW Group increasingly uses electromechanical steering systems even more sensitive and precise in their set-up and response. The Active Steering developed by the BMW Group, for example, offers exactly the right transmission ratio for all road speeds and steering angles, maintaining direct steering response up to a speed of approximately 90 km/h or 55 mph. Then, at higher speeds, the Active Steering transmission ratio becomes increasingly indirect in the interest of superior directional stability, driving safety and motoring comfort.

When oversteering in bends and when applying the brakes, Active Steering likewise makes an active contribution to the enhanced stability of the car. For example when braking on different surfaces in a modal split, Active Steering counter-steers specifically as required and in a discreet process to prevent the car from swerving out of control.

Steering both axes front and rear: Integral Active Steering.

This specific highlight of active safety is raised to an even higher level through Integral Active Steering in the new BMW 7 Series acting not only on the front wheel steering angle, but also for the first time on the steering angle at the rear. Particularly at higher speeds, Integral Active Steering gives the car a safe and secure response when changing lanes and in bends. In abrupt steering manoeuvres, the BMW 7 Series thus precisely follows the course determined by the driver.

The steering angle of the rear wheels is a maximum of 3°. At low speeds, the rear wheels are turned against the steering angle of the front wheels to give the BMW 7 Series significantly greater agility. Depending on the current speed, the car's turning circle thus decreases by up to 70 centimetres or 27.6". And last but not certainly not least, the greater agility ensured in this way is further enhanced by extra comfort thanks to the reduced steering effort (see upper section).



At higher speeds Integral Active Steering ensures an extremely comfortable and superior response of the vehicle when changing lanes and in bends, the steering angle of the rear wheels following the movement of the front wheels. Intervention by Active Steering on all four wheels furthermore optimises the response of the steering and reduces the steering effort and movement of the steering wheel.

A further advantage of rear-axle steering is particularly noticeable on the rear seats, with a change in direction under dynamic driving conditions building up the right level of lateral acceleration without the usual yaw rate of the car increasing to the same degree. With these two factors – lateral acceleration, on the one hand, and the yaw rate, on the other – being separated from one another, passengers riding in the car experience a particularly high standard of motoring comfort (see Fig, lower section).

The combination of Active Steering on the front axle and rear-axle steering benefits both motoring comfort and the agility of the car in the same way.

Extra stability: Dynamic Stability Control.

The outstanding driving experience in a BMW is borne out clearly in all situations, even on bad roads and under the most difficult conditions. Intelligent control systems enhance the car's potentials in such a case, DSC Dynamic Stability Control, for example, together with integrated ABS anti-lock brakes, forming the nucleus for the dynamic driving assistance systems used today.

Maintaining the driving dynamics so typical of a BMW, DSC serves first and foremost to stabilise the car when driven to the limit, preventing the car from swerving out of control, say, in abrupt manoeuvres, by applying the brakes appropriately on individual wheels. Then, automatically intervening in the car's suspension, DSC maintains the car's driving stability or reinstates stable driving conditions more quickly than before. Accident research has also shown that DSC reduces the number of dangerous rollovers and side-on collisions.

The engineers at the BMW Group have enhanced the various functions of DSC to an even higher standard on vehicles with xDrive all-wheel-drive technology, ensuring an even smoother and more harmonious transmission of power in bends. In a BMW equipped with iDrive, appropriate application of the brakes in precise "doses", together with compensation of the torque acting on the individual wheels, prevents understeering right from the start.

This control function is activated as soon as DSC recognises even the slightest tendency to understeer. To prevent the vehicle from pushing out of the bend over its front wheels, the brakes are applied slightly on the inner wheel in a bend. At the same time the control system feeds exactly the right level of power to the wheels in order to set off the brake forces acting on the car.

The bottom line is that the car behaves even more safely in a bend without the driver feeling any loss of dynamics or driving performance. A typical example of this kind is driving on a mountain road along snow-bound serpentines, the car smoothly following the bends on the road without requiring the driver to correct the steering and without the slightest interruption of power or traction.

Driving even more precisely through appropriate distribution of engine power: Dynamic Performance Control.

Dynamic Performance Control opens up a new dimension in the distribution of power and torque, feeding drive forces precisely as required to the two wheels at the rear. The system therefore acts according to the same principle as DSC, but exactly the other way round, not applying the brakes on specific wheels in order to generate greater stability, but rather feeding additional torque to the wheels where required. As soon as the driver accelerates hard in a bend, for example, engine power is distributed in exactly the right way to the two drive wheels, depending on steering lock. This once and for all puts an end to the old phenomenon of the inner wheel spinning in a bend, which in practice means a loss of traction.

A further point is that extra torque is fed to the outer wheel, the specific, asymmetric distribution of torque ensured in this way enabling Dynamic Performance Control to generate yaw momentum keeping the car more stable and following the driver's commands more directly. This applies both to the process of giving gas and taking one's foot off the gas pedal.

Through its greater steering precision, good steering behaviour and superior tracking stability, the car is safer and easier to control in critical situations. A further advantage is that the DSC stability control system is no longer required to intervene as often as before.

Less body sway, greater directional stability: Dynamic Drive.

Steering precision and directional stability as fundamental requirements for active safety depend not only on the design and configuration of the suspension. Rather, the movement of the car's body also plays an important role every time the driver changes direction, increasing with the force and abrupt action applied by the driver on the steering wheel.

To prevent such body movement to the greatest possible extent while at the same time maintaining a very high standard of motoring comfort, the BMW Group has pioneered the development of Dynamic Drive, an active suspension control system. Benefitting from this technology, the driver and passengers hardly feel any bumps or unevenness on a straight-ahead stretch of road thanks to controllable anti-roll bars virtually separating the two sides of the car from one another, while at the same time Dynamic Drive prevents any body sway or roll in bends. The result is superior agility and stability under all driving conditions, the extra safety, agility and precision in steering manoeuvres setting new standards in suspension technology.

Active safety with enhanced comfort:
Dynamic Drive and its technical features.

Dynamic Drive largely eliminates the conflict of interest between handling, body sway, and roll comfort. The adaptive control functions of the system ensure a significantly higher standard of active safety in dynamic driving manoeuvres such as a lane change, when driving round bends, or when suddenly avoiding an obstacle on the road.

Dynamic Drive is made up of two active anti-roll bars, a valve unit with integrated sensors, a tandem pump, a lateral acceleration sensor, a control unit, and other supply components. The key components are the two active anti-roll bars integrated in the front and rear axles instead of conventional mechanical anti-roll bars. An active anti-roll bar or actuator is made up of a hydraulically operated step motor where the step motor shaft and the housing are each connected to one half of the anti-roll bar.

An active anti-roll bar converts hydraulic pressure into torsional momentum and, through its connection, builds up the stability forces required. The pressure generated by the pump is controlled by two electronically masterminded pressure control valves serving to

- minimise or completely eliminate body sway in a bend,
- build up superior agility and directional precision throughout the entire speed range of the car, and
- generate optimum steering and docile load change behaviour.

At the same time the actuators are free of any pressure when driving straight ahead or under very low lateral acceleration, ensuring that

- the rotational spring rate of the anti-roll bar cannot make the fundamental set-up of the suspension unduly hard, and that
- the usual “copying” movement of the car’s body is reduced to a minimum.

The main control signal used by the system is the car’s lateral acceleration measured by the appropriate sensor. Chassis management control then receives further signals on lateral and longitudinal dynamics subsequently evaluated in order to obtain even better and more robust information on the car’s lateral dynamics. Applying the lateral dynamic signal calculated in this way, the control unit finally determines the valve flow required for the valve block.

The system is set up to significantly reduce the roll angle under driving conditions typical of the “regular” motorist: Dynamic Drive serves to completely avoid any relative sway angle under lateral acceleration from 0 to 0.3 g. Up to 0.6 g Dynamic Drive then generates quasi-stationary roll behaviour of the magnitude we generally experience with passive suspension up to 0.1 g. In other words, body roll under lateral acceleration of 0.6 g is reduced by more than 80 per cent. And last but not least, Dynamic Drive reduces the steering angle required versus a car with conventional suspension.

Under higher lateral acceleration beyond 0.6 g, Dynamic Drive informs the driver that he is slowly but surely reaching the limit. Hence, the steering angle radius continuously and tangibly increases under such conditions, informing the driver – without alarming him in any way – that even Dynamic Drive does not – and cannot – override the limits to physics.

In all, a BMW with Dynamic Drive behaves in a more neutral manner under low lateral acceleration, significantly reducing the steering angle required versus a vehicle with conventional suspension. Then, with lateral acceleration consistently increasing, the control system intentionally gives the car more understeer in the interest of better feedback to the driver.

The supreme authority in control of all active control systems: Integrated Chassis Management.

Integrated Chassis Management (ICM) efficiently connecting the various suspension systems ensures the perfect balance of all functions and features. Serving as the central “brain” in the car, ICM links all individual sources of data

and information, distributing the messages required to the individual systems further down the line. Carefully and thoroughly analysing driving conditions in accordance with a wide range of information, ICM can decide which settings are most suitable in which situation to ensure perfect harmony of the driver's wishes and the response of the car. The appropriate commands are then transmitted to the systems further down the line and are implemented appropriately.

The ICM network established in this way also allows the introduction of new functions only made possible by integrating several control systems. As an example, Dynamic Performance Control interacts directly with Dynamic Stability Control, Active Steering or Dynamic Drive. The specific structure of ICM thus allows full use of all the benefits and strengths of Dynamic Performance Control. Two other examples are combined intervention in the steering and brakes for even shorter stopping distances and even greater driving safety when applying the brakes on roads slippery on one side, as well as the transmission of higher anti-sway forces to the front axle in bends in the interest of greater traction.

The particularly fast and appropriate response of Integrated Chassis Management is made possible by high-speed FlexRay data transmission introduced by the BMW Group as the world's first car maker in standard production. Offering a transmission rate 20 times higher than other transmission systems, FlexRay enables up to 16 control units to communicate with one another in the new BMW 7 Series, setting the foundation for the extremely fast, precise and perfectly coordinated use of control units in the car's drive, suspension, damping, steering and brake systems. Indeed, no other car allows the same precise control of longitudinal, lateral and vertical movements as the new BMW 7 Series.

The interaction of individual systems within and through ICM is clearly described by the process of taking a typical bend in the BMW X6:

- When steering into a bend, the smooth build-up of steering forces and steering feedback as well as the steering momentum turning into the bend generated when required by Dynamic Performance Control are crucial to the car's dynamic driving behaviour.
- Continuing round the bend, the distribution of roll forces ensured by Dynamic Drive and the extra torque and precise management provided by Dynamic Performance Control are crucial to the car's steering behaviour. Indeed, the combination of these two systems offers neutral driving behaviour all the way to a limit never seen before.

- Any slight understeer caused for example by different road surfaces on each side with varying grip is set off by reducing the turning effect of Dynamic Performance Control and Dynamic Drive. This effect is then significantly enhanced by Active Steering correcting the steering wheel lock, with intervention in the brakes by DSC required only in extreme cases with a great need for extra stability. The result is extremely agile and, at the same time, stable driving behaviour.

Less stress, more safety:

Active Cruise Control with Stop & Go and Proximity Warning.

Introducing ACC Active Cruise Control using radar to maintain an appropriate distance to the car ahead in a long line or row of traffic, the BMW Group has taken a significant step in relieving the driver off his usual chores. Now, adding the Stop & Go function to ACC, the new generation of intelligent distance control offers even greater advantages in a production car.

Active Cruise Control with Stop & Go allows automatic distance control enabling the driver to comfortably cruise along the autobahn or country roads, keeping a safe distance under all conditions from the car ahead, even in congested traffic and to standstill. The advantages of the system in such slow traffic under congested conditions are significantly greater comfort and safety also in situations often regarded as strenuous and difficult to handle. The driver nevertheless still retains his responsibility, being required for example after a short stop of more than three seconds to briefly give gas in order to set off and accelerate again.

Even with ACC/Stop & Go in its active mode, the driver can still influence the speed of his car at any time by giving gas or applying the brakes. With Active Cruise Control and Stop & Go featuring the latest generation of radar sensors, the driver is indeed able to choose from four different distance levels. And should the distance to the vehicle ahead chosen by the driver no longer be maintained, ACC and Stop & Go adjusts the speed of the car accordingly by intervening in the engine's drive management and building up brake pressure wherever appropriate. The system even acts independently in reducing the speed of the car all the way to a standstill, slowing down the car to zero and holding it in position. The maximum stopping power generated by Active Cruise Control with its Stop & Go function is 4m/s^2 , further limited to the even more comfortable level of 2.5m/s^2 at higher speeds. The driver will be urged by optical and acoustic signals to respond accordingly.

The collision and proximity warning function is always available even when ACC Active Cruise Control with Stop & Go is not switched on. This system reduces the response thresholds of the Brake Assistant and activates the

brake standby function of DSC in the process. Given an appropriately fast response on the part of the driver, this reduces the risk of a bumper-to-bumper collision by shortening the car's stopping distance accordingly.

Watching out for the neighbours: Lane Change Warning.

The latest generation of BMW assistance systems is not limited to the management of physical processes while driving, but also supports the driver directly, for example in the process of manoeuvring. One example is Lane Change Warning available for the first time in the new BMW 7 Series, helping the driver change lanes safely and smoothly by warning him of any possible danger caused by vehicles approaching from behind on the adjacent lane.

The Lane Change Warning system uses radar sensors at the rear of the car monitoring traffic conditions on the adjacent lanes. These sensors cover a range extending from the blind angle on the adjacent lane all the way back over a distance of 60 metres or almost 200 feet. A triangular symbol lighting up permanently on the foot of the exterior mirror housing shows the driver whether there is another vehicle in the critical range. Then, as soon as the driver operates the direction indicator in preparing for a lane change, he will receive a warning through an LED signal as well as a second, discreet but unmistakable warning through vibrations on the steering wheel.

Of course, the new 7 Series also features Lane Departure Warning which recognises any unintended deviation from the driver's course and direction of travel. The system is made up of a camera fitted near the interior mirror on the windscreen, a control unit comparing data received, and a signal actuator generating the vibration effect on the steering wheel.

Always travelling at the right speed: Speed Limit Indicator.

In combination with a navigation system and Lane Departure Warning, the BMW 7 Series now offers yet another exclusive function: For the first time worldwide, the Speed Limit Indicator informs the driver at all times on the maximum speed limit currently allowed.

This function relieves the driver of an old chore in particular on long distances, informing him at all times of the current speed limit without requiring him to constantly check out road signs. Instead, a camera fitted near the interior mirror registers speed signs by the side of the road as well as variable signs on larger signals and bridges above the motorway. The data obtained in this way through the recognition of traffic signs is then compared with the data saved in the navigation system, information coming from the camera being given priority wherever the speed limit has possibly been changed due to current requirements, for example at a building site.

The Speed Limit Indicator even considers specific restrictions applied to speed limits, the instrument cluster or, as an option, the Head-Up Display therefore always showing the speed limit currently to be observed. Clearly, this significantly reduces the risk of breaking the speed limit by mistake.

Eyes on the road: intuitive control and minimal distraction.

Full concentration, perfect visibility and appropriate, mutual appreciation of traffic conditions are crucial to safe motoring. Apart from optimum ergonomics, the process of concentrating on the car and traffic conditions means that the driver must not be distracted from his driving responsibilities in any way.

By tradition, the BMW Group has always played a leading role in developing new concepts for an intuitively controlled, ultimately distraction-free and highly functional display and control concept. The new cockpit of the BMW 7 Series Saloon is indeed an outstanding, cutting-edge example of this superiority, its horizontal subdivision making it much easier to control the car with maximum ease and optimum safety.

After the driver has made himself acquainted with the car within a very short time, the separation of control instruments and visual displays offers significant benefits: First, the driver enjoys an optimum view of all the information he requires, moving his attention away from traffic conditions only for an extremely short time when necessary in order to check out a display or indicator. Indeed, such movement of the driver's eyes may be further reduced by the optional Head-Up Display projecting selected information on to the windscreen and, as a result, directly into the driver's line of vision.

The second point is that all buttons and switches, levers and controls are arranged highly ergonomically for easy reach and intuitive control by the driver. Among other things, this means that the driver is only required to make minimum movements in performing the various control functions, operating the systems involved even more quickly and minimising any distraction in the process. This effect is further enhanced by the easy-to-remember vertical arrangement of all displays and control units. Driver-relevant information and control units, for example, are on the side of the cockpit facing the driver, while all displays, controls and keys serving to operate comfort functions are positioned in the middle of the car.

The arrangement of controls on the multifunction steering wheel also follows this logic, again giving the driver maximum operating safety at all times: To take up information or activate a specific function, all the driver must do – if at all – is briefly take his eyes off the road. So there is no need to spend a long

time looking for controls not used regularly, since all controls are appropriately located where they should be. As an example, the control units for the driver assistance systems supporting the driver in perceiving traffic conditions and maintaining a high level of attention are positioned in a joint control panel directly next to the lights switch.

The clear structure of the cockpit quickly helps the driver build up the necessary routine in operating the various systems even when using additional functions not required under all conditions. As a result, the driver will appreciate the wide range of technical features as a genuine enrichment and improvement of his driving experience adding active safety at all times.

Better visibility at night: intelligent headlights.

Proceeding from the bi-xenon headlights, BMW has developed an assistance concept significantly enhancing visibility and clear perception of the car above all in poor weather and with bad visibility. Variable light distribution introduced for the first time on the current BMW 6 Series optimises visibility also on straight roads, innovative control operating as a function of road speed automatically enlarging the driver's field of visibility by broadening the light beam. In the city light mode at speeds below 50 km/h or 30 mph, for example, a broad light beam makes it much easier to recognise objects to the left of the car. In the Autobahn or Interstate mode, on the other hand, the driver's field of vision is increased by extending the length of the light beam and again brightening the left-hand side to a higher level. Activation of the foglamps at speeds of up to 70 km/h or 50 mph again broadens the light beam and brightens up the nearby area directly in front of the car. And at high speeds, finally, headlight range is increased in addition to the broader distribution of light.

Adaptive Headlights included in the lights package and offering variable light distribution serve to illuminate the road ahead according to its particular course and contours. In this case the headlights swivel from one side to the other in accordance with the steering lock, the yaw rate and the speed of the car.

Adaptive Headlight Range Control introduced for the first time in the new BMW 7 Series also considers the vertical contours of the road, lowering or raising the light beam as required when crossing a crest, driving through a tunnel or up or down a steep ramp in order to provide optimum illumination of the road ahead without dazzling oncoming traffic.

The Bending Lights function is available in combination with Adaptive Headlights and is activated at speeds below 40 km/h or 25 mph as soon as the driver operates the direction indicators or the system recognises a particularly

strong steering lock. The Bending Lights are switched on in tight bends at speeds of up to 70 km/h or 43 mph, supplementing the Adaptive Headlights in the process. Again, the big advantage is optimum illumination of the road ahead when manoeuvring and on narrow serpentine roads.

Automatic driving light control makes driving under constantly changing conditions even safer than before. In this case the on-board electronic control system, using two sensors in the windscreen, monitors light conditions and automatically switches on the low-beam headlights as soon as required, for example when driving through a tunnel or with dusk setting in.

The rain sensor automatically determining the inception and degree of precipitation by way of optical measurement ideally supplements BMW's drive light control, automatically activating the windscreen wipers whenever required and adjusting wiper frequency to the intensity of precipitation. The optimum visibility ensured in this way in all kinds of weather and under all driving conditions provides the foundation for safe motoring at all times.

These systems are supplemented by the High-Beam Assistant automatically switching off the high beam as soon as oncoming traffic or other vehicles ahead driving in the same direction are in sight or if the road the driver is taking – for example within a built-up area – is adequately illuminated. The system also switches over automatically from low to high beam whenever required and is masterminded by a camera integrated in the interior mirror supervising both headlight brightness and traffic conditions.

Preventive pedestrian safety:

BMW Night Vision with detection of individual persons.

Available as an option, BMW Night Vision ensures extra safety when driving at night. The “heart” of BMW Night Vision is a thermal imaging camera providing a video image clearly showing human beings, animals and other objects even beyond the headlight beam by registering differences in temperature. Objects emitting heat are detected by BMW Night Vision both on and next to the road at a distance of up to 300 metres or almost 1,000 feet, the image then being presented in high contrast and high resolution in the control display. This draws the driver's attention to possible risks and hazards he would not be able to see with his naked eye.

The BMW Group is the world's first manufacturer to offer this advanced technology with detection of persons and an appropriate warning function in the new BMW 7 Series. The video data obtained through the system is analysed by a control unit using intelligent algorithms to search for pedestrians

then highlighted in the video image in yellow. And as soon as the system detects a possible risk involving people on or next to the road, the driver receives an additional active warning.

To limit such warnings to pedestrians really at risk, the control unit conducts a complex situational analysis, not only warning the driver in the case of pedestrians within a specific warning corridor determined as a function of speed, the steering angle and yaw rate, but also recognising a person standing at the side of the road, walking towards the road or already on the road itself. In such a situation the driver receives an early warning by means of a symbol flashing on in the Control Display. And if the car is fitted with a Head-Up Display, the warning is also shown there.

Enhanced visibility in city traffic.

As in the case of pedestrian detection and warning just described, active safety does not necessarily depend on the speed of the car. On the contrary, most accidents occur in town, particularly in unclear traffic situations. Precisely this is why the BMW Group has developed and introduced a number of assistance systems serving to make the process of manoeuvring in town even easier and safer.

The back-up camera, for example, facilitates the process of parking and manoeuvring in confined spaces with poor visibility. The high-resolution images provided by the broad-angle lens are shown in colour and in exactly the right perspective on the Control Display, interactive trace lines serving furthermore to highlight the optimum angle of the steering wheel and the tightest turning circle when parking. This video system facilitates not only parking and manoeuvring, but also ensures extra safety, for example, for pedestrians or children playing behind the car.

Supplementing the back-up camera, the BMW 7 Series is available for the first time as an option with a Side View function. Side View uses two cameras integrated in the front end of the car giving the driver an even better and clearer view of traffic crossing from the side also at road junctions with poor visibility.

Particularly when leaving a narrow gateway, a car park or in many other merging situations difficult to appreciate in advance, the image presented in the Control Display provides an immediate overview of traffic conditions both left and right of the car. This enables the driver to recognise cyclists suddenly crossing ahead, without having to drive the complete front end of the car out on to the road. In the interest of rapid availability, the driver is able to activate Side View by means of a direct selection key in the centre console.

Training the driver:

Efficient practice for extra safety and supremacy at the wheel.

BMW was one of the first car makers in the world to realise that the enhancement of active safety requires not just the right technologies offered to the driver. Rather, it is just as important to offer the driver at the wheel the right kind of training and practice.

More than 30 years ago BMW implemented this philosophy to provide a truly safe experience of sheer driving pleasure, BMW Driver Training teaching the motorist how to behave at the wheel, how to understand and appreciate the limits to technology and his driving skills, and how to recognise and handle potential hazards, as well as – most importantly – how to avoid such risks and hazards right from the start. And since really effective training must be tailored to each specific car and its features, the BMW Group offers driver safety courses also on the front-wheel-drive MINI.

BMW Driver Safety starts where regular driving schools stop. Precisely this is why the highly attractive training schedule is of great interest to both beginners and skilled drivers alike, especially because driver training must consider and cover all speed ranges. Even in town at typical city traffic speed, exercises such as applying the brakes in an emergency or completing a double lane change are practised with utmost care, assuring significant improvements. As an example, participants immediately learn and experience the differences in stopping distance between, say, 30 and 50 km/h. Oversteering and understeering in specific situations, combined with an appropriate counter-response by the driver, prepares participants for critical situations they may easily encounter in everyday traffic.

Taking all this into account, the Driver Training Programme proceeds in a number of steps, offering training sessions at the speeds typically encountered on country roads as well as Autobahn speed and showing the driver how to respond appropriately on ice and snow.

2.3 The Point of no Return – Even the last few Seconds Can Save Lives.

Even the last few seconds shortly before an inevitable collision may save lives, provided the driver and other parties involved take the right action. So this is precisely where the BMW Group comes in with its all-round integral safety concept.

Again, supporting technologies and assistance systems enabling the driver to act appropriately or supporting him in his action are of utmost significance also in this phase: Warning the driver in advance through the Collision Assistant, for example, the brakes will apply the brake pads in good time, preparing the entire brake system for maximum grip. Dynamic Brake Control (DBC) is then able to immediately build up maximum stopping power. A fast response means additional reduction of speed prior to a collision and, as a result, an appropriate reduction of impact energy and forces.

Obviously, the suspension control systems minimising, for example, the consequences of the car swerving out of control and the risk of a rollover or side impact also come in at this point, just as crucial safety measures for the occupants are activated here prior to the actual collision, for example with the rollover sensors detecting a rollover and moving up the rollbar in, say, the BMW 1 Series Convertible whenever required.

2.4 Should the Worst Come to the Worst: Passive Safety for Extra Protection.

Passive safety comes in when all the usual options to prevent an accident have been exhausted. The purpose of passive safety, therefore, is to reduce the consequences of an accident for the car's occupants to a minimum.

Only a broad range of interacting features and technologies is able to provide the optimum safety concept meeting all the demands and requirements of the BMW Group. Indeed, these requirements made by the BMW Group go beyond the increasingly strict laws and provisions applicable worldwide as well as the demands made in consumer protection studies – particularly because the standard applied by BMW is derived directly from accidents genuinely occurring in the real world. Obviously, such accidents are far more diverse in character and require a very different set-up and configuration of the car.

To minimise the forces acting on the occupants and maximise the survival space available, a BMW Group car comes with load-bearing structures able to take up the most significant forces, deformation zones used in full for optimum protection, an extremely stiff passenger compartment, as well as compatible design and configuration of the front-end structure to provide a complete and highly effective safety concept.

Added to all this, every BMW boasts a highly effective restraint system incorporating airbags, seats, efficient headrests, seat belts, belt latch tensioners, belt force limiters, the steering wheel, and steering column. And last but certainly not least, the car's interior is set up to allow maximum forward movement of the occupants.

Passive safety is however more than the sum total of all these features. For the essential point is to perfectly coordinate all of these functions, factors and components to offer the decisive benefits affording the car's occupants optimum protection within fractions of a second.

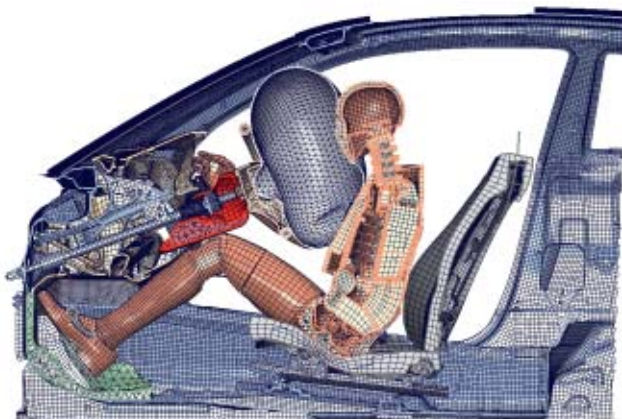
Practical results confirming theoretical studies: crash tests and simulation.

To meet the greatest demands in vehicle safety, the BMW Group has enlarged and enhanced its test facilities most significantly in recent years. Through these crash facilities and testing equipment, the BMW Group benefits from unique capacities and qualities in ensuring passive safety on an all-round scale.

Before the first prototype of a new BMW hits a block of concrete weighing 90 tonnes, bits and bytes literally crash together in computer tests simulating all kinds of overall vehicle collisions in virtual experiments: The configuration of the extra-strong and stable passenger cell as well as the interaction of deformation zones giving in where required are studied in the initial phase in computer simulation tests. Similarly, the qualities of the car's airbag and belt systems are harmonised in a virtual process and the requirements made to the interior are determined in exact studies.

It is only when in such simulation tests the virtual prototype is able to meet and, indeed, outperform the strictest legal standards applied the world over and fulfil all consumer tests worldwide that experiments are carried out subsequently with hardware prototypes.

In conducting such experiments, experts at the BMW Group use the Abaqus/Explicit simulation program. Simulations are then carried out with the finite element method providing a realistic view of physical reality. In the process various materials are considered for their elasticity, their strength and many other parameters. A numerical approximation method then calculates the complex processes taking place during a crash, again working with utmost precision and according to an exact time-scale. In this process a whole range of different elements shows and represents the design and configuration of the body structure and the interior.



Each model of the complete vehicle currently comprises up to two million elements, the calculation process incorporating eight CPUs on a high-performance computer cluster taking no less than 40 hours. The results required for final evaluation and analysis of all details, finally, amount to a total data volume of more than four gigabytes.

Hundreds of calculations of this kind are conducted from the start of concept development all the way to the actual start of vehicle production in order to harmonise and coordinate the various systems with one another. This complexity results from the wide range of different requirements and the many features and qualities to be determined, such as inner pressure within the airbags, the different ignition points for the seat belt and the airbag, as well as the different features of adaptive elements in the restraint system, the interior design and stiffness of the car. Only optimum configuration and harmonisation of all these features will ultimately lead to the desired objective.

In the case of virtual configuration the test results are of particular significance, since their meaning and implications in the simulation process are still limited even when applying the most advanced simulation methods and the most sophisticated models, thus requiring careful coordination with actual test data. Practical tests allow validation of the computer models, confirming the simulation process and allowing even more realistic statements. In the years to come there will still be a need for an intensive combination of testing and simulation crucial to success in optimising the standard of passive safety.

Testing the worst case: crash tests.

One of the BMW Group's key competences is the ability to develop a passive safety concept meeting the strictest and most demanding requirements. Precisely this is why the Company has a network of three crash facilities not only conducting all the crash tests required by law, but also fulfilling the most demanding safety standards applied internally within BMW in a realistic process.

To meet this high standard, the test technologies applied by the BMW Group have been enhanced in recent years, the so-called C2 Crash Facility in Aschheim near Munich being converted and modernised at an expenditure of no less than Euro 5 million. Apart from conventional rear-end and side-impact tests, this allows all kinds of test scenarios required neither by homologation authorities nor consumer organisations.

One of the test facilities, for example, is an embankment covered by test cars at a precisely defined speed before they intentionally roll over to the side. Driving up a ramp on one side of the car, in turn, the BMW Group's test engineers simulate the process of driving up an embankment next to the road or hitting the guide rails at the roadside.

BMW's experts also examine the sensors used for determining the risk of a rollover and are able in the process to refine the activation algorithm to an even higher standard. This benefits both the occupants in an open sports

car and in a convertible with rollbars moving up automatically as well as the passengers in cars with a fixed roof. In all cases the restraint systems may be pre-set and the ignition of the airbags particularly for safety at head and thorax level is tailored to the actual course of an accident in order to once again ensure optimum safety and protection.

Consistently following the conditions actually encountered in an accident, BMW Group experts use this test facility to examine further scenarios. As an example, they let test cars slide down into a sand bed measuring about 40 centimetres or 16" in depth, where the car ultimately rolls over, in the process measuring the loads acting on the occupants and where necessary adjusting the safety features required in such an extreme case. Again, this specific type of accident scenario is not to be found in any of the usual test cycles applied the world over.

But even that is not all: The facilities used at BMW's test centre are likewise essential for the ongoing development and enhancement of active safety. Using such facilities, therefore, BMW Group engineers determine under what conditions a car will tend to roll over and analyse the conditions prevailing in such a process. Using an algorithm of the DSC stability control system as well as Dynamic Drive suspension control precisely tailored to each model and type of car, the engineers are able to take counter-measures against any kind of instability right from the start, ensuring that the car does not reach the critical rollover momentum (or only does so under extreme conditions).

Since tests such as the sand bed rollover just described require a long period of preparation, only about 100 tests are conducted each year in the C2 Crash Facility. Most crash tests are nevertheless conducted in two facilities operated at the BMW Group Development Centre well-known worldwide as the FIZ Centre: The smaller test laboratory referred to as the C1 Facility specialises on crash tests at low speeds, experts examining head-on collisions at such low speeds and bumper tests in impacts of up to 27 km/h or 17 mph approximately 50 times a year.

Most crash tests are conducted in crash facility 3 referred to as C3 for short. Here accidents are simulated at test speeds in head-on collisions of up to 64 km/h or 40 mph, in rear-end collisions of up to 80 km/h (50 mph), and in side impacts of up to 62 km/h or 38 mph. This covers far more than 90 per cent of all accidents actually experienced in practice. New homologation rules, new markets and the introduction of further BMW and MINI models indicate that the number of crash tests conducted each year will continue to increase.

But even so, the BMW Group is well prepared also for this challenge and invested some Euro 25 million in 2005 alone in the new construction of the C3 crash facility.

In this large number of tests, cars hit barriers weighing several tonnes with either full overlap of the crash area or in an offset collision. The number of such tests is indeed increasing, new homologation rules, new markets as well as new models from BMW and MINI indicating that there will be even more crash tests in future. Be it as it may, the BMW Group is well prepared for such requirements and has invested some Euro 25 million in the reconstruction of the C3 Crash Facility in 2005 alone.

Safety systems need not always be tested in a complete bodyshell and the cars and components involved need not always be damaged or destroyed in the process. Precisely this is why the BMW Group uses an innovative catapult system exposing entire vehicles and components to all kinds of collisions in acceleration tests, without causing even the slightest scratch in the process. The catapult simulates deceleration processes typically occurring in realistic head-on, rear-end or side collisions, thus conducting tests required by law or consumer protection associations.

Tests are conducted both on individual systems and seats as well as on body or body sections partly fitted with their final equipment. This enables the engineers to conduct complete test series involving various parameters within a very short period, using the same test array in the process. As a result, they are able to conduct tests with various activation times, inflation behaviour and inflation rates on airbag systems.

The network of BMW Group crash laboratories is rounded off by a special test facility for pedestrian safety simulating the impact of a pedestrian on the front end of the car. In these tests special test bodies simulate the legs, hips and head of the pedestrian, a hydropulse cylinder accelerating the test bodies and impacting them against the vehicle after a certain free-moving distance at a defined speed. Then, taking the deceleration data determined in the process, the engineers are able to assess the risk of injury.

Free spaces beneath the engine lid and behind the radiator and bumpers serve to enhance pedestrian safety by taking up impact energy and minimising the results of an impact. Currently the BMW Group is using this crash laboratory also to develop the sensors for an active front lid providing longer deformation travel by moving up in the event of a collision and thus reducing the forces acting on the pedestrian.

Since such systems obviously only take their effect once a collision has occurred and can therefore only reduce the consequences of a collision afterwards, the primary focus is on preventive pedestrian safety, that is preventing an impact from the beginning. The latest examples in this context are BMW Night Vision and Side View – and looking into the future, BMW's researchers and development experts are also working hard on systems applying the brakes actively to protect a pedestrian in a hazardous situation. Indeed, a driving prototype developed by the BMW Group Research and Technology already demonstrated this function to the public in 2007, showing how the brakes may be applied automatically under hazardous conditions in order to protect pedestrians on the road.

The standard of passive safety required by law and other statutory provisions will continue to increase in future. This not only creates the need to develop new technical solutions in the car, but also calls for the use of new dummies with even more sensitive and comprehensive measurement sensors particularly around the legs.

The BMW Group already uses more than 60 dummies of this kind at a cost per dummy between Euro 100,000 and Euro 250,000, incorporating up to 200 sensors for the measurement of acceleration, temperatures and impact depth. The dummies cover all sizes of occupants ranging from a baby still in the womb all the way to a fully grown man. Serving as highly sensitive and standardised measuring units able to precisely cover approximately 10,000 data in a second, the dummies are certified every 3–5 crash tests, depending on their specific use and application, in the interest of maximum reliability and optimum results.

Built for consistent safety: BMW Group vehicle concepts.

All BMW Group vehicles feature progressive deformation zones front and rear serving in conjunction with the car's active restraint systems to reduce the forces acting on the occupants in the event of a collision. Thanks to its high level of stability keeping its shape even under extreme conditions, the passenger cell forms a safe survival area for the car's occupants in all kinds of crash scenarios. Indeed, this superior stiffness of the passenger cell is the result of a wide range of features and technologies precisely geared to one another: The foundation is provided by the extremely stiff floorpan, appropriate load-bearing structures and joining technologies holding the various body components together likewise making a significant contribution. After all, a chain is only as strong as its weakest link, as the old saying goes.

Even this, however, is not enough, since the various components must be particularly strong and stable at one point and extra supple and flexible at another. In many cases a truly safe car must indeed fulfil both of these requirements at one and the same point, as we see from the front axle area of a BMW: On the one hand the front axle subframe is firmly connected to the engine carriers in order to take up engine forces (torque) and transmit wheel forces to the body of the car. On the other hand the front axle subframe must give in in a defined process at specific deformation points determined in advance in order to absorb energy.

The steering column is also designed to disengage from the steering transmission with the help of a precisely operating deformation element in the case of a head-on collision, preventing any backward movement of the steering transmission from forcing back the steering wheel. A further point is that the steering column rests in a slide bearing and is held firmly in position on a crossbar between the A-pillars, keeping any backward movement to a minimum even when the worst comes to the worst, for example in an offset collision.

Ensuring this kind of safety, the BMW Group not only observes the most demanding international test criteria with cars tested at an impact speed of 64 km/h or 40 mph, but also follows the results obtained in realistic tests by specialists in accident research.

**Very safe even when open:
BMW convertibles and open-air sports cars.**

Clearly, an open car gives the engineers focusing on road safety a particularly challenging task, since an open sports car or convertible lacks both the B- and C-pillars as well as the roof and essential components in the vehicle's structure. So without using appropriate reinforcements, the body of such a vehicle would buckle and give way like an open shoe box.

Precisely such reinforcements and advanced technologies make the open-air BMW 1 and 3 Series as well as the 6 Series Convertible or the Z4 sports car particularly stable and robust, extra-strong crossbars and side supports adding further stiffness and resistance. In the upper sections of the A-pillars around the windscreen high-strength steel plates form an extra-strong frame guaranteeing superior stiffness and acting at the same time as a highly effective rollbar.

Depending on the type of car, further safety systems protect the occupants in the event of a rollover, even though this is a relatively rare kind of accident accounting for only about 3 per cent of all accidents in road traffic. Behind the

driver and front passenger of a BMW Z4 or MINI Convertible, for example, a rollbar fastened permanently in position and made of high-strength steel affords superior protection. The BMW 1 Series and 3 Series Convertible, as well as the BMW 6 Series Convertible, on the other hand, come with an active rollover safety system made up of two bars behind the rear seats automatically activated by a sensor system in the event of an acute rollover risk without damaging the rear window even when the roof is up. To really rule out all risks and eventualities, the rollover safety system comes with a low release threshold, again in the interest of extra safety. But then the rollbar may be easily moved back to its initial position in a simple and quick operation involving just a few settings.

Side protection in the doors.

A rather sensitive spot on a car is its flank or side area. The first point is that here there is not even an arm's length to slow down an intruding body, the second point is that four large door openings make any firm and inseparable reinforcement virtually inconceivable. Precisely for this reason, all BMW saloons offer uncompromisingly sophisticated and elaborate side protection: Diagonal, high-strength crossbars in all doors, interacting with the stable passenger cell, ensure optimum protection in a collision from the side. They cover a larger area than any other safety concept, the ends of the crossbars coming to a rest in the door frame in the event of a severe collision from the side, thus forming a complete network of reinforcement elements against sideways intrusion.

To allow assistance from outside as quickly as possible in an emergency, all BMWs also come with a crash logic automatically opening the central locking and activating the interior light as well as the hazard warning flashers.

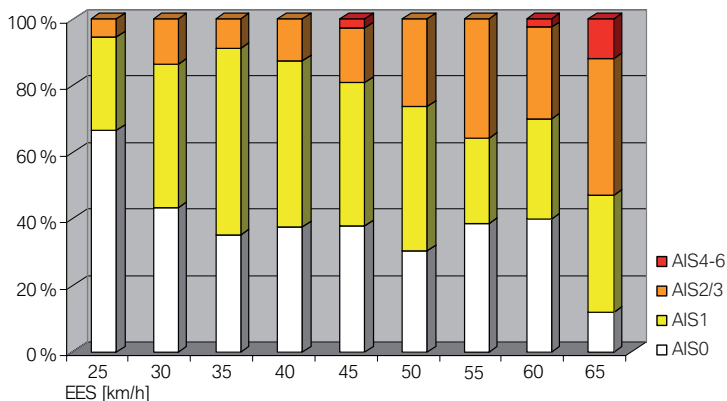
The foundation for superior occupant safety: seat belts and airbags.

Although deformation areas in the body serve to take up energy and keep the impacts of an accident mostly away from the occupants, the acceleration forces acting on the driver and passengers in a collision are in some cases quite significant. So this is where the car's restraint systems come in, with all BMW Group models being fitted as standard with three-point inertia-reel seat belts on each seat.

The effect of the belts is further enhanced by belt latch tensioners and belt force limiters. In a relatively insignificant collision where the restraint function of the seat belt is quite sufficient, only the belt latch tensioners are activated and no airbags. In the new BMW 7 Series with comfort seats the belts are additionally pre-tensioned by the electric roll-up safety unit activated automatically under extremely dynamic driving conditions.

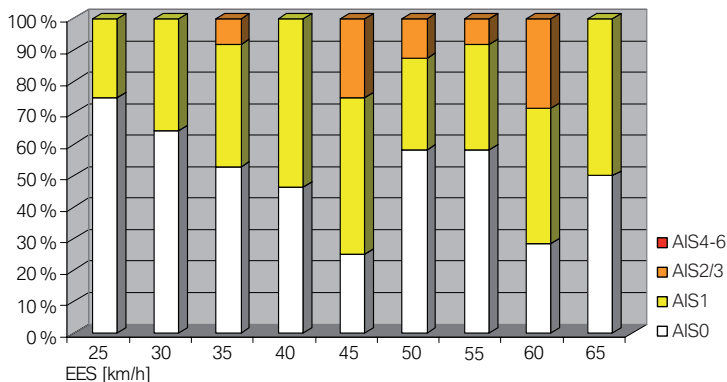
In a severe accident, on the other hand, the restraint effect offered by the belts alone is not sufficient anymore. To ensure optimum restraint also in such a case, all BMW Group cars come with airbags for the driver and front passenger in the steering wheel and the instrument panel above the glove compartment. The belt and airbag systems are precisely tailored to one another, the airbag inflating within a few milliseconds whenever required to protect the occupant's head and upper body from dangerous impacts – all the safety processes required are completed within a few split-seconds. The results of BMW accident research clearly prove how significantly airbags supplement and enhance the effect of the seat belt.

Head/thorax injuries suffered by the driver and front passenger wearing their seat belts in a head-on collision (large overlap) – no airbag



(Diagram 1)

Head/thorax injuries suffered by the driver and front passenger wearing their seat belts in a head-on collision (large overlap) – with airbag



(Diagram 2)

A comparison of head-on collisions with the driver and front passenger secured only by their belt in one case and by their belt and airbag in the other clearly shows the difference: The colours in the diagrams show that very severe and even fatal injuries (red) and slight to medium injuries (brown) are suffered far less frequently or not at all in the case of the driver and front passenger protected by their seat belt and airbag (Diagram 2).

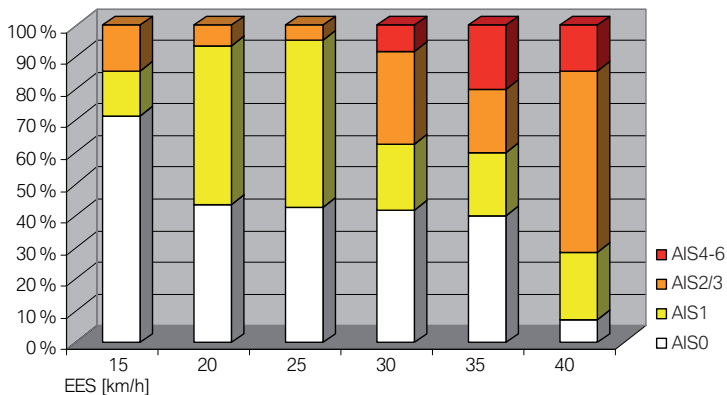
AIS is the abbreviation for Abbreviated Injury Scale and describes the severity of the injury suffered. This is an international injury scale compiled by physicians and bio-mechanics ranging from 0-6 and showing the risk to life caused by injuries. The speed range shown in the diagram goes all the way to an Energy Equivalent Speed (EES) of 65 km/h or 40 mph, thus covering more than 99 per cent of all head-on collisions.

This EES (km/h) speed factor is calculated from the deformation energy generated on the vehicle taken up by the structure of the car in a collision. The high level of passive safety in a BMW Group car is clearly confirmed by the fact that many occupants survive even such a collision of such severity without suffering severe injury to their head and upper body.

Two further airbags likewise fitted as standard ensure a similarly high standard of safety for the driver and front passenger in a collision from the side: the head and thorax airbag. Their task is to protect the head and upper body (thorax) from direct impacts on the intruding side structure of the car against the occupant's head or upper body, as well as direct contact with intruding objects such as, say, a tree. Within just a few milliseconds the side airbags form a protective cushion around the occupants also in the case of a glancing impact. And since the occupant's head and upper body are supported at the side by the airbags, rotation of the head and, as a result, forces acting on the cervical spine are significantly reduced.

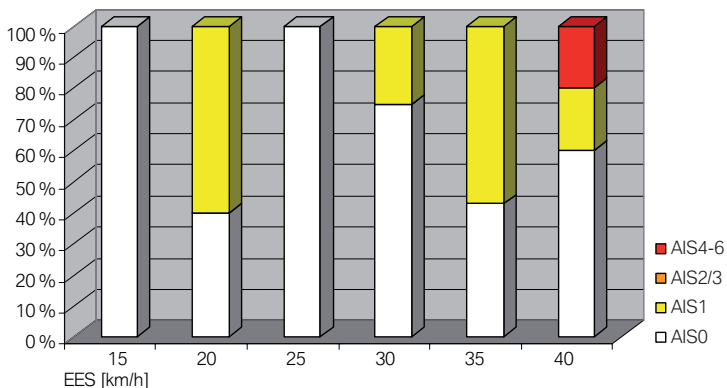
The protective effect of the airbag system often even saving lives in a collision from the side is similar to the protective effect in head-on collisions. The red colour indicating severe head injury suffered by occupants protected by an airbag (Diagram 4) is to be seen only as of an extremely severe side impact with an EES factor of 40 km/h or more. Without the head airbag (Diagram 3), however, we see medium injuries (brown) as of an EES of 15 km/h and severe injuries (red) as of an EES of 30 km/h.

Head injuries in side-on collisions without an airbag



(Diagram 3)

Head injuries in side-on collisions with the airbag inflating



(Diagram 4)

In autumn 2007 occupant safety in BMW cars was optimised to an even higher standard through the introduction of crash-activated headrests. Masterminded by the car's safety electronics, these headrests ensure that in the case of a collision from behind the front section of the headrest is moved forward by up to 60 millimetres or 2.36" and upward by up to 40 millimetres/ 1.57" within fractions of a second. This reduces the distance to the occupant's head before he is thrown to the back by forces acting on the car. The headrest therefore offers an even better stabilising and safety function, reducing the risk of injury or over-stretching the occupant's cervical spine.

It is important to note that all of these restraint systems ensure their optimum effect when the occupants are buckled up and properly seated. And finding the best seating position is incidentally one of the first exercises in all BMW and MINI Driver Training courses.

2.5 Rapid Assistance in an Emergency: the Advanced Emergency Call.

Even with all these improvements in passive safety, the BMW Group's safety concept has not yet reached the end. For the BMW ConnectedDrive communication network offers occupants a truly unique rescue assistance service: In the overall context of BMW ConnectedDrive, BMW offers individual online, assistance and service systems in the car for direct use via the navigation system or the telephone in the interest of significantly greater comfort and safety all in one.

The BMW ConnectedDrive Advanced Emergency Call function provides rescue helpers with detailed information on the type of collision and the risk of injury right from the start before they even arrive at the scene of an accident, thus allowing them to prepare adequate medical treatment of the victims in good time. Apart from the precise location of the car and information on the model involved (type of vehicle, colour, numberplate), the Advanced Emergency Call function provides vehicle data immediately after the collision, enabling the rescue algorithm to determine the severity of the accident, and with this information going directly to the BMW Call Center.

This is done by evaluating the data compiled by sensors in the car providing information on the type of collision and the occupants' risk of injury. The rescue helpers alarmed by the BMW Call Center therefore not only know precisely and in good time where the accident occurred and what vehicle was involved, but are also able, thanks to the Advanced Emergency Call, to assess the risk of injury, thus initiating rescue services not only quickly, but also in line with specific needs and requirements.

BMW ConnectedDrive also establishes a direct telephone connection to the car enabling the BMW Call Center as well as the rescue helpers to directly contact the injured occupants. The time saved and information obtained in this way may in an extreme case decide on life or death.



Automatic Emergency Call initiated by BMW ConnectedDrive

On average, the time which elapses in Germany between the first alarm and the arrival of rescue helpers at the scene of an accident is 10–15 minutes. Clearly, this requires an immediate rescue call with a precise description of the location and scene of the accident.

Precisely this is why BMW equipped its first cars with a manual and automatic emergency call function as early as in 1997 – and in the meantime more than 600,000 cars are equipped with this system developed in the context of BMW ConnectedDrive. The BMW Emergency Call Service has so far provided rapid assistance and support in far more than 25,000 cases. And this service also benefits third parties, since a BMW customer encountering an emergency may initiate the right rescue response via a manual emergency call when others are involved, immediately reaching the police, the fire brigade and the emergency medical service at the touch of one single button.