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Introduction.

The BMW Group's ConnectedDrive suite of technology already allows it to offer an array of unique and innovative functions which create an intelligent network of driver, vehicle and surroundings. These features enhance convenience, take infotainment into a new dimension and significantly increase safety in the BMW Group's vehicles.

The BMW Vision ConnectedDrive concept car, which showcases a clear vision of this extensive link-up of driver, vehicle and the outside world, represents the first time that engineers have given such a network a "face". The functions presented inside the car create a unique, safe and comfortable driving experience which provides the driver and passengers with personalised and individual entertainment and information at all times. Connectivity has become an integral part of the world in which our customers live – inside their cars, as well as outside.

To turn this vision into reality, engineers, IT experts and a host of other specialists at BMW are engaged in research and development projects aimed at exploring the potential of the cars of the future. Whether it is new functions helping route guidance technology to meet the driver's needs even more effectively, links to web servers, contact analogue displays for navigation or driver assistance purposes, or the development of vehicle functions through the integration of mobile devices with vehicle-specific apps, this vibrant field of innovation is constantly opening up new avenues when it comes to enhancing safety, convenience and infotainment.

As in the conception of the BMW Vision ConnectedDrive, the BMW Group's research projects also prioritise the driver and passengers along with their needs. Indeed, the development engineers are focusing intensively on the desires and requirements drivers have of their vehicles today and in the future. Individuality and personalisation are, after all, trends which extend well beyond cars.

As far as the link-up of the vehicle, driver and environment is concerned, we can expect much more to come. And with every step, the functions showcased in the BMW Vision ConnectedDrive concept car come a little bit closer to reality.

1. The seventh sense – more knowledge, better visibility and intelligent light functions enhance safety on the roads.

1.1 Dynamic Light Spot – targeted light beam for improved safety

The risk of a pedestrian being killed or injured in a traffic accident is four times as high at night or during twilight than in daylight. The same applies to the passengers themselves. Nighttime accidents – in particular serious accidents – are very often caused by the late recognition of persons or animals (e.g. deer) on the road. With BMW Night Vision, BMW has deployed a very effective assistance technology for driving in the dark under the umbrella of the BMW ConnectedDrive technologies. BMW Night Vision helps the driver by means of a thermal imaging camera for proactive, safe driving at night.
This support will be expanded by another BMW innovation for increasing the safety of night driving, in the form of the Dynamic Light Spot. Through targeted illumination of pedestrians on the road, the system ensures increased safety for all those involved, including the driver of the vehicle. By using BMW Dynamic Light Spot, the driver can usually avoid a collision or at least reduce its severity. The BMW Dynamic Light Spot is a so-called marker light. This system uses sensors to identify potentially endangered objects in the driver's surroundings which are then illuminated in a targeted manner with a light spot. At the same time, a strip of light projected onto the road in front of the vehicle leading to the possible collision object draws the driver's attention to that object. Thanks to early recognition of the pedestrian, the driver can either brake in time or take appropriate evasive action.

All cats are grey at night and visibility is very limited.
Conventional low-beam light allows drivers a theoretical range of vision of about 50 to 85 metres at night, which does not, however, mean that objects can be recognised at that distance. In tests, the recognisability of a darkly clad pedestrian in twilight was found to be just 29 metres. This is understandable, since at greater distances only the feet are illuminated. If the rule "drive so that you can stop within your visible range" were followed in the dark, it would not be advisable to drive even at 80 km/h since at this speed the braking distance is as much as 63 metres.

Night vision assistants are good, but in future things will be even better.
Today, night vision assistants such as BMW Night Vision are available. They provide the driver with an image of the area in front of the vehicle so that pedestrians and animals can be seen even from several hundred metres away. However, this presupposes that the driver uses the Night Vision screen like the rear view mirror and casts a glance at it from time to time. The technology works like this: BMW Night Vision uses an infrared camera with a viewing angle of 24 degrees which generates a thermal image that shows warm objects – people or animals – as bright shapes.

The marker light – targeted illumination helps to gain time.
Today, it is technically possible to identify the position of pedestrians very accurately. Once this position is known, a headlight can focus on that area and show directly where a potentially endangered pedestrian is. BMW calls this system Dynamic Light Spot. The major difference compared to other marker light assistants is that the BMW system projects a strip of light onto the road to

direct the attention of the driver to the hazard. The light automatically draws the attention of the driver to the possible collision object and thus triggers an intuitive and fast reaction.

See earlier, react sooner.
In general, it is assumed that a vehicle driver heads in the direction in which he is looking. This has been observed in vehicle safety training when, for example, the driver learns to take evasive action in a tight situation – he usually concentrates on the zone directly in front of the vehicle. So in vehicle safety training, when a collision is imminent, the driver is taught to focus on a free pathway – or "escape route" – away from the road so that this particular direction for evasive action is within the line of vision. With Dynamic Light Spot, things are different. When an illuminated object that is beyond the braking distance is made visible to the driver, he has sufficient time to use the brakes to stop before the obstacle is reached. At the same time, Dynamic Light Spot and the strip of light on the road are switched off as soon as the vehicle is close enough for the normal lights to continue to illuminate the object. What BMW's Dynamic Light Spot does is to indicate hazards to the driver from as far away as possible and direct his attention to them. The technical components of this system are essentially highly efficient sensors and headlight systems.

The sensor system recognises living creatures by their heat radiation.
To be able to warn the driver of a hazard in time, a recognition distance from the hazard of about 100 metres must be ensured, regardless of weather conditions. To achieve this, the light marking system must have a sufficiently perceptive sensor system. All currently available night vision systems based on near infrared require an input of 100W for illuminating the surroundings in front of the vehicle. This corresponds to additional CO_2 emissions of 3 g/km, which is not acceptable these days. The BMW Night Vision Assistant has a far greater recognition range and no additional light source is required. That is because BMW Night Vision is based on detection of the heat radiated by objects and is also less susceptible to the influence of the weather. BMW Night Vision guarantees positive recognition of persons at a distance of 97 metres on average.

Headlight systems: with LED arrays, the obstacle is in direct view.
If, as in the case of BMW Night Vision, the vehicle is fitted with a suitable sensor system to achieve recognition of persons at a sufficient distance, it must be complemented by appropriate headlight technology to enable the Dynamic Light Spot function. There is a wide range of technical possibilities available, from pixel light headlights and xenon, to swivelling modules and so-called LED arrays – all with particular advantages and disadvantages. At present, the light marking is achieved using a swivelling LED spotlight. This ensures that, with a low, short-burst energy requirement, a beam of light that is optimal for the driver is dynamically generated, and a pleasant light image is generated by the swivelling movement. In the case of BMW Dynamic Light Spot, these high-power LEDs are integrated in the installation space of the fog lamps so that the remaining vehicle lighting can be based on conventional technology; full-LED headlights are not a system requirement.

Dynamic Light Spot can significantly reduce accident figures.
BMW is planning to include the Dynamic Light Spot functionality as a part of the special BMW Night Vision option – a result of the BMW ConnectedDrive innovation philosophy for its future new models. The targeted gain in safety – for drivers and passengers as well as those who might be involved in a collision at night – has already been proved in the course of system development. During

BMW test drives in the development phase of Dynamic Light Spot, on average one object was highlighted and illuminated every hour.

1.2 Headlights of the future – laser light.

As a globally successful carmaker within the premium segment, the BMW Group attaches the utmost importance to advanced technology in all sectors of automotive manufacturing. Exclusive innovations and technological leaps secure BMW's lead amongst the competition. In the field of exterior vehicle lights, BMW also leads the way for example with full-LED headlights for the BMW 6 Series and with new developments such as the Anti-dazzle High-Beam Assistant, as well as with Dynamic Light Spot. The latter refers to a marker light system that automatically illuminates pedestrians in good time, thereby guiding the driver's attention to them.

After LED technology, laser light is the next logical step in car lighting development. BMW engineers are currently already working on the introduction of laser light as a further pioneering technology for series production within a few years. Laser light could then facilitate entirely new light functions for even more safety and comfort and at the same time contribute significantly through its higher degree of efficiency towards a saving in energy and fuel respectively.

Laser light produces virtually parallel light beams.
By definition, laser lighting is radically different from sunlight, and also from the various types of artificial lighting in common use today. For a start, laser lighting is monochromatic, which means that the light waves all have the same length. And it is also what is known as a "coherent" light source, which means that its waves have a constant phase difference. As a result, laser lighting can produce a near-parallel beam with an intensity a thousand times greater than that of conventional LEDs. In vehicle headlights, these characteristics can be used to implement entirely new functions. Also, the high inherent efficiency of laser lighting means that laser headlights have less than half the energy consumption of LED headlights. Simply put, laser headlights save fuel.

The intensity of laser light poses no possible risks to humans, animals or wildlife when used in car lighting. Amongst other things, this is because the light is not emitted directly, but is first converted into a form that is suitable for use in road traffic. The resulting light is very bright and white. It is also very pleasant to the eye and has a very low energy consumption.

Laser diodes are already in use today in the consumer sector.
Completely safe laser lighting technology is already in use in a variety of consumer products, though in many cases this is a product feature that goes unnoticed by the customer. That won't be the case when this technology is used in cars, however, as planned by BMW. Here the whole point is that the advantages should be noticeable and visible. A further feature of laser technology, which has important implications, is the size of the individual diodes. With a length of just ten microns (µm), laser diodes are one hundred times smaller even than the small, square-shaped cells used in conventional LED lighting, which have a side length of one millimetre. This opens up all sorts of new possibilities when integrating the light source into the vehicle. The BMW engineers have no plans to radically reduce the size of the headlights however, although that would be theoretically possible. Instead, the thinking is that the

headlights would retain their conventional surface area dimensions and so continue to play an important role in the styling of a BMW, while the size advantages could be used to reduce the depth of the headlight unit, and so open up new possibilities for headlight positioning and body styling.

A further advantage of laser lighting technology, and one which the BMW engineers intend to use to full effect, is its high inherent efficiency. A single statistic will make this clear: whereas LED lighting generates only around 100 lumens (a photometric unit of light output) per watt, laser lighting generates approximately 170 lumens. With statistics like this, it is not surprising that BMW is also planning to take advantage of laser lighting technology to increase the efficiency of the overall vehicle. And appropriately enough it is in a concept vehicle from the new BMW i sub-brand, the BMW i8 Concept, that laser lighting will get its first airing. After all, BMW i stands for a new premium concept that is strongly oriented towards sustainability.

Laser lighting: high efficiency and safety.
Safety is a key consideration in the development of laser lighting for use in passenger cars. For BMW, the complete eye safety of this technology for all road users and its complete reliability in day-to-day use have top priority. Importantly, therefore, before the light from the tiny laser diodes is emitted onto the road, the originally bluish laser light beam is first of all converted by means of a fluorescent phosphor material inside the headlight into a pure white light which is very bright and pleasant to the eye. As a result, in future it will be possible to use laser light to implement all the familiar – including more recent – BMW lighting functions such as Adaptive Headlights, the Dynamic Light Spot spotlighting system and the Anti-Dazzle High-Beam Assistant. It will also be possible to use BMW laser lighting to implement completely new functions, which will have only minimal power consumption.

1.3 Proactive Connectivity – more knowledge, greater safety.

What will you find around the next corner? Can you expect tailbacks at some point along the route? The more drivers know about the journey ahead of them, the better they and their vehicles can prepare for and react to upcoming situations. That's why the BMW Group development engineers have for some time been focusing on collecting information on the road ahead, and telling drivers what is happening a certain distance down the road. This helps to promote safety, and the information can be used for proactive driver assistance technology, navigation systems and energy management. Two ongoing BMW Group research projects with these aims in mind are entitled "Local Hazard Warning" and "Proactive Connectivity".

Local Hazard Warning.
The aim of local hazard warning is to alert the driver in good time to difficult-to-foresee dangers on the motorway, for example the end of a tailback around a corner, an accident or a narrowing of the road through moving roadworks. Local hazard warning technology flags up potential danger at an early stage with the aim of reducing its impact.

"A hazard I know about before I reach it is only half as dangerous, as I can prepare for it in advance." (Georg Obert, Project Manager Local Hazard Warning at BMW Group Traffic Management)

The BMW Group development engineers are currently testing initial scenarios for local hazard warning technology in Hesse, Germany. All mobile roadwork trailers sent out by the motorway authorities have been fitted with a transmitter which sends out their precise current location and other relevant information. The transmitter also tells the driver if a lane has been blocked, which lane it is, which lane the driver should move into as a result, and what the maximum permitted speed is through the roadworks. This data is sent via a backend server into the traffic managers' test vehicle – a current BMW 5 Series – where it is processed and prepared. The roadwork trailers are extremely well suited to conducting series of tests, as their GPS positioning and connection to a backend server make them clear reference positions against which to calibrate the vehicle system. They can therefore also supply the basic information required as and when the technology is extended to include other situations.

If the test car receives the information via a trailer on the road ahead, it alerts the driver to the danger at an early stage through the car's navigation system. At the same time, the system gives the driver firm indications on the maximum possible speed and on the likelihood of needing to change lanes. As the BMW Group development engineers are currently testing the system for accuracy and reliability, it is set up with the warning threshold at one kilometre before the incident. Scientific studies have shown this to be the optimum warning distance for when this technology is fitted in a vehicle further down the line.

Local hazard warning can be integrated in conjunction with the next generation of navigation systems. Their ability to process extremely accurate location information (to within five metres) allows the timing of the warning and location of the hazard to be determined and displayed extremely effectively. Further stages

of development could conceivably allow local hazard warning systems to be set according to the car's speed and that of the surrounding traffic, and calculations on tailbacks, for example, to be incorporated. Reliable auto recognition using Extended Floating Car Data already helps BMW vehicles to contribute to an improvement in traffic information. Indeed, in summer 2011 the BMW Group was able to put the fast-working and far-reaching traffic information service Real-Time Traffic Information (RTTI) into production. In the future, BMW vehicles will also be able to record data, which can help to generate local hazard warning alerts. And that will add to the effectiveness of RTTI.

Proactive Connectivity.
Another BMW Group Forschung und Technik GmbH research project, focusing on connectivity to enable proactive driving, sees the development engineers homing in on another specific area:

"With our Proactive Connectivity project we are aiming to look into the future and foresee what will happen down the road in two minutes' time." (Dr Ilse Kulp, Project Manager Proactive Connectivity at BMW Group Research and Technology)

The engineers' aim is to provide a reliable prediction on the speed and therefore flow of the traffic for the next two minutes along a given route. Depending on the driving scenario, this means casting an eye a few hundred metres down the road in the city or several kilometres on the motorway. The idea with calculating predictions of this kind is to keep drivers supplied with information on the traffic situation ahead at an early stage and combine this with recommendations on speed and route guidance to help them reach their destination safely and efficiently.

Several data sources deliver unbeatable reliability.
Proactive connectivity is based on simulation of the traffic on the same road over the next section of a car's journey. Using a number of different data sources ensures that the prediction is as reliable as possible from the outset. One of these sources is historical traffic data based on the observation of a predefined section of traffic over an extended timeframe. As such, it allows forecasts to be made as to the volume of traffic and its average speed at a particular time and in a particular place. This allows us to draw initial conclusions on the probable traffic density and therefore the likelihood of tailbacks, for example.

This is complemented by data from car-to-car and car-to-backend-to-car communications. Car-to-car communications enable direct communication between vehicles over a distance of up to 500 metres. This allows the driver's car to "see" what the vehicle ahead is "seeing", and therefore make a prediction on how quickly it will reach the position of the vehicle in front. This "forecast horizon" is further expanded – and to a significant degree – by car-to-backend-to-car communications, as the link to a server removes the need for a direct connection between vehicles. Important elements here include information on the number and speed of other vehicles in the vicinity. Complementing the spread of data used to create the traffic flow simulation is information from the driver's car, such as its current position and speed, a profile of its journey so far and the driver's destination.

An algorithm calculates the future.
Based on the intelligent fusion of this data, an algorithm calculates how the traffic will develop in the next two minutes. The algorithm uses this data to provide recommendations on how the driver should respond. These can take the form of

warning alerts, for example, or recommendations on the speed the driver should keep to in order to arrive at traffic lights when they are green. Another possibility would be an early warning that the traffic lights are about to turn red, allowing the driver to save fuel by coasting to a stop (while taking into account the expected queue of other vehicles waiting at the lights).

The major challenge in proactive driving lies in making the most accurate prediction possible of what will happen down the road – i.e. in distilling probable scenarios and reliable instructions from all the available data.

"We've collected a vast amount of data on actual conditions, such as the speed at which the vehicles ahead are moving, traffic light signal data and data from the driver's car. The task since has been to use it as the basis for a reliable prediction on how the traffic situation will develop over the next two minutes. At first that sounds a bit like gazing into a crystal ball." (Benno Schweiger, BMW Group Research and Technology team member working on the Proactive Connectivity algorithm)

The algorithm uses micro traffic flow simulation to enable the complex fusion of all this data into a reliable prediction. Here, the stretch of road ahead is recorded in one-dimensional form and all available data from the area – such as from vehicles, which transmit their position – is added. Plus, the algorithm uses historical data and the current speed of the driver's car to calculate an assumed traffic density, and fills the gaps between the vehicles randomly with virtual equivalents. The virtual vehicles in the simulation adjust their speed automatically to the speed of the vehicles around them, based on precalculated speed and distance models.

100 scenarios per second.
The algorithm runs this simulation approximately 100 times per second, with the distribution of vehicles on the road and the responses of their virtual drivers changing randomly each time. This produces 100 different variants per second of what might happen in the next two minutes on the road. From this wealth of possible scenarios and data on the frequency of particular incidents, reliable predictions are deduced on how the next two minutes will unfold in reality. The algorithm then sends the driver suitable warnings or indications if it detects that one or various scenarios are highly likely.

This prediction method allows not only traffic tailbacks but also the "movement" at the end of a tailback to be accurately predicted, as increases in the size of tailbacks are also included in the calculations. All of which means diversion recommendations are that much better, plus drivers can adjust their speed at an early stage to slow-moving traffic, and they know at what point down the road the traffic is starting to move again. BMW Group Research and Technology development engineers are currently working with colleagues from other departments to establish how much of a role future use cases based on the algorithm can play in connectivity-led proactive driving.

Vehicle or backend?
In the latest research prototype a large computer in the boot supplies the required processing power, but this could theoretically also be provided in the backend. For this reason the development engineers are currently exploring ways of both scaling and integrating the processing unit into the vehicle, and of transferring processing to the backend. The aim is to find the most effective solution going forward.

The special feature and therefore also the major advantage of connectivity-based proactive driving lies in the combination of underlying data. Car-to-car communications supply the driver with immediate updates on things happening close up ahead, while car-to-backend-to-car communications cover incidents further down the road. Here, historical traffic data form the basis for the calculations. In order to provide even more accurate predictions in the future, real-time traffic data such as RTTI, information from traffic lights, data from variable message signs and weather information should expand the reach of the data pool available for calculating traffic flow simulations.

2. The almost limitless possibilities of connectivity.

2.1 The wonderful world of apps.

With the introduction of MINI Connected in 2010, the BMW Group became the world's first carmaker to allow the application-based and extensive integration of the Apple iPhone into its models. Available as an option, MINI Connected links up with a simple USB connection and the MINI Connected App to turn the smartphone into a central interface for infotainment inside, and relating to every aspect of, the car. This technology has provided the launch pad for an all-new in-car infotainment experience. In spring 2011 this interface and app were also made available for BMW vehicles in the form of BMW Apps and BMW Connected. Added to which, the BMW Group has since expanded the app concept to include the internet-based services from BMW Online (available since 2001) and, this summer, also BMW Live. Other compatible apps – and therefore services – from third-party providers can also be integrated into the concept and used in BMW and MINI vehicles.

Scope for rapid and flexible expansion.
With the app concept – using either the application-based integration of a smartphone or a browser inside the vehicle – the BMW Group developers have created a highly flexible and still unrivalled platform. Indeed, the functional scope of the vehicle can be significantly broadened with the help of vehicle-specific apps certified by the BMW Group, enabling functions such as web radio, Google™ Local Search and Facebook™ to be used inside the vehicle safely and in convenience. But that is only the start. The app concept allows the range of functions to be expanded almost infinitely. Updating the app or installing another compatible app brings new functions into the car – without the need for any modifications to the car itself.

"For us, the whole issue of apps is about not only the individual functions inside the vehicle, such as web radio or Google, but also the avenues this opens up to us beyond them. This technology makes our vehicles fit for the future." (Florian Reuter, Product Management MINI Connected)

A current example of the constant expansion of the apps' functionality is the new calendar feature of BMW ConnectedDrive. An update for the app enables the actual calendar from the iPhone to be accessed in the car and the diary function of the smartphone to be linked up to the car's infotainment system. Drivers can now access their calendar on the central information display and even have entries read out to them.

Third-party apps from external providers.
In addition to the special functions it has created itself, the BMW Group is also using the technical capability provided by MINI Connected and BMW Apps as a platform for the integration of services from other providers. These "third-party apps" will allow a host of infotainment functions which customers already use at home to be transferred seamlessly to the car and operated by the driver. And that means they will have access to the services they want – such as personalised music streaming – at all times, whether they are on foot or travelling in the car.

"With third-party apps we're aiming to give customers the chance to select the provider they prefer, or at least one they are familiar with, for each specific application. In addition, when it comes to new functions through other apps we can, of course, also recommend a provider offering the service they are seeking." (Andreas Schwarzmeier, BMW ConnectedDrive)

By opening up this platform to apps from other providers, the BMW Group is underlining its leading position in both the integration of mobile devices into its cars and the introduction of internet-based in-car services. Development times are getting even shorter, and the selection of products wider and more customer-specific. And, most importantly, local requirements can be covered to optimum effect by a diverse structure underpinning the available services. In the USA, BMW Apps and MINI Connected customers can already use the popular and cost-free personalized internet radio service Pandora®.

"Our aim for the future is to take our cooperation with premium infotainment providers to the next level in order to give our customers in-car access to the services they already use at home." (Andreas Schwarzmeier)

Only apps which meet the requirements of the BMW Group for in-car use are certified and approved by the BMW Group for MINI Connected or BMW Apps. Development partners assist the BMW Group to this end with suitable guidelines, tools and car-related expertise.

Innovative functions, adapted to the brand.
The flexibility of the local interface is also evident in the brand-specific development of BMW Apps and MINI Connected. Both apps offer access to web radio and Facebook, for example, but MINI Connected also features driving and community-oriented functions such as the MINIMALISM Analyser and Mission Control. BMW Apps, meanwhile, serves the need for seamless functionality and ease of information access with functions such as the integration of the iPhone calendar.

"MINI drivers are different from BMW drivers. That's why it's important for us to be able to offer them a specially developed service – in the form of MINI Connected. This also applies to apps from third-party providers. Here we can work effectively with exciting external partners to give customers access to their services inside the MINI." (Florian Reuter)

The latest version of MINI Connected already offers up to ten different functions, but the developers at the BMW Group are also working on the integration of additional features. As well as the integration of streaming podcast services and virtual travel guides, foursquare® would enable the community area of MINI Connected to expand to include the link-up with location-based services and social networking. Customers can use foursquare to explore their surroundings or check out a nearby restaurant, for example, and to access any tips the community can offer. They can also see where their friends are hanging out.

"We have a local interface, which can be adapted along individual and customer-specific lines so that every customer – BMW or MINI – can access a set of functions which suit their personal requirements." (Uwe Higgen, Head of the BMW Group AppCenter in Munich)

Personalising applications in BMW Online.
From this summer, BMW ConnectedDrive customers have been able to widen their app experience beyond iPhone-based BMW Apps to include browser-based applications from BMW Online. Added to which, they can use their internet-compatible smartphone to access the latest applications from BMW via BMW Live. For example, BMW offers all customer groups and markets a constantly updated and configurable range of functions. To enable this browser-based functionality, the car needs to be specified with BMW ConnectedDrive and have an Internet connection – either via the integrated SIM card or the customer's mobile phone – to the backend servers on which the applications are running. The applications can then be selected from the menu of the on-board system via BMW Online or BMW Live and accessed immediately. In this way, the BMW ConnectedDrive package offers comfortable access to the desired applications, in the style you would expect from BMW.

"With BMW Online and BMW Live, MINI Connected and BMW Apps, we are offering a range of technically contrasting but complementary solutions which appeal to different customer groups. Keeping both smartphone and backend applications separate from overall car development will allow our models to stay at the leading edge of technology over a period of years." (Uwe Higgen)

My BMW Remote app goes Android.
The BMW Group doesn't only offer solutions for the integration of Apple smartphones; in the future, smartphones based on the Android operating system should also be able to use the BMW and MINI apps. The first step along this road is the Android version of the My BMW Remote app, which controls the same remote functions as its iPhone counterpart. In addition to opening and closing the car, the driver can also use the Climate Control function to access the car's climate control system and activate its auxiliary ventilation or heating. Added to which, the driver can use the Flash Light or Horn Blow functions to gain a visible or audible reminder of their car's location (not available in all markets). If the car is out of sight and earshot, it can still be located by the Vehicle Finder function within a radius of up to 1,500 metres. A map then guides the driver to the car. Google Local Search rounds off the portfolio of functions. Here, customers can use the Google search function or the smartphone's address book to send relevant Points of Interest (POIs) to the car's navigation system. The e-mobility-specific remote functions of the BMW ActiveE, such as battery charging from outside the car, will also be available for Android phones, as will the upgrade for the My BMW Remote app – slated for introduction in autumn 2011 – which adds the Real-Time Traffic Information (RTTI) function.

Android is currently the fastest-growing software platform for smartphones and tablets. As open-source software, it can be adapted to and used on a wide range of devices from different manufacturers. It is here that the challenge lies for the BMW Group developers. Different resolutions, not to mention the technical requirements and particular characteristics of the different devices, have to be taken into account in the development process. And that means the testing phase for Android phones is far more extensive and time-consuming than for apps for the iPhone, which only comes in two variants. Adapting the graphics as required is also a complex business. Android places different demands on the user interface and operating architecture. To this end, the user interface has to be adapted to the look and feel of Android phones, without making too many changes to the familiar and well thought-out appearance of the app. Here, the design of the Android user interface has already incorporated feedback from existing My BMW Remote app users and allows it to integrate new functions even more easily.

BMW AppCenters. Ideas factories for the future.
The importance the BMW Group is attaching to the area of apps is also reflected in its decision to expand development capacity in this area. The three AppCenters in Munich, Mountain View (California) and Shanghai are working together on the research and development of groundbreaking new applications for smartphones and browser-based technologies. With these three locations linked up closely together, the BMW Group is responding extremely effectively to different customer requirements and the desire for a local range of apps.

The close proximity of the AppCenter in Mountain View to Silicon Valley allows far-reaching insights into and exciting link-ups with highly innovative and creative start-ups, while the AppCenter in Shanghai incorporates the needs of the Asian market into the development process. Working together with the Munich-based AppCenter, they allow the BMW Group to ensure that development keeps pace with the times. The three AppCenters operate as a network, underpinned by identical platforms, technologies and software components. And short development times of between two and 12 months allow a rapid turnaround of high-quality market and brand-specific solutions. The developers are currently focusing primarily on apps for community development, car-related functions, infotainment and location-based services. However, these focal points can be varied and extended to respond to differing brand requirements and objectives. After all, the BMW Group experts are expecting busy times ahead in this area.

Leadership stretching back years.
The BMW Group already has something of a tradition when it comes to taking the lead as an innovator in the integration of CE devices. In 2004 the BMW Group became the world's first carmaker to allow the Apple iPod to be integrated into the audio system of its models. Indeed, the BMW Group exclusively unveiled the first technology solution for the integration of the iPhone into the infotainment system of its cars just in time for the device's launch in 2007. Also, since March 2011 the iPod Out function has allowed the familiar Apple iPod interface to be displayed in the car's on-board monitor and operated via the iDrive Controller or multifunction steering wheel. Since the vehicle can thus access the iPod function of the iPhone directly, BMW also offers customers all the native add-ons for the iPod, such as the Genius function, which searches the user's music library and automatically compiles playlists of tracks that go well together.

2.2 Infotainment Assistant – your personal range of multimedia.

The continuing growth in the number of integration options offered by BMW ConnectedDrive has been accompanied by an increase in the scope of personalised infotainment available to customers. Indeed, vehicles can already be specified with a wealth of information and entertainment technology. Familiar functions such as FM, DAB+ and satellite radio, local infotainment servers, USB, iPod and iPhone integration, MP3 players and mobile phones have been joined by new BMW ConnectedDrive services such as office functions with email access and calendars, and new media like Facebook, Twitter and podcasts. Each of these sources contains information which may be of interest to customers. Yet all this content has to be selected according to source; in other words, drivers not only have to decide what they want to listen to, but also know where to find it. Intelligent search functions and intuitive control systems, such as the voice operation function available from BMW ConnectedDrive for the user's music collection, can make source-based searches significantly easier. However, the Infotainment Assistant – a new BMW Group research project already tested in a vehicle prototype – goes a step further. This intelligent system overcomes the barriers of source identification and opens the door to personalised infotainment on a whole new level.

"Our aim with the Infotainment Assistant is to look at all the information and entertainment options available to customers inside the vehicle, filter out content which might be relevant and interesting to them, and present it to them without them having to lift a finger." (Thomas Helbig, Project Manager Online Entertainment)

The Infotainment Assistant plays the role of personal butler to the driver during a journey, proffering suggestions on entertaining or informative content. The suggestions are geared towards the driver's preferences and the driving situation at hand, ensuring that the range of options always hits the mark.

To this end, the Infotainment Assistant compiles an all-round infotainment portfolio of office, news and personalised music content. To do this the current prototype accesses podcasts, an email service, a calendar service, a music community and a music provider. It uses these sources to select and suggest content tailored to the situation and the user. For example, the Infotainment Assistant detects if the driver is running late for a meeting by checking the next appointment entry in the calendar and the time and destination entered into the route guidance function of the navigation system. The new technology can then compose an email informing the other people due to attend the meeting that the driver has been delayed. Equally, if the meeting is put back the assistance system updates the driver on the time he now has in hand.

The different content is presented as if by a personalised radio station, with important emails, calendar entries or favourite songs from friends in the community incorporated dynamically. Text-based content, such as emails, calendar entries or information from communities such as Twitter, is read out through the speakers via the Text to Speech function in order to distract the driver as little as possible from the task of driving.

The assistance system recommends, the driver decides.
As well as using audio output, the prototype also presents the various content in visual form in the central information display. Here, drivers can view the current selection and content presented previously, and this is also where the Infotainment Assistant flashes up its next suggestion. This personalised "infotainment horizon" can be altered at any time. For example, the driver can skip to the next item, actively reject one of the assistance system's suggestions or miss out several items and go straight to something of particular interest, such as new emails. In the same way, drivers can also state their wish to stay with the current content and only listen to music, for example, from now on. The Infotainment Assistant registers each of these active interventions and refines its selection of content for the future; every entry from the driver adds to the system's knowledge base. In order to make content as easy as possible to identify, it is presented to the driver – in Cover Flow-style – using icons through which the driver can navigate.

Drivers may also like to enter some core preferences before they use the system for the first time so the Infotainment Assistant has one or two pointers on which to base its recommendations. The aim here is to use a small number of details to prompt the system into drawing as many conclusions as possible on habits and wishes. The more the system is used, the more accurate the personalisation.

"It is important to us that the Infotainment Assistant presents the customers with a personal and well-chosen range of content. Drivers can choose to hand over compilation of their entertainment programme to the assistance system entirely. But if they intervene to make a choice, the assistance system automatically registers their selections." (Dr Wolfgang Haberl, Project Manager Future In-car Entertainment at BMW Group Research and Technology)

News in the morning, music in the evening.
The Infotainment Assistant also allows suggestions to be adapted to suit the situation. On the way to work, for example, drivers may like to set the system to prioritise incoming emails and news, with the odd musical interlude in between. In other circumstances, however, they might prefer to listen to music and nothing else, or only to sports news. Users can compile these profiles themselves and tweak them according to the services available.

The aim of the Infotainment Assistant is to entertain and inform drivers as effectively as possible – according to their preferences – during their journey, regardless of the source from which the information and content have been taken. In so doing, the system offers personalised, straightforward and fast access to content, and ensures it never stops learning.

2.3 Network of the future: functionality with LTE over-the-air high-speed internet.

Internet streaming of music or videos over the air from a mobile phone network to a CE device has been a reality for some time. However, the bandwidth of the current UMTS (3G) wireless standard is limited, and the streaming quality is not always optimal. The videos are transmitted in low resolution, and inadequate network coverage in some areas can cause problems with video and audio stuttering or dropouts.

These problems will soon be a thing of the past with the arrival of the new LTE (Long-Term Evolution) standard. LTE, also known as 4G, is a fourth-generation wireless standard and the next major technology standard after GSM (2G) and UMTS/HSPA (3G).

High bit rates, low latency.
The main highlight of LTE is that it combines extremely high bandwidth with very low latency. Whereas UMTS/HSPA can currently achieve theoretical downlink speeds of up to 14 Mbit/s, LTE is around ten times faster. With peak downlink speeds of 150 Mbit/s and latency in the tens of milliseconds, the mobile internet experience provided by LTE is on a par with, or may even surpass, the kind of quality previously confined to home computers with a landline connection. Uplink speeds for this standard will be in the order of 50 Mbit/s. The higher bit rates are achieved by using state-of-the-art modulation and coding methods and multiple antenna technology.

Low latency is a key factor for ensuring high-quality, delay-free operation. Latency is amongst other things a measure of the speed with which the network processes inputs. The extremely low latency offered by LTE is an important enabler for new functions in the car which are supported not by onboard processing power but by backend servers. The combination of low delay times (thanks to the high transfer speeds) and high backend computing power also brings data-intensive cloud applications ever closer. The delegating of processing-power-intensive operations to high-performance backend servers so that the necessary computing power does not have to be available on board the vehicle also reduces space requirements and therefore offers scope for reducing vehicle weight and energy consumption.

LTE also provides better area coverage than previous mobile phone networks, since it can operate not only in the high-frequency 2.6 GHz range but also at low frequencies in the 800 MHz range which have better physical propagation characteristics. The high bandwidth is therefore also available when travelling at high speeds. So LTE can continue to offer high-speed internet access even on motorways and main roads.

Another feature of LTE is the possibility of prioritising specific data packets. For example, the new backend configuration makes it possible to give highest priority to services which must not be interrupted, in order to increase the probability of continuous transmission. This would have particular advantages for safety-related functions.

Efficient use of air interface.
One reason for LTE's high transfer speeds is its high spectral efficiency. Spectral efficiency is the number of bits that can be transmitted per second per Hertz of bandwidth. LTE currently offers a peak spectral efficiency of 16, compared with just 0.2 for GSM. This means LTE offers 80 times more bandwidth.

"LTE makes much better use of the air interface. Over-the-air data traffic can be managed far more efficiently with this technology." (Dr Michael Schraut, Head of the Information and Communication Team, BMW Group Research and Technology)

Another first for LTE is the use of multiple antenna systems, that is to say two physically separate transmitting (and two receiving) antennas operate on the same frequency at the same time. The different streams can be identified by their different signal paths. Known as MIMO (Multiple-Input Multiple-Output), this principle provides the high reception performance necessary to support high bit rates. In the research prototype developed by BMW Group Research and Technology, the LTE antennas are integrated in the typical BMW roof fin.

LTE in the car.
The big challenge when it comes to in-car LTE application is to ensure that LTE's advantages of faster transfer speeds, combined with sufficient bandwidth and spectral efficiency, continue to be maintained while the vehicle is on the move. Peak bit rates will not be available at every point on the route and there may be wide variations depending on factors such as the position of the vehicle in relation to the stationary transmitter, or line-of-sight conditions. The on-board reception systems must be designed to compensate for signal fluctuation in the moving vehicle and also for Doppler shifts.

BMW Group Research and Technology is therefore conducting intensive research, in parallel with extensive live testing, to evaluate the performance of LTE in in-car applications. The live tests are being carried out in urban conditions in Munich and in the surrounding rural area. The focus is on evaluating parameters such as transmission characteristics, latency times and transfer speeds under real-world conditions. Initial promising results show peak download speeds of up to 70 Mbit/s, with average speeds of 23 Mbit/s in town. Overall, the tests show significantly improved area coverage combined with the improvement in bit rates.

"LTE will ensure continued delivery of a perfect in-car BMW ConnectedDrive experience. It will also allow us to provide new, innovative functions." (Michael Schraut)

The services already offered by BMW ConnectedDrive can benefit greatly from the improved speed, performance and area coverage offered by LTE. Server-based services such as video or music streaming to the car will become more attractive thanks to the high bandwidth and low latency offered by LTE.
BMW Group Research and Technology is also investigating other application scenarios – for example outsourcing of traffic sign recognition to backend servers. The front-mounted camera would scan the signs and stream the information via LTE to the backend server. There an algorithm would identify the signs – including new, unfamiliar ones – and send back the relevant information to the vehicle. This would provide a simple and convenient way of keeping this driver assistance system state-of-the-art and abreast of new traffic signs throughout the life cycle of the vehicle.

When will LTE be here?

That question is quickly answered: LTE is here already. It is now available in 20 countries via 29 commercial networks. In the USA, the first LTE-capable smartphones are already on the market and some operators both in the USA and in Germany are predicting that LTE will be as big as the current UMTS network as early as 2013. The better area coverage means the high bandwidth will also be available when travelling on motorways and main roads. As soon as these goals in terms of availability and area coverage are realised, the BMW Group will be excellently positioned to take its in-car BMW ConnectedDrive services to a new level.

3. Enhanced convenience with innovative control and display technology plus intelligent navigation.

3.1 Augmented Reality – new dimensions in driver assistance and navigation with the contact analogue Head-Up Display.

In 2004, the BMW Group was the first automotive manufacturer to bring out a colour Head-Up Display which projected driving-related information directly in the driver's line of sight. In early 2011 the latest generation of this system was introduced, featuring full-colour graphics. But already the BMW researchers and developers are working on a new milestone in this technology which will see the Head-Up Display acquiring "contact analogue" functionality. This is a technique whereby virtual "markings" are superimposed on real objects in the external environment, so that navigation information or information from the driver assistance systems can be displayed at exactly the right points on the driver's view of the road scene. Navigation instructions can be blended into the road, and vehicles or safety-relevant objects can be highlighted or marked in context.

What exactly is augmented reality, or a contact analogue display system?
The Head-Up Display was the first step towards in-car implementation of augmented reality. The HUD augments the external scene with additional information and artificially generated objects which react to and adapt to the situation in real time. The Head-Up Display presents useful information such as current speed and navigation information directly in the driver's line of sight, but the technology has much greater potential than that: its applications can be greatly expanded by the use of contact analogue display technology.

Contact analogue displays are a special form of augmented reality. The displayed information is integrated into the external environment in the correct perspective and at the actual point or points in the scene to which it relates, so that effectively the information appears to be "attached" to the external objects. Contact analogue displays have many advantages. The fact that the information is presented in the driver's direct line of sight, and that it is overlaid on the objects it is referring to, means that the driver does not have to shift his attention away from the driving scene. His gaze is not distracted and he does not have to change focus, as he does when looking back from an instrument cluster or central information display to the road. This means that information relevant to the driving situation can be scanned more quickly and more directly. At the same time, currently required actions can be displayed in an intuitive form.

"With the contact analogue HUD, we place the information at exactly that point in the driver's field of view where it belongs and is required. The driver no longer has to correlate abstract information to the concrete driving situation. Since the display is directly congruent with the real world, we can also selectively direct the driver's attention to specific information or hazards, so that he can respond quickly and in an appropriate manner." (Dr Bernhard Niedermaier, Head of Human-Machine Interaction at BMW Group Research and Technology)

Contact analogue displays are already a reality.
Ideally, contact analogue displays would make use of the driver's entire field of vision. From the technical point of view, however, this is not yet possible. Nevertheless, contact analogue display functionality can already be implemented even within considerably smaller display areas, with significant benefits for the customer. Two application scenarios are described below which illustrate the wide-ranging possibilities offered by contact analogue displays.

Contact analogue navigation.
The first scenario shows the possibilities of contact analogue display applications in the field of in-car navigation. Whenever a navigation manoeuvre needs to be performed, such as turning at an intersection, the system presents the information in such a way that it appears to blend with the road itself. The driver can keep his eye on the road throughout, and intuitively drives in the right direction.

"Turning manoeuvres and lane recommendations are shown in such a way that they appear to be directly mapped onto the road. Drivers no longer have to correlate the abstract image from a map to the road in front of them. Instead, the task is delegated to the contact analogue Head-Up Display." (Robert Hein, Head of Navigation and Data Services of the Future at BMW Group Research and Technology).

Since the driver is better informed, he is able to drive more proactively and also more confidently. The spatial congruence between the displays and the road makes it easier for the driver to absorb information even in complex driving situations. In one of the first contact analogue systems developed by the BMW Group, the Head-Up Display is approximately four times the size of typical HUDs used in current production vehicles. With such a display, it is already possible to present contact analogue information in the vehicle's own traffic lane. In an upcoming version, the display area will be further enlarged to include neighbouring lanes as well.

Contact analogue navigation works like this: the navigation system calculates the optimal route based on digital road map information. If lane-level information is available, the route is further refined and the necessary lane manoeuvres are computed. Positioning information continuously supplied by GPS and vehicle sensor systems allows the vehicle to detect the lane it is currently travelling in and compare it with the optimal lane for the given route. If the vehicle is not in the correct lane for an upcoming manoeuvre, the system computes a 3D model of the road situation ahead using the signals from the camera system, and superimposes the instructions congruently on the external scene.

Application in driver assistance systems.
A second application scenario for contact analogue displays is in the field of driver assistance systems. Here the contact analogue functionality provides the driver with a better understanding of what is going on around him and makes it easier to absorb highly specific instructions. For example if the driver activates Active Cruise Control with collision warning, the system not only shows the driver – in the real-world environment – which vehicle is currently serving as the "lead vehicle", it also shows the preset following distance, superimposed directly onto the road surface. Instructions to the driver to intervene are therefore more easily and more quickly understandable. Other information that could potentially be "projected" in this way includes lane boundaries, lane departure warnings, nighttime highlighting of pedestrians not readily visible to the driver, and even

recommendations for evasive manoeuvres into other lanes, complete with marked-out paths.

Outlook and technical challenges.
The bigger the display area, the more applications contact analogue display technologies can offer. Looking further ahead, the developers are therefore already aiming to increase the size of the displays as much as possible. In the first prototypes, they have already been successful in presenting contact analogue information for the vehicle's own lane, using an area just four times bigger than that of current head-up displays. In a test environment, they have also already implemented wider display areas, capable of presenting information for a number of lanes. A further consideration when integrating driving-related and location-based information into the external scene is that the virtual images need to be projected at a considerably greater apparent distance from the driver than the 2.20 metres most appropriate for current HUDs. Also, the display area must be moved further up towards the horizon, so that the displays are positioned over the driving situation. One of the main challenges the developers face now is to free up the necessary space and to develop the requisite technological solutions for head-up displays of this kind.

"The issue now is to develop new technological solutions for these large projection areas and to integrate them into the vehicle." (Gunnar Franz, Head of Head-Up Display Development)

Another challenge as far as contact analogue displays are concerned is to ensure precise matching between the virtual and real worlds. If the projected imagery and the external situation are not in sync, this supplementary information can quickly distract or confuse the driver. The developers are therefore using intelligent sensor fusion methods to ensure good matching and a high-quality display experience. To create the impression of convergence between reality and the displays, the system uses the vehicle's high-performance environment-recognition and sensing technology such as GPS systems, the front camera and the Active Cruise Control radar, further supplemented by advanced digital road map data including lane-level information. All this data is used to compute and display contact analogue information.

The developers see the contact analogue Head-Up Display as the key to a new dimension in display technology. The two application scenarios described above, in navigation and driver assistance systems, are just the first stages in this process. Other potential scenarios are illustrated by the BMW Vision ConnectedDrive concept car, which features contact analogue representation of numerous different types of information.

Testing in the driving simulator.
Initial testing of new display systems, like the contact analogue Head-Up Display, is carried out mainly in the BMW Group driving simulators. Driving simulator testing is more cost-efficient, and modifications can be made more quickly, than using real vehicle prototypes. Different versions can be quickly implemented and tested under identical conditions, within a short time scale and with large numbers of pilot users – without the hazards of road testing. These are particularly important considerations in view of the amount of verification testing required when developing pioneering new display concepts like the contact analogue Head-Up Display.

The BMW Group driving simulators are an optimal tool for highly realistic testing of complex display processes. Up to seven full-HD projectors provide a high-

resolution, sharply focused simulation of the driving environment. This is particularly important for detecting and classifying more distant objects and for identifying the direction of the road. The special projectors also provide highly realistic simulation of moving objects. Fluent and sharp imagery is of great importance when simulating urban driving scenes, where large numbers of objects are represented in great detail, in order to ensure that pilot users have a sound basis for judging driving manoeuvres.

The high-performance projectors jointly generate a 240-degree horizontal and a 45-degree vertical field of view around the driver. The projection of driving scenes onto wall screens alongside the car allows intersections and complex turning manoeuvres to be optimally simulated – and optimally assessed. Drivers know exactly where they are in the real-world environment and can therefore perform precise turning manoeuvres just as they would in reality.

As a tool for testing and evaluating new systems, over the past years the BMW Group has developed and refined a simulator-based reproduction of a complex city driving environment. The results of this work are unique, both in form and in quality. It demands a lot of processing power, of course. For example, an image refresh rate of 60 Hertz – i.e. the traffic scenario is updated 60 times per second – is needed to ensure fluent simulation of heavy traffic volumes. The complex intersections and road network in this simulated city environment now provide an ideal basis for testing lane-level navigation and contact analogue displays.

“The closer our simulation comes to reality, the more meaningful the results. These results are very valuable for developing navigation systems, driver assistance systems and control and display systems.” (Martin Strobl, Head of Driving Simulation at BMW Group Research and Technology)

Needless to say, when evaluating their display concepts the BMW Group development team doesn’t only rely on the highly promising results of simulator testing but also carries out road testing with real prototypes. Results obtained in the simulator are applied to the vehicle, where they undergo further refinement. Both types of testing are indispensable for reliable and robust evaluation of control and display systems.

3.2 Gesture recognition – in-car control with simple hand movements.

Gesture recognition – point your finger and the car will obey.
Many electronic devices already make use of gesture recognition as a simple, fast and above all intuitive method of user operation. Whether using finger gestures on a smartphone or to play computer games on the TV at home – gesture recognition is playing an ever more important role in human-machine interaction. And now the BMW research teams are looking at ways in which this technology can be applied to cars as well.

"Gesture recognition creates a whole new user experience. It offers drivers a novel and much more 'emotional' way of controlling vehicle systems. Gesture control is inherently fascinating and can make the act of controlling in-car systems enjoyable in itself." (Dr. Verena Broy, Control and Display System Concept Development)

The idea is nothing new in itself. But so far, there has always been a problem guaranteeing that gestures will be correctly interpreted. One problem is the whole issue of so-called "false positives", that is to say the risk of the system incorrectly interpreting a non-gesture as a command.

Accent on the user experience.
Particularly in the field of home entertainment, however, gesture recognition technology has now evolved to a high level of maturity. The BMW researchers are taking such existing commercially available technology as an empirical starting point for their work on gesture recognition in automotive applications. This relatively new research project will focus on gesture control in the car, with reference also to the user experience. Of particular interest is the question how and in what applications gesture recognition is a practical and intuitive option, and also where this interaction technique has its limits. The findings will shed light on the potential and preconditions for use of in-car gesture control. The next step will be the translation of validated results into concrete in-car technical systems.

Gesture recognition in the car.
Use of gesture recognition in the car is subject to various restrictions, since it has to take into account a number of requirements which are less important in the field of home entertainment or smartphones. In the vehicle environment, gestures must be short, concise and unambiguous. Performing them must not cause more than brief distraction and must not negatively impact the driving task in any way. In short, gesture control in the car must meet the same high standards in terms of interruptibility, non-distraction and straightforwardness as any other control system used to operate infotainment functions in premium vehicles of the BMW Group.

A further consideration when it comes to selecting what gestures are suitable for use as commands is cultural differences regarding the significance of different gestures. The gesture "vocabulary" will therefore initially be restricted mainly to gestures in which the operator performs a directional movement.

Less is more.
The research project is currently working on six different gestures whose point of reference is the current screen content in the central information display. These gestures comprise swiping the hand to the right or left, or up or down, or moving the hand towards or away from the instrument panel.

The focus is on simple gestures. For example, the hand can be moved to the left or right to switch the split screen on or off. It can be moved up or down to scroll through the screen content. And it can be moved towards the screen to cause the display to return to the main menu.

A further aim of the research work is to rule out the risk of incorrect inputs, so that typical movements such as operation of the gear lever are correctly recognised and not misinterpreted as a command gesture.

Not a substitute but a useful complement.
Gesture recognition is in no way intended as a substitute for the iDrive Controller. Rather, it is intended as a way of complementing and facilitating use of that interface wherever helpful. Also, gesture recognition will not be used to control functions which are relevant either to the driving task or to safety, such as starting the engine or releasing the parking brake. The main focus is on providing a fast and simple way of operating infotainment and convenience functions.

"With gesture recognition, we are not aiming to support full menu navigation. Rather, we want to offer drivers the satisfaction and thrill of making something happen with no more than a brief hand movement." (Verena Broy)

3.3 Intelligent navigation: how will we get from A to B in 2015?

Intelligent route planning – i.e. planning a route to a given destination taking into account criteria such as speed, fuel-efficiency or intermodality – has been a development focus at the BMW Group for many years. Such technology has already reached a high standard in the latest navigation systems, with the integration of functions such as BMW Routes and Real-Time Traffic Information (RTTI). In the latest R&D projects, further innovative and useful functions are being developed with the aim of facilitating or improving various aspects of the navigation process. The imaginary scenario below accompanies you through a hypothetical working day, presenting some of the systems that are already reality or are likely to be coming soon.

From A to B with future BMW ConnectedDrive functions.
8.00 hrs: It's Monday morning and you're preparing for your regular commute to work. However, this time you have decided to depart a little earlier than usual. That's because an hour before you would normally leave the house, you got an email on your smartphone from the BMW Routes portal advising you that to get to work on time you would need to set off 20 minutes early. The reason is congestion on the motorway, which there is no way of avoiding.

The right departure time, thanks to BMW Routes (incorporating RTTI).
You got this message – an exclusive service for BMW ConnectedDrive customers – because you had already pre-planned your commute to the office in the www.bmw-routes.com online portal and saved it, together with your desired time of arrival, as your standard route for Mondays to Fridays. Having been entered in the portal, the route is also accessible on board the vehicle, where it can be imported straight into the navigation system. Available since 2008, the BMW Routes portal now also incorporates RTTI.

Use of real-time traffic information allows the navigation system to calculate routes and possible diversions even more accurately and reliably than before. Amongst other things, RTTI uses anonymous mobile phone location data, analysing the number and speed of location changes within the mobile phone network to gain an accurate picture of current traffic flows. Further real-time data providing information about current traffic jams and congestion is also supplied by fleet vehicles and taxis whose navigation systems are linked to a central control point. In this way RTTI can precisely monitor conditions on motorways, dual carriageways, main roads, and main and secondary roads in urban areas.

Taking all this data into account, the BMW Online internet route planner calculates the journey time for your route. If the estimated time of arrival would be later than your desired arrival time, due to traffic conditions, the function can optionally send you an email anything up to an hour before your planned departure recommending you set off earlier in order to arrive on time. In other words, as well as using the RTTI function in the vehicle, BMW ConnectedDrive subscribers can now also visit the portal from any internet-capable device to check RTTI information about the latest traffic situation. This on-line access to RTTI will from autumn 2011 also be available for smartphones equipped with the My BMW Remote App.

In future, it is planned to further enhance the route planner function using traffic predictions based on historic traffic data which has a high probability of recurrence. In addition, the alert function described above could potentially be extended to include text messaging or a push notification from an app. These developments represent an important first step towards outsourcing the job of route calculation from the vehicle to a backend server, where much more processing power and information is available, the results simply being passed back to the vehicle when generated. The effect would be a further improvement in navigation quality.

Urban navigation.
8.30 hrs: You encounter the predicted congestion on the motorway. But thanks to the tip-off, you still have time in hand. You take your usual exit, but as soon as you are off the motorway the navigation system recommends you take a different route from normal. One of the main traffic routes is closed due to an event due to take place in a few hours' time. Your navigation system was forewarned because it has access to local authority traffic management data. It was therefore able to calculate an appropriate alternative route involving minimal loss of time. When calculating this new route, the system also took into account traffic light phasing so that you are automatically given a route that will make the most of "green waves". By taking into account such local authority traffic management and traffic planning data, this future routing option, which is known as "urban navigation", is able to recommend an urban route on which the traffic is most likely to be free-flowing – which also means a more eco-friendly journey.

Finding parking places without the search.
9.00 hrs: You are nearing the end of your journey and, as ever, your vehicle informs you about parking availability in the vicinity of your destination. Today it recommends parking on the street parallel to your office. This is where you are currently most likely to find a vacant, free-of-charge parking space.

Today's systems already show the location of parking garages and other designated parking space. And soon it will also be possible to show how much parking is currently available at specific car parks, so that alternative options can be recommended. However, particularly in large urban areas, a lot of parking is also available at the roadside, and many drivers prefer this option to multistorey car parks. In our imaginary scenario, you too belong in this group.

As soon as you approach your destination, your navigation system helps you find a parking space quickly and in the immediate vicinity of your destination. It not only tells you about nearby car parks but also shows you roads where you are most likely find a vacant roadside parking space. The choice is then up to you. The BMW Group is collaborating with a variety of partners such as local authorities and operators of parking ticket machines to obtain data about parking-related traffic and parking habits and to aggregate this data over time. This information can be used to identify streets with a high parking turnover, i.e. shorter average parking times, and therefore to predict where drivers are most likely to find a parking space. Internal BMW studies show that as much as 80 per cent of the traffic volume in certain areas at certain times can be due to parking searches. The information services described above allow drivers to find parking much more quickly, thereby not only saving them time but also reducing traffic volumes.

Another solution aimed at making more efficient use of parking space is "ParkatmyHouse", which makes temporarily unused parking space available for use by the general public. ParkatmyHouse is an internet platform which allows

private individuals to rent out their unused parking space. This idea has all sorts of interesting applications, particularly in urban areas. For example, ParkatmyHouse provides a way for banks to rent out parking space they don't need at night, or for hotels to rent out parking space which would otherwise stand empty during the daytime.

Dynamic navigation.
16.00 hrs: You're now on your way home from work and have just joined the motorway. The Real-Time Traffic Information service, which continuously monitors current problems on your route, soon gives you a local hazard warning about roadworks three kilometres ahead. The right-hand lane is closed and an 80 km/h speed restriction is in force on this section, but there are currently no hold-ups. Thanks to the warning, you are able to adjust your speed and move over to the left-hand lane in good time.

Fuel Assistant.
16.30 hrs: On the last part of the journey, the vehicle suggests you take the opportunity to stop off at a filling station which has lowered its prices for the day. The Fuel Assistant has reviewed the various possibilities for refuelling along the route, taking into account the current fuel tank level, your route, your end destination and your preferred fuel brand, and made a recommendation based on present prices and filling station location.

16.45 hrs: While stopped at the filling station, you see a poster for a concert this evening which you would like to go to. You make a call to BMW Assist to book the tickets. BMW Assist sends you the address of the advance booking office and sets it as a stopover on your route. You stop off to pick up the tickets and drive home, feeling glad that now you won't have to queue for tickets this evening.

Mobility Packages.
19.00 hrs: To get from your home to the concert, your BMW Connected App recommends that you use local public transport. Since you have bought a BMW Group Mobility Package, you can make the journey free of charge. These packages will, in future, provide the ultimate in flexible mobility. When you signed the leasing agreement on your BMW, the mileage allowance did not refer specifically to vehicle mileage but to personal mobility in general – because BMW has got together with transport operators to allow you to use local public transport at no charge.

Before starting out, you use your app to check when the next convenient train will be departing and how long it will take you to get to the station. When you arrive there, you won't have to queue for a ticket or worry about complicated fare systems because you've already got your ticket to hand – on your smartphone. All you need to do is log in using your smartphone when you get on the train and log out again when you get off. The journey will then be automatically docked from your mileage allowance. The same thing happens if, on the return journey, you decide to use a car-sharing vehicle after leaving the train because it has started to rain. In other words, the mobility package is integrated, convenient and intermodal – and leaves it up to you to decide how to travel.

Some of these ideas are still some way off – like the mobility package or the roadside parking tips. But others, like ParkatmyHouse, RTTI or advance warning of delays on a planned route, are already a reality in BMW vehicles today.

4. Man, the measure of all things.

What will customers of the future want from a car? What will they need? In order to find the answers to these questions and to develop from them new ideas and innovations for the customers of tomorrow requires more than specialists in market and trend research. In specific areas of development, where the results directly impact on human beings, the BMW Group experts need to get to know their customers better. That is why, for example, the BMW Group Ergonomic Development department or those dealing with display and operating concepts are working together with customers and "guinea pigs" in order to learn more about them. On the one hand, the wide range of differing needs and characteristics play a crucial role in this – for example in the ergonomic layout of a new seat design – and on the other hand, it is also important to understand more precisely the demands of specific customer groups.

In a current study by BMW Group Forschung und Technik, the focus is not placed on a specialised area of technology, but on the requirements and needs of a growing group of people: those in the over-60 age group. The study deals in particular with the needs and demands of this group with regard to display and operating concepts and the associated functions of BMW ConnectedDrive.

Learning from one and all.
In order to find out what a target group wants and needs, the development engineers explore deeply into the lifestyle of the study subjects. They want to learn how they live from day to day and how, to what extent and for what purpose they make use of technology inside and outside their car. In the course of the study, the experts of the BMW Group place particular importance not only on understanding the participants from a theoretical standpoint, but also on getting to know them as people.

The focus of the study is on the post-war generation who, thanks to the economic growth of recent decades, are well educated and well off. This generation is sharply distinguished from the pre-war and wartime generations in its awareness of standards and quality, a fact that is reflected in a new level of enjoyment of life.

The object of the study is to identify, on the basis of the knowledge gathered, areas of future potential and possible starting points for new customer-oriented developments in the field of displays and operation, and derived from these, in BMW ConnectedDrive functions. That is why the BMW Group experts have opted for a multi-stage exploratory and qualitative procedure.

A search in the literature on the current status of research led to the choice of several areas for special attention, ranging from fitness and leisure activities through to the family and personal values. These topics were then broadened and deepened in interviews with leading experts in market research, gerontology and product development. On the basis of this preliminary work, questionnaires were then developed for the customer study. A total of 30 people aged between 50 und 70 took part in the study, one third of them aged between 50 and 60, and two thirds between 60 and 70 years old. The younger group provided an

insight into future customer trends – specifically in relation to their anticipated affinity with technology.

Once the participants had been selected, the lifestyle of the target group was examined. With the aid of a diary, the 30 participants documented their activities over five consecutive days and, of course, their everyday use of transport. Then 15 participants were visited at home by BMW Group experts. As well as having an intensive discussion, the experts were chiefly interested in sharing some experiences with the people they visited and seeing how they behaved in a variety of situations. During a car journey together, for example, the BMW researchers were able to observe the subjects' driving style and discuss questions about their car with them. With the aid of small experiments, the developers than tested various functions in the car, such as the programming of music channels, use of the luggage compartment or setting the satnav. From the results of the discussions and observations, initial areas for potential modification can now be derived.

Better understanding of the target group – and a surprise.
The results of general market research show that Germany's "pensioners", in contrast to the previous generation, are not only more numerous, but also healthier, better informed and more prosperous. They are more au fait with technology and more active, as well as possessing higher standards and greater quality awareness. Added to these there is often a greater need for mobility. Through the study, it has been possible to widen this available information significantly, especially for the development areas of display and operating concepts and networked services. From common factors in the target group such as self-image and the importance of mobility, through to differences in the use of technology, for example, the study was also able to show what customers of the future will hope for from a car. For during the study it was possible, with the help of diary entries, to record 300 mobility events, of which some 80 per cent were associated with cars.

Asked the question about what they expect from a car, the participants in the study chiefly wanted, in addition to a high standard of interior convenience, specific assistance with driving. Functions that extend their skills, such as Park Distance Control or Surround View, were as positively valued and in demand as were functions that ease the driving burden, such as an automatic gearbox or an electrically closing tailgate. Many of these demands are already being met today by cars from the BMW Group and extensions are currently being worked on or have just reached the market – such as the hands-free tailgate opening function from BMW ConnectedDrive.

As for the use of infotainment provided in the car, the experts found in the study that the participants varied greatly in their acceptance of new technology, and especially in their ability to handle it. In addition to age-related differences – the younger participants tend to be more open to new technology – differences in personality type are clearly discernible: in general, there are techno-enthusiasts and there are those who are chiefly concerned with the utility of a technology. The latter only make use of a function or technology if it offers them personally a recognisable added benefit. The third type has strong reservations toward modern technology. The researchers also encountered mixed types and technical overlaps. For example, some test subjects did make use of an internet route planner, but then took a printout with them in the car as they did not have a navigation system in the vehicle, or felt that using certain navigation systems was beyond them.

The preferences of the test subjects in relation to in-car information provision are very varied and sophisticated. Numerous topics were mentioned, from information on local public transport connections, through traffic reports and warnings, all the way to parking or sightseeing information, including directions to the destination. What was important to most of the less technically-minded test subjects was simply to receive the right information at the right time, if possible without themselves having to perform many operational steps. This intuitive, personalised and time-, location- or mood-dependent information provision is identical to what other customer groups demand from their car.

This shows that, precisely from BMW ConnectedDrive's angle, there are fewer age-specific demands on a car than was thought. Meeting the desire for personalised information provision – that is to say, adapted to individual needs – is taking on increasing importance. With its ideas and visions regarding future opportunities for interaction and new functions derived from them, the BMW Group is heading in the right direction. Examples of this are the Infotainment Assistant (see Chapter 2.2) and the research project into operation by hand gesture (Chapter 3.2), as well as the Emotional Browser in the BMW Vision ConnectedDrive concept car.

Demographic change and ergonomics.
The impact of demographic trends also presents new challenges to the ergonomic layout of a vehicle. How physically mobile will the customers of the future be? How can a comfortable entry and exit from the vehicle be preserved? These are just two of many questions that occupy the ergonomic development team – made up of engineers, designers, sports scientists, and specialists in orthopaedics and ergotherapy – with a view to adapting the cars of the future as closely as possible to human characteristics.

Ergonomics and the feeling of comfort.
All the functions in the car which are designed to ease the burden on the user also serve to enhance ergonomics and the feeling of comfort. Here the border between the two areas is fluid. Something that is a necessary ergonomic requirement for one car user represents a gain in convenience for another. If an electrically opened tailgate is an added convenience for one, it is an absolute must for the other – due to physical size or restricted mobility. Seat belt extenders or a reversing camera are further examples of features that provide direct utility as well as a gain in convenience.

"We design our vehicles for people from birth up to advanced age. We pay attention to children and child seats when designing cars, just as we do to the requirements of an aging society. And in the same way we observe very closely the anthropometric data and changes in the entire world population."
(Peer-Oliver Wagner, Head of Ergonomics and Convenience)

Geometric layout of the cars for customers.
As a matter of principle, BMW Group cars are ergonomically designed for body measurements that range from the fifth percentile of women right up to the 95th percentile of men. In this way BMW Group cars meet the convenience requirements of 95 per cent of the population.

Yet the application of vehicle geometry always involves a little prediction too. This is because a car project which the ergonomists are currently working on does not go into production for another six or seven years and then has a model life that is as long again. Added to that is the age of the car itself: the geometric design of the vehicle must still fit the customer in 20 to 25 years' time. And it is a

fact that body measurements alter not only in the course of one lifetime, but also from one generation to the next.

Accelerated change in body measurements over the generations.
In order to find out how the anthropometry, or body measurements, of the population is changing over time, the BMW Group took part in Germany's mass measurement programme "SizeGERMANY" in 2008. That enabled the development staff to obtain up-to-date anthropometric data and, by comparing it with data already available, show how the population has evolved. However, the ascertained change in body measurements affects not only height but also girth. On average, both are continuing to increase and at the same time the span between the extremes is growing ever larger. Up to now, an average increase in height of approximately 1.5 centimetres every ten years has been observed. However, from about 2025 onward a definite levelling-off of this trend is expected. This is not true of girth, which the experts believe will expand continuously.

And demands on interior vehicle geometry are not only changing at a national level. If we look at the international distribution of BMW Group customers, big markets have grown up in recent years whose customers make different demands on the the geometric layout of a vehicle. For example, in China the average height of a man is 1.69 metres, whereas men in Germany are on average 1.78 metres tall. In addition to this, there is a wide spread between upper and lower limits: if we take Germany and China together, the range is even wider – from 1.49 metres (for the 5th percentile of women in China) up to 1.93 metres (for the 95th percentile of men in Germany). At the same time, customers differ with regard to their proportions, for example the ratio of torso length to leg length. All these requirements have to be integrated into the layout of the cars. For this reason the BMW Group makes use of numerous international databases on body measurements so that the vehicle geometry can be adapted to international markets.

Studies of physical mobility by the BMW Group.
Not only do a person's body measurements change in the course of a lifetime, but so does the person him- or herself. Aging has an effect on various characteristics, skills and abilities, such as vision and sense of hearing, but most of all on coordination, agility and strength.

"If you ask the professionals in this field what the demographic trend means in practical terms, you often only get vague answers. The problem lies in the fact that the range of physical characteristics has expanded. Today there are 70-year-olds who jog every day and 40-year-olds who remain sedentary all day. For us, one very interesting dimension is mobility. The aspects of mobility which we have so far perhaps simply associated with the concepts of youth or age, we now want to place an objective basis so that we can work with them." (Maximilian Amereller, doctoral student in the Ergonomics and Convenience Team)

In contrast to the well-researched body measurements, there is data on mobility which has scarcely been evaluated up to now. Though it is known that mobility tends to diminish with age, there is little information about the actual situation or about disparity within the age groups. Nor do we have measuring instruments or specialised methodologies that are capable of measuring mobility in a standardised and uncomplicated way. Yet mobility is a critical factor when it comes to using a vehicle.

In order to gather usable data and to be able to adapt the layout of vehicles to demographic trends even better in the future, a current study is engaged in the measurement of physical mobility and how to assess it objectively in relation to factors such as age, gender, body ratios and state of fitness. A similar situation applies to the strength parameter.

Aims of the study.
The study is being carried out on people without any serious physical disabilities. A series of 84 individual movements is examined, covering the entire range of bodily motion. The aim is to find out in what movements the test subjects are restricted and whether these restrictions display a specific distribution due to certain factors. This may provide important clues for the future design of solutions and functions in the vehicle. These discoveries then have to be objectivised in the form of anticipated customer demands and characteristics, so that an ergonomic evaluation of vehicle geometries and designs can be carried out on the basis of these mobility profiles. The results of the study should also produce a percentile breakdown, that is to say a classification of the population in terms of physical mobility.

Currently the necessary measurement methodology and appropriate instrumentation are being developed, so that data gathering can start as early as this year. After the methods and apparatus have been validated, mass measurements will take place, on the basis of which percentilised mobility data will be produced for people aged from 17 to 85. This data will be fed into existing software systems for virtual validation in order to facilitate, at an early stage and without building a model, a more precise evaluation of design and prototype work with regard to spatial concepts, customer functions and convenience. The BMW Group's long-term aim with this study is the complete classification of the physical requirements of customers in the form of a comprehensive, internationally valid and constantly expanding database.

"For us, man is the measure of all things – including cars." (Peer-Oliver Wagner)

Virtual study of getting in and out of cars.
Getting in and out of cars represents a specific case of a mobility event. Today, most ergonomic concept development and subsequent implementation is already being performed virtually. It means that, even in the initial phase of the project, it is possible to generate target data which it is necessary to achieve in order to reach a prescribed high level of comfort. These targets form an important reference point for the vehicle developers at a subsequent stage. For the entry and exit scenario, this could not be done virtually until now. Both entry and exit from a vehicle require movement of the whole body and are thus among the most complex sequences of movements relating to a vehicle. Furthermore, a large number of vehicle measurements have to be fed into the evaluation, which also have a mutual impact on each other.

"The degree of comfort in getting in or out of a car is influenced by the vehicle geometry and by the individual body measurements. For this reason, it has usually been necessary up to now for complete prototype models to be built for us to be able to judge the effect of vehicle geometry on movement as well as the 'discomfort experience' of various test subjects." (Peer-Oliver Wagner)

However, this is about to change: the specialists of the BMW Group are currently working on a procedure by which complex entry and exit events can be virtually simulated and evaluated for the first time. The great advantage lies in the fact that even at an early stage – without having built a prototype – it is possible to

make valid assessments of the comfort of an entrance and its suitability for a vehicle and the target group in question. What were once subjective impressions of test subjects are now objective, measurable and thus comparable data.

And this is how it works: using data for planned vehicle geometry and the mobility data from the BMW Group's database, the tool calculates a simulation of the entry or exit movement. The calculated movement is then analysed and assessed. Factors for assessment are firstly biomechanical parameters such as apparent strength in the joints. Secondly, since the surroundings of the vehicle play a part in entry, the simulation and assessment also take account of different scenarios, such as getting out in a narrow parking slot. This indicates how far the geometry meets the demands of comfort and ergonomics, at what point critical patterns of movement appear, and how they can be optimised.

The long road to simulated motion.
Before the BMW Group specialists could simulate motion at all, they had to create a database from many pieces of motion information to which the simulation could refer. In the course of an extensive data gathering exercise, the movements of numerous real test subjects getting into a car were recorded and digitalised in a variable entry model.

The model is fitted with force sensors and force measurement pads in the footwell, on the steering wheel and on the door, which can record how much force is exerted at what point in time during entry in each area. Infrared sensors and a motion capturing system (familiar from the film industry) make it possible to record the entry and exit movements of the test subjects. From these, data on motion and force are digitally reconstructed. The recorded movements are then transferred to a virtual human model with muscles and a skeleton, so that the strains on the individual muscles can be illustrated and reproduced. For even movements that can scarcely be picked up by eye may require a high expenditure of force and can thus be uncomfortable. The human model was then validated by a comparison of the calculations with measurements actually taken and with an external database.

In total, well over 2,000 recorded entry and exit movements provide a basis for the simulation. The variable model enabled the development engineers to simulate every entry and exit geometry within the BMW Group, from that of the BMW Z4 right up to that of the BMW X5.

"When validating the motion simulation we quickly saw how good the calculated values were, even in the early phase of testing. The simulations come very close to reality." (Raphael Bichler, biomechanics specialist in the Ergonomics and Comfort Team)

Assessing motion.
Once the database and calculation model for the motion simulation have been set up, the next stage is the assessment. The challenge here lies in assessing the entire movement through time and not only parts of or extracts from it. In order to be able to classify the ergonomic quality of a movement, the development engineers compare it with a predefined, optimal entry scenario. This "Less Restricted Motion", an entry movement without geometric hindrances such as the entry opening or roof pillar, serves as a reference for the movements to be assessed.

In addition to parameters such as the angle or forces of joints, the assessment also allows observation of specific parts of the body. Comparison with the

reference movement then makes it possible to identify and optimise tight spots, obstacles or excessive exertions. For all the parameters, affinity values are calculated from which an overall value – the affinity coefficient – is then formed. This affinity coefficient shows whether the entry movement closely matches the reference or not. In this way, for example, vehicle concepts can be compared with each other objectively. Thus the ergonomic experts of the BMW Group are ensuring that, in the future too, people will be able to get into "their" cars in comfort, regardless of their size, age and nationality.

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