Innovation Days 2009 – Interior, Infotainment, Mobility.
Contents.

Innovation Days 2009 – Interior, Infotainment, Mobility. (Long Version)

1. In the Car of the Future.

Walking up to your car – particularly at night – the first thing you notice once you have unlocked the car by remote control is the interior lights coming on. And precisely this was the starting point for the BMW Group's light designers, in asking what new technologies would be able to offer in this respect.

Once you have arrived at your car, the seat is your permanent companion, generally remaining unnoticed, on every trip you take. So how can the car seats of the future be made lighter but nevertheless remain comfortable and safe? Answering this question, BMW Group experts have developed three different seat concepts, the best features of which will go into the series development of future seats.

Information and entertainment functions in the car are increasing in both magnitude and significance. So what must displays be able to offer in technical terms in future and how can they be integrated attractively in the car to meet these demands? Different display locations call for new technical solutions – and again, the BMW Group is perfectly prepared.

The acoustic experience in the car has a sub-conscious but significant effect on the driver and passengers. The research prototype by the BMW Group's acoustic engineers therefore offers personalised and emotional driving experience through active sound design.

1.1 Creating the Right Light Architecture within the Car.

Inspired by the use and presentation of light in interior architecture, specialists at the BMW Group have revised and updated the complete interior in terms of light technology. For like in a building, light in a car may also structure spaces, set highlights, emphasise certain features or conceal others, guide the occupants through the interior, and even create powerful emotions.

An important source of inspiration in this context was the BMW Group's cooperation with a strong partner company working so far only in architecture. The result is a brand-new world of experience in the automobile.

"The automobile is part of the world we live in. And, using light appropriately, we would like to make this world a pleasant place where you feel at home."
(Hans-Peter Bailer, High-Value Light Design Project)

Specific, individual use of light may give the same interior a very different look and experience ranging, for example, from calm to dynamic. This is achieved by positioning light sources at appropriate points within the interior, by using different light colours and light intensity. Theoretically, each vehicle is able, through the style of illumination used, to present its particularly character also at night, helping to make the driving experience more intense. Today and in future new technical solutions offer greater choice and individual potentials light experts are carefully testing and introducing in creative style.

The new concept no longer makes do with just one central source of light. Instead, several sources of light arranged in different positions illuminate, say, the pillars in the greenhouse, the instrument panel, the centre console and the driver's seat.

This new light concept is astounding in its effect even from outside. Opening the car by remote control, the driver and passengers experience a welcome scenario with a stimulating feeling of generosity right from the start through the windows. Then, getting into the car, they will receive an even more positive impression, with everything looking bright, pleasant, and spacious.

"The welcome scenario virtually begs the driver to take a seat."
(Jan Seeburg, responsible for interior space design)

Once setting out in the car, night illumination helps your eyes grow accustomed to the dark surroundings, without making the car completely dark. The various surfaces, materials, information relevant to the driver and functions are discreetly illuminated and thus kept clearly visible and recognisable.

Let there be light – the new light concept.
The BMW Group has already been working for several years on new options for illuminating the interior of a car in even more pleasant and sophisticated style. Indeed, such light technology was introduced for the first time in the BMW 7 Series in 1994 (E38) as a special tool serving to enhance the interior.

> "We turned light into a real performance, indirect illumination of the interior giving the entire passenger compartment that unique flair of generosity and elegance".
>
> (Dr Wolfgang Reitzle, at the time Board Member Development, on the light concept of the BMW 7 Series

New examples of ambient light are to be found in similar style and quality in various cars. The objective of these improvements in all cases was and is to upgrade the interior in offering an emotional experience in space.

Examples of light effects in the MINI and the BMW 5 Series Gran Turismo – "Light has a great emotional potential." (Jan Seeburg)

To create an emotional setting as a genuine experience, the BMW Group's current Light Research Project covers a much wider range of design and features than in the past. The objective is to create and enhance an individual and harmonious cocoon of light within the car. And indeed, the term "cocoon" is to be taken quite literally in this context, leading to a brand-new concept inspired by interior architecture and implemented in cooperation with an experienced partner in light planning and design.

The idea is to give the car a and very distinctive style and flair – a new look. Depending on the situation and the specific requirements, the interior is highlighted in different ways and with different features. When welcoming the driver, when he gets in and when he actually drives the car, the new light concept changes in its style and features, in each case reflecting the current situation and conditions.

Clearly visible from a distance and truly generous – welcome light.
Light is now used in a completely new way to welcome the driver and passengers. Once the driver presses the unlock button on his remote control, the complete interior is illuminated, several sources of light brightening up the greenhouse and inviting the driver and passengers to come in. The roof pillars are illuminated individually, making the car look more spacious. Appropriate arrangement of light sources generates an enormous feeling of depth as well as a particularly generous experience of space also conveyed to the outside.

Welcome scenario in the BMW 1 Series experimental car (source: Bartenbach Lichtlabor)

Getting in the easy way – get inside and take a seat.
As soon as the driver opens the door, light shows him the way to his seat. A distinct light beam illuminates the surface on the driver's seat, while the door light at the top brightens up the entry area as long as the door is still open. Then, once the driver has taken his seat and closed the door, light beams guide his eyes to the dashboard and the steering wheel while the instrument cluster "wakes up". This highlights the driving experience and accentuates the sporting ambience in a BMW.

With the driver preparing for the next job of driving the car, the lights are subsequently dimmed, ambient light accentuating the driver-oriented interior geometry and making the entire surroundings clear and perceptible. This conveys a strong feeling of safety, since the driver is now able, albeit sub-consciously, to recognise his position much more clearly.

Apart from the appealing optical effect, the concept also offers a further benefit, with discreetly illuminated surfaces reducing the contrasts between the displays, instruments, the road and dark surfaces at night. And this helps the driver adapt his eyes more quickly and efficiently, with his pupils adjusting more efficiently to light conditions.

Ambient illumination – free of fatigue and pleasant for the eyes.
Traffic coming the other way is often a problem at night. Bright headlights may be very dazzling, particularly when you are travelling in a car completely dark inside. Precisely this is why the interior lights are not switsched off completely even when driving. Instead, homogenous illumination of the instrument panel around the instrument cluster brightens up the interior once the engine has started. Similar to the light of the full moon in terms of colour and intensity, this ambient lighting effect makes driving at night much more pleasant and safer. Discreet illumination of the interior allows the eyes to adapt more quickly, helping to avoid fatigue and, again, enhance the standard of safety.

Tests with the new light concept show that the driver is less dazzled by oncoming traffic and is able to read the instruments more quickly and easily, again in the interest of less fatigue. The effect of irritating, intermittent shadows is also reduced significantly.

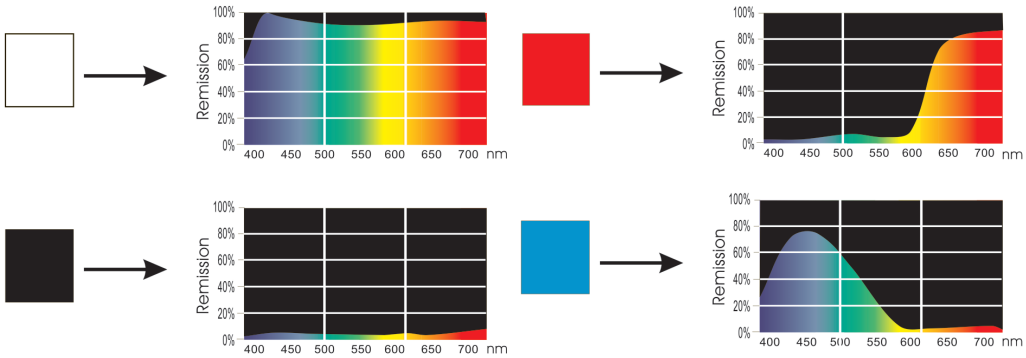
Further tests are however still required to double-check the researchers' ideas, enhancing the systems and technologies involved to the standard required for introduction in series.

Individual light character.
Appropriate adaptation and harmonisation of light to the features and character of a car requires a careful approach taking specific conditions into account. For light is not simply light – rather, light gives materials and surfaces a different effect and look, depending on its intensity and colour.

The perception of materials in terms of their colour depends first and foremost on their molecular composition crucial to whether light is reflected or absorbed. The sensation of colour perceived by the eye results from the balance and ratio of light reflected. While white bodies reflect all shares of colour in light, we do not perceive the light as such, but rather only the object actually emitting the

light. White light pointed at a green body, for example, only makes that body look green because only the green components contained in the white light are reflected.

Quite generally, this means that colours and surface structures look “authentic” in white light, as we know from what we see in normal daylight. This is why the BMW Group’s engineers are now concentrating on white light in providing ambient illumination, enabling the interior effect to develop also at night and presenting the interior experience in the car even better than before.



Remission spectrum of various surface colours

(source: Ch. Bartenbach & W. Witting: Manual of Light Design; Springer, Vienna 2008; pp 149)

Changes in the colour temperature of light may even emphasise the specific features of materials, various colours and intensities of light being highlighted by different surfaces and materials and therefore bringing out their character even better.

Studies show that with a warm, white colour of light the materials have a pleasant effect and are experienced authentically, just like your own skin. Conversely, the effect of light also varies significantly as a result of the choice and combination of materials and their specific features such as reflection, absorption and structure.

The BMW Group is currently conducting a series of tests to find out which light colour matches which type of interior, bringing out the respective features and highlights. With a lighter interior, for example, a warmer white – similarly to the light of a bulb between 2,700 and 3,200 Kelvin – gives natural colours such as brown or beige an even more pleasant and intense effect. In a black interior with metal trim, on the other hand, cooler light (4,000-5,000 Kelvin) gives greater emphasis to the technical and metallic character of the individual surfaces and components, emphasising the technical, cool and sporting flair of the car.

"The new light concept opens up brand-new design options and ideas in highlighting and accentuating the interior."

(Hans-Peter Bailer)

More colour inside the car – the light of the future.
In BMW's current models ambient light in its natural intensity is already adapted to the respective interior. In addition, the light may be dimmed for individual adjustment by the customer, depending on his personal feeling of well-being.

It is quite conceivable that in future the customer will be able to choose different light temperatures in his car – depending on his personal mood and the colour and style of the interior. Conversely, the light inside the car might respond by itself to different driving conditions, changing whenever you are driving on the motorway, on a country road or in town. Or, to go even further, what would it be like in a car able to adjust its interior colour temperature and brightness depending on the time of day and the season to the driver's circadian and circannual rhythm?

Illumination in and on the car will therefore have far more tasks and purposes in future than just brightening up the vehicle. Whenever the driver opens his car by remote control at night, light will show him the way. He will recognise his car through the illuminated corona rings, the illumination around the car, as well as the brightly lit interior with its flair of style and generosity. And in the same way light within the interior will then serve while driving to make the driver feel at home, happy, safe and content in every situation.

Light research – how do you develop good light?
In developing the new light concept to give the car the right appearance at night, the BMW Group's research engineers intentionally took a completely new approach and left the beaten track far behind. Their focus was on creating something brand-new, highlighting the car as an architectural experience with a more emotional and, at the same time, supportive light effect, depending on current conditions.

This philosophy allows the use of many parameters and design features. Whether it is the position of the light sources, the angle of imminent light, or the use of various light colours and intensities – there are many different options and possibilities, with highly complex interaction of the individual factors. The challenge is to make the right adjustments and pull the right levers to provide a well-balanced overall effect.

> "We are entering brand-new terrain, without any footsteps we might follow. So we have to go our own way."
>
> (Hans-Peter Bailer)

The objectives were clear from the start: The first step is to put together a detailed list of requirements depending on the character of the car. This comprises both overriding features such as "sophisticated" and "generous", as well as specific parameters such as the speed of the dimming process and the diameter of light beams. This leads to the implementation process in individual steps, with the development engineers using different methods and tools for the purpose of implementation.

The first step is to conduct individual tests in the laboratory, taking a closer look at individual parameters. One point, for example, is to consider which kind of light makes a certain material look more pleasant or authentic, or what influence different levels of brightness have on the driver's and passenger's perception. The findings obtained are then applied in the virtual presentation of the car as interactive light simulation – now with results surprisingly realistic.

Simulation of light or: "Here we can do almost everything."
How many sources of light do you need to obtain the desired light effect? Where do these sources bring out their effect best and how intense should they be?

After having examined such questions for a long time only with the help of elaborate and costly models and test specimens, BMW Group specialists are now able to clarify such points quickly, flexibly and above all at low cost thanks to the simulation of light in virtual reality. Such simulation brings together the individual parameters and effects, showing their specific interaction.

Taking CAD data provided by various departments, the light specialists put together their model of the overall vehicle and integrate appropriate light information. This visual basis then allows further decisions, for example whether and to what extent the ideas presented should be pursued.

The simulation of light in the development process fulfils two functions. On the one hand it provides the initial, three-dimensional presentation and analysis of ideas as well as their modification in real time. On the other hand it uses the physically correct presentation of light scenarios right down to the last detail, making this concept an indispensible step towards construction of the first body specimens in which the actual effect of light can be recognised and assessed on the spot.

The two functions of light simulation.

The first purpose and function of light simulation is to present the car in its entirety in an interactive process. The engineer or designer is then able to move completely freely inside the car in real time, fitting and adjusting light sources at random, and changing their colour and intensity. Apart from various geometric options (eg sports steering wheel/normal steering wheel), materials and colours on the seats and trim surfaces may be exchanged individually as desired. Even entire illumination processes may be simulated and checked for their effect within the interior. Each and every step in the process of presentation, from unlocking the car to starting the engine, may be simulated and considered from virtually every angle. And while this presentation is not quite correct in physical terms due to the enormous computer capacity required, it provides a good impression in real time.

Light simulation is also used to examine and check out this impression for its physical correctness, but under different conditions. For while the overall presentation of the vehicle depends on a smooth flow of processes in real time, the focus is now on realistic presentation of each and every detail to the most precise point, again true-to-reality in every respect.

Shadows, reflections and the flow of light within the interior present a great challenge in terms of computer capacity. The interior of a car, together with the trim bars, door panels, leather seats and the carpet, covers an area of several square metres, within which each square centimetre reflects light quite differently. This is why physically correct presentation is currently only possible from a perspective defined in advance, for example from the driver's seat to the front passenger's area.

The computer time required for a picture depends on the complexity of the scene involved as well as the quality and resolution desired. At the beginning of the calculation process the image is still very rough and comes with a small number of pixels, then gaining accuracy and becoming finer with increasing calculation time. After about 15-30 minutes the interior is clearly recognisable (left picture), while a high-resolution, sharp image of the interior with a complex scene involving a larger number of light sources (right picture) requires several nights of calculation. Theoretically, the software used would refine the presentation rendered in an infinite process, if the engineer did not after a certain period stop the process since no further change is to be observed with the naked eye.

A cluster of several computers and several processors serves to further shorten these processing times, twice the number of processes just about halving the processing time required. The data capacity involved in the calculation process may well be very substantial, with each image made up of several gigabytes.

This presentation also allows at least a certain degree of interactivity. While the perspective chosen cannot be changed, the intensities may be varied individually for all sources of light applied. Proceeding from a stationary picture, for example, the engineer can check in a physically correct process what effect a specific position of the light source has in this intensity. And he can do this both for each individual source of light and for the overall impression conveyed.

The two functions of light simulation form a perfect match. On the one hand, motion within the car in real time serves to determine the effect of light sources and their position and style of presentation. On the other hand, physically correct presentation is an important tool for verifying a presentation in real time.

"We are working with the best of both worlds."
(Dr Tim Burkert, Light Effects in Virtual Reality)

Powerbench.
Every light situation may be described in mathematical terms. To visualise these complex situations, the engineer requires significant computer power and the highest level of optical equipment. The Powerbench allows two- and three-dimensional presentation in four-fold full-HD resolution.

"Technically we are working with the latest equipment to make the future visible today."
(Dr Tim Burkert)

Several interacting computers provide the computer power required and prepare the image for large-scale projection (5.6 x 2.7 m/18.4 x 8.9 ft). High-resolution beamers used together with 3D glasses and infra-red tracking make the data processed almost tangible. Hence, presentation through the Powerbench provides realistic photographic quality and makes the simulation very meaningful.

1.2 Innovative Seating Systems.

The seat in a car is far more today than just a simple structure with a padded cover of cloth or leather. Rather, a modern seat must fulfil many different demands and requirements in today's world – safety standards are becoming stricter all the time and customers expect an increasing level of comfort. And it is only obvious that a seat, despite drivers of different size and with different bodies, should be ergonomical, comfortable and safe for all occupants.

Seeking to meet these many requirements, car seats have become increasingly complex and sophisticated in recent years. Step-by-step, the seat of a car has become a high-tech feature with up to 18 motors serving to provide a wide range of adjustments and comfort functions. Precisely this is why a modern car seat now takes up a lot of space within the car and may weigh up to 36 kg or 80 lb. In other words – the seats of a car offer a significant potential for reducing weight and, accordingly, fuel consumption.

The objective in creating new seat concepts was clear from the start: to reduce dimensions, lower the weight of the seat, and cut back fuel consumption accordingly. The big challenge with the new concepts, however, was to do all this while maintaining the usual high standard of comfort and crash safety required. The only savings, therefore, were to involve the weight of the car.

Querying conventional solutions.
To consider all options in the development of a car's seats and to go beyond conventional wisdom, BMW Group engineers are working in many directions. Completely separated from series development, research engineers are querying the seat structures used so far and taking a brand-new approach in the process. Physiotherapists and orthopaedic experts are also involved in the development process, since the objective of the work involved is clear: A modern car seat must meet all the requirements of the occupant, and not vice versa.

"The human being is the benchmark in everything we do."
(Matthias Franz, Seat Development Engineer)

Looking for the car seat of the future, the engineers are therefore following nature and the anatomy of the human being, and have been able to find very interesting solutions in the process now being applied for the first time in different seat concepts.

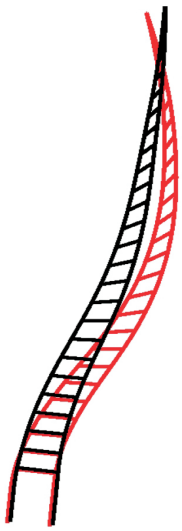
Using the competences and synergies of individual departments within the company, BMW Group engineers have developed three new seat concepts. And although these concepts are the result, at least in part, of a different approach, they all clearly show the potential offered by ongoing development of the car's seats.

1.2.1 The Bionic Seat: Following the Example of Nature.

Over thousands of years, nature has created an appropriate solution for each and every requirement, then further enhanced and perfected in every respect. So whether it is the highly stable lightweight structure of bones, dynamic surfaces such as the skin of shark, or the perfect aerodynamics of a bird, nature offers an enormous range of carefully evolved "technical" solutions. So what could be more obvious than to follow the example of nature also in technology?

Precisely that is what bionics is all about. The challenge in this case, however, is not just to recognise these interacting effects and principles, but also to apply them in the appropriate context. And how this can be done successfully we see from the work done by BMW Group engineers in research and development in creating the bionic seat based on the fin ray effect.

The fin ray effect – quality from and by nature.



The fins of a fish show quite unusual behaviour under pressure from the side. Pressing your finger slightly against the tail fin of a trout, therefore, you will find that the fin does not turn away against the pressure exerted, but rather moves towards such pressure, towards your finger.

This change in function under pressure from the side is referred as the "fin ray effect" resulting from the particular structure of the fin: The fin is made up of two flexible trusses coming together at the tip to form one unit. Between these two flanks with their elastic bending effect we find transverse bars keeping the flanks at a distance and allowing elastic motion.

The same principle is applied on the backrest of the bionic seat: Two "organic plates" (plates made of flexible, thermoplastic composite glass-fibre) form the outer surfaces, while small, flexibly mounted trusses link these two flanks to one another.

The fin ray principle has two effects in one: First, the structure chosen allows a progressive degree of elasticity first giving in but then becoming increasingly hard and building up growing support. Second, the backrest uses the particular property of the fin ray effect – the change in function under load – like a dynamic lever: As soon as the two surfaces move towards each other, for example due to pressure in the middle of the seat, the backrest moves up more closely to the occupant. So when the driver leans back, the backrest will provide support around the lumbar spine and give way to a certain degree around the shoulders, while the neck padding will shorten the distance to the occupant's head.

"Our fin ray concept ensures individual adjustment to the driver but at the same time is sufficiently stable for a crash."
(Thomas Klawitter, BMW Group Research and Technology)

Take a seat and feel at home – superior comfort for driver and passengers.
The flexible structure adjusts the backrest precisely to the driver's body, without requiring any special re-adjustment. There is no need for adjustment motors or mechanisms, and the prototype does not require any electronic functions.

But at the same time the bionic seat offers a very high standard of comfort particularly in the sensitive backbone area. Thanks to the flexible fin ray structure, the occupant's backbone has greater freedom of movement than on a conventional seat. His backbone muscles are activated and the supply of blood to the backbone improved. Hence, the bionic seat helps to keep the backbone flexible, taking the load off the vertebrae and keeping the occupant's back muscles loose and flexible as an important prerequisite for relaxed motoring.

The seat structure provides support only where it is really needed. Precisely this is why side pads are provided only in the shoulder and lumbar spine area, while the backrest itself remains surprisingly slender. These shoulder and lumbar pads surround the driver, as it were, to provide the side support required, while the surfaces between the individual pads are intentionally kept open. The result is a higher standard of climate comfort, with the area covered by the back resting on the seat being a lot smaller and therefore allowing better passive ventilation than on a conventional seat.

The slender backrest saves not only weight, but also space. Indeed, the rear seat passengers in particular benefit from this extra space, since they are able to place their legs conveniently to the left and right of the backrest, enjoying extra legroom as a big advantage on the rear seats particularly in a small car. A further advantage is that the special structure of the backrest gives the bionic seat with its integrated functions an unusual and very "airy" look quite different from any conventional seat so far.

Integration of functions saves weight.
Intelligent use of materials allows consistent lightweight construction with full integration of all functions. "Organic plates", as they are called, made of a composite material including a uni-directional glass-fibre tissue in thermo-plastic, set the foundation for the backrest with its particular structure. These plates are processed like metal and may be heated and pressed into virtually any shape. Then they remain stable in their shape, but still offer greater flexibility thanks to the particular properties and qualities of the material.

A big advantage of this material is that the connecting trusses may be injected into the same mould, ensuring a perfect bond of all components and sections used.

"The special thing about this seat is the really successful integration of all functions."

(Thomas Klawitter)

While in today's seats a steel frame provides stability and foam padding together with a spring mat ensures the comfort required, the new seat concept brings together two structural elements in one, offering the same high standard of function as before. At the same time the slender backrest and the fin ray principle ensure a high standard of elasticity, stability and comfort in one single, light element.

Through the use of light composite materials, the small amount of padding required and the integration of functions, the backrest structure alone reduces weight versus a conventional seat by about 20 per cent.

Meeting all requirements.

The new materials bring together the qualities of both a stable and comfortable backrest structure, at the same time providing an even more intense driving experience. When accelerating the driver is pressed back into the seat, which first gives way and then cocoons his body. At the same time the backrest absorbs slight bumps and unsmoothness.

Elaborate static and dynamic driving tests have already confirmed the optimum physiognomic fit and the appropriate body contours of the seat, the bionic seat therefore ensuring appropriate safety and comfort for drivers of all sizes.

> "It was particularly important for us to carefully consider drivers of all shapes and sizes, making sure that the seat really fits in all cases."
>
> (Thomas Klawitter)

In simulation tests the seat already fulfils most crash requirements in terms of stability and deformation.

A further advantage of the backrest structure is the full integration of the crash-activated headrests, the fin ray system, through its kinematics, helping to counteract the whiplash effect in a rear-end collision. As soon as the driver is pressed back on to the seat backrest in a collision, the upper section of the backrest moves towards the driver's head, preventing it from swaying to the rear.

Further possible options are to integrate side airbags in the seat and to introduce comfort functions such as seat heating, a lumbar support or backrest width adjustment.

Even this, however, was not yet enough for the engineers and researchers at the BMW Group. Because looking at the new concept with its slender backrest and individual seat pads, they had yet another idea – to exchange the individual pads easily, quickly and conveniently whenever required. This allows the use of new colours, new materials or even leather, depending on the customer's personal wishes – quickly and conveniently, without having to change the padding of the seat in a long and elaborate process.

1.2.2 Anatomy as a Role Model – the Right Seat for the Right Body (Space Comfort Shell).

Focusing on the space comfort shell, that is a seat shell precisely tailored to the driver and his body, the BMW Group's engineers concentrated first not on the seat, but on the human being. The question was what a seat would look like starting from the human being as the main design criterion and then developing it around his individual seating requirements. Hence, the conventional path of development was completely turned around on this seat concept, with the human being coming first and then the computer – and not with the seat being developed first with the help of a computer and then being modified to fit the human being, as is generally the case.

The objective, therefore, was to create a very light and thin seat nevertheless highly comfortable for all occupants – a seat ideally fitting both the very short and light occupant as well as the tall and heavy driver.

A further point is that the thinner a seat, the more it must match the human body, since otherwise the driver would feel unpleasant and uncomfortable pressure points. The challenge for the engineers, therefore, was to fulfil all requirements at the same time, developing a seat both thin and light but equally comfortable for all drivers, regardless of their body stature or proportions.

> "Creating a seat shell equally comfortable for many appeared to be impossible so far – but we have done it."
>
> (Matthias Franz, Project Manager Seat Shell)

The human being serving as the role model.
In developing a new seat concept, the first step was to determine the seat profile of numerous test persons of very different weight and size. Using deformable vacuum mattresses like the ones used for rescuing severely injured persons in providing whole-body support, the engineers were able to "record" and preserve the seat "imprints".

A particularly feature of the vacuum mattress is that it adjusts perfectly to the occupant and at the same time provides the necessary support: When you put in the patient, the mattress is soft at the beginning, since it is filled with air and loose foam balls. Then the air is slowly let out and the patient "creates" his particular contours through his own weight. Once the air has been completely deflated the filling of foam balls provides very good support and cocoons the patient with utmost comfort and precision.

To obtain the right seat imprints, the engineers placed the mat on a seat frame and had the test persons take a seat. Asked to complete a simulated driving task, the test persons then left their particular seat imprint and contours in the mat. Letting out the air, these seat imprints were then preserved, digitalised by a laser scanner, and conveyed in 1:1 scale into a CAD design process.

The next step was to superimpose all contour scans upon one another, the data compiled in this way ultimately creating a seat shell meeting the physical requirements of all motorists with maximum precision.

"We concentrated in particular on the representative choice of test persons, since that criterion was crucial to the success of our work."
(Ümit Kilincsoy, doctor's student in the Seat Shell Project)

To ensure that the data compiled was really representative, virtually all conceivable body proportions were taken into account. In the process the engineers also considered different types and "configurations" of the human body, such as a short trunk with long legs or vice versa. Even without any padding, the shell clearly offers a surprisingly high standard of seating comfort.

For reasons of weight and space, the engineers nevertheless opted against conventional padding in determining the exact dimensions for everyday use, with a special surface cover providing the ultimate level of precision.

Building up and reducing pressure.
The surface is made up of several air pads each incorporating a nylo mesh providing a soft response to individual loads at specific points while spreading out broad loads very efficiently without giving in excessively.

A further advantage is that through its rough structure the mesh has an active breathing effect and is therefore already used on a smaller scale in BMW's climate seats.

To provide the final touch in adjusting to the body, the engineers took up a process already used in medical treatment to stabilise the position of an injured person: The first step is to extract air from the seat padding while the integrated mesh, like a rescue mat, maintains the body imprint required. The next step is to pump some air back in to the mattress in order to fill up any free spaces and give the driver even better support. The seat therefore cocoons the body, offering enhanced support and a firm position to the side, adjusting to the driver's individual anatomy even if he changes his position while driving.

The seat nevertheless retains its shape only until the valve is opened again, then returning to its starting point, as the mesh has a very strong and effective reverse adjustment effect.

Considering all kinds of options.
This innovative seat concept offers a great potential – and it not only gives designers significant margin for further development, but might also be enhanced in future by intentionally pumping up the air cushions at particular points to provide adaptive configuration of the seat. At the touch of a button the customer would then be able to choose appropriate seat characteristics in each respective situation – or, conceivably, the seat itself might even set these characteristics automatically.

Taking vehicle data such as the angle of the steering wheel, speed, longitudinal and lateral acceleration, the seat could adjust actively to driving conditions. The bottom line, therefore, is that one single seat could serve at the same time as a sports seat offering extra safety on winding mountain roads and as a comfort seat featuring active cervical spine support for pleasant driving conditions on long motorway journeys.

"All comfort functions may easily be integrated into the seat."
(Matthias Franz)

Since the pneumatics for adjusting the seat contours are already in place, various additional functions are easy to incorporate. The seat cushion sections on the seat bottom separated from one another may already fulfil well-known comfort functions such as massaging, adjustment of backrest and seat bottom width, lumbar support or active adjustment of seat backrest width. Indeed, the seat might even adjust individually to the specific dimensions and contours of the driver's back.

With all this being done entirely by air in a pneumatic process, there is no need for other adjustment options or additional motors – the seat shell simply fits. The only seat adjustments still remaining are the backrest angle and seating position.

Compared with BMW's current multifunction seat using no less than 18 electric motors, the new seat shell with its individual padding philosophy reduces the weight of the overall seat by approximately 50 per cent.

What the future holds in store.
BMW Group engineers are already working all-out on the integration of crash standards and requirements. The prototype tubular structure developed so far as the backrest support ensures extra safety as well as a unique feeling of space at the rear, with up to 50 mm or almost two inches more legroom.

"Blind" tests already confirm the extra comfort offered by the seat shell, which, in a short static test, has received the same positive comments and ratings from test persons as BMW's comfort seat currently in the market.

1.2.3 Good for your Back: the Ergo Seat.

Looking for an innovative seating system able to meet all the fundamental anatomic needs of the individual human being, the Ergo Seat Pre-Development Project combines the concept and features of the bionic seat and the ergonomic seat shell with its attractive design. The seat was indeed consistently improved even in the concept phase through intense exchange of information with colleagues employed in the other projects.

From the rotor blade to the seat skeleton.

Developing the basic frame or "skeleton" of the ergo seat, the engineers at the BMW Group's Innovation and Technology Centre in Landshut, northeast of Munich, initially followed the example of the human skeleton, a kind of "backbone" forming the basic structure of the ergo seat. Following the kinematics of helicopter rotor blades adjusting only by bending their shape and without the use of joints, the engineers decided to form the skeleton structure out of organic blades. These blades may also be bent easily to the shape of the human body, again without requiring any joints. A further advantage of the material used is its progressive flexibility, organic blades offering the driver good support but nevertheless adjusting actively to the contours of the human body.

Two functions in one: the fin ray effect.
In adjusting backrest width to the individual requirements of the driver, the engineers again used the fin ray effect already featured on the bionic seat – but this time for a different purpose. Through its particular geometry, the fin ray effect, like a gear transmission ratio, converts relatively short adjustment travel of 8–10 mm (0.31–0.39") in the middle of the backrest into a significant adjustment of up to 40 mm (1.57") on the side supports. And thanks to the low level of adjustment power required, the adjustment drive units chosen may be correspondingly small and light.

Through their inner structure, the side supports also provide an adaptive support function: The more the driver is pressed into the side support through lateral acceleration, the more stable these supports become in holding the driver in position.

The same applies to longitudinal acceleration in a straight line: With the driver being pressed harder into the backrest, the side elements surround (or cocoon) his body even better.

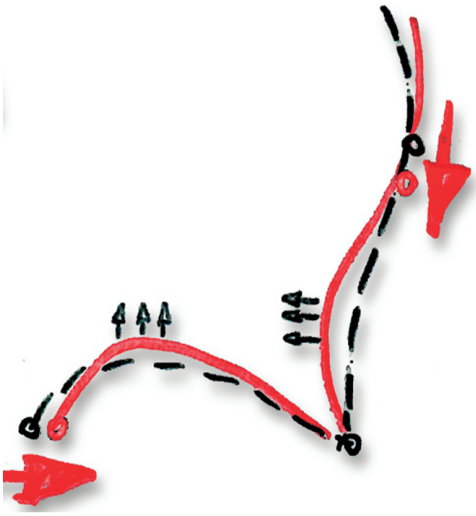
Through its flexible load-bearing structure, the ergo seat does not just remain rigid while driving, but rather responds smoothly to every situation. Driving round a bend slowly, the seat remains relatively soft while the side sections and padding give in. Driving fast and dynamically round a bend, on the other hand, the seat grows harder to support the driver, thus offering enhanced sportiness and comfort through its construction alone.

"In the driving tests conducted so far our test drivers were very happy with the brand-new and more intense driving experience."
(Andreas Müller, seat expert at the Landshut Innovation and Technology Centre)

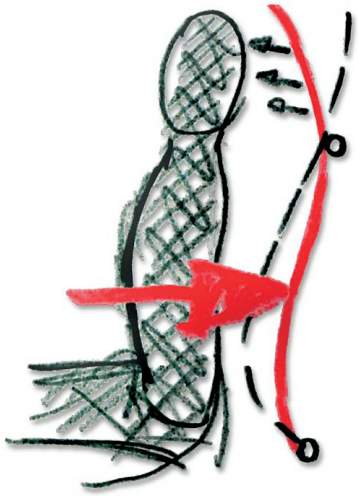
Flexible structure with progressive spring effect.
Apart from this automatic adjustment, the occupant is also able to pre-set the seat to his or her individual requirements. Pulling and pushing the support structure, for example, he can adjust the backrest appropriately in its contours. The same applies to the lumbar function, which may also be adjusted and varied accordingly. If the backrest structure is stretched, for example, the driver will have less support around his lumbar spine, while pushing the backrest together will increase this support.

In part, the seat bottom and backrest adjust automatically in width through the flexibility of the plastic components used. Then the driver is able to additionally adjust the wrap-around effect of the side backrest elements through the adjustment mechanism in the backrest section.

Active driving tests already confirm the initial, positive impression, with test persons lauding the comfort of the seat as very positive and emphasising that even after long distances they felt less body tension and discomfort than on conventional seats.



Contour adjustment of the backrest



Integration of the crash-activatedheadrest

Seat comfort and superior safety all in one.
It almost goes without saying that crash safety with this seat concept has been confirmed also in virtual tests. The flexible seat and backrest structure is suspended dynamically in a stable tubular frame also featured on the space comfort shell and offering enhanced stability in the event of a collision. A further point is that the kinematic qualities of the seat system allow appropriate deformation of the backrest in a collision from behind. Through this change in the contours of the seat, the upper section of the seat backrest moves forward in an impact like a crash-activated headrest, preventing the occupant's head from flying back in a whiplash effect.

Yet a further advantage is that the ergo seat, through its structure alone, is much lighter than a conventional seat. Indeed, it is approximately 1.5–2 kg (about 10 per cent) lighter than the BMW sports seat and offers more functions on lower weight. In addition, the ergo seat takes up less space, with the particular advantage of greater legroom for the rear-seat passengers.

The best of each concept.

The three seat concepts are the result, at least in part, of the different approach and perspective now taken by the BMW Group. All of these philosophies show how the seat of the future may offer appropriate comfort and safety while becoming much lighter and therefore contributing to the reduction of fuel consumption. But exactly what the car seat of the future will look like still remains to be seen. The only definite point is that the best features and qualities of the three concepts will all go into the development of the car seat of the future.

1.3 Displays of the Future.

For many years the BMW Group has been examining how information may be presented best to the driver without distraction and with maximum safety and clarity. Introduction of the Head-Up Display in 2003 already marked a major, trendsetting step in this direction. In the process of consistently enhancing and optimising various display concepts, the BMW Group is currently focusing in particular on how to use the potentials of the Head-Up Display as well as the Central Information Display as the main display unit.

The basics: history and function principle of the Head-Up Display.
Presentation of important information directly in the user's line of vision has been an underlying principle in aviation ever since the 1940s. So it was only logical for the BMW Group to carry over this concept to the motor vehicle, offering it for the first time in the new BMW 5 Series in 2003.

This display concept presents a virtual picture on the windscreen visible only to the driver as if it were hovering above the engine compartment lid. A light source within the dashboard sends a beam through a transparent TFT screen and conveys the image through specially contoured mirrors on to the windscreen.

Using the windscreen as a reflector is a very difficult and complex task due to its curvature and the physical properties of glass. Normally the windscreen deflects and refracts the beam of light when entering and leaving the windscreen surface, creating double images in the process. To prevent this unwanted effect, the windscreen in this case comes with a special film superimposing images on one another in order to provide a homogeneous picture.

> "Our Head-Up Display remains the benchmark in terms of graphics, brightness and clarity, without distracting the driver."
> (Gunnar Franz, Head of Head-Up Display Development)

Ever since its introduction into the automobile, the Head-Up Display has not only been the most innovative and attractive place for presenting information in the car, but has also made a significant contribution to active safety by presenting information relevant to the driver in his direct line of vision, making sure he does not have to take his eyes off the road. A further advantage is

that this kind of display means less driver fatigue, since the driver does not constantly have to switch his eyes from close-up to long-distance vision. And last but not least, display brightness is perfectly adapted to the surroundings, without requiring the driver to adjust his eyes every time he looks back at the speedometer.

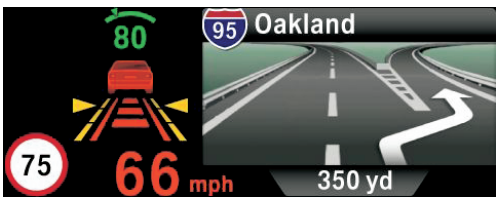
1.3.1 The Full-Colour Head-Up Display – Bright is Beautiful.

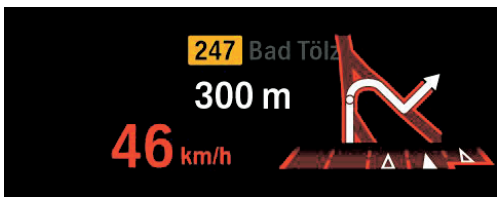
While the Head-Up Display previously used only the colours red, orange, yellow and green, the new full-colour Head-Up Display comes with the complete range of colours in the display area. This clearly offers entirely new options: While the driver currently has to process and understand usually simple symbol graphics, letters and figures – for example in the navigation process – the new concept makes it easier for the driver to take up information quickly and efficiently.

Full-colour presentation allows realistic and, as a result, even more intuitive presentation of images and symbols which speak for themselves, are easier to understand and allow specific action without first having to be decoded and interpreted. A further advantage is that full-colour presentation offers more appealing and sophisticated flair strongly underlining the premium character of the BMW brand. In practice, this means enhanced options in, say, the navigation function.

Presenting traffic signs for the first time in the Head-Up Display, the Speed Limit Indicator, as progressive as it may be, so far presents only signs and rules against a certain speed or activity. Now the full-colour display is able to authentically present all road signs such autobahn signs, exit and distance signs far beyond the borders of Germany.

In practice, this means clear presentation of highway signs in America or Australia, exit signs in Spain or Norway, and even the most complex signs and colours using Asian or Arabic letters. The advantage for the driver is that the signs are presented to him as a virtual signal, the same way they are positioned next to or above the road. They are identical in their shape, colour and contents, and make it much easier and quicker to take up and process the information required. Highway signs in the USA, for example, come in blue, white and red, while federal highway signs in Germany are bright orange.





Navigation functions already in use today may also be presented more clearly and understandably through full-colour presentation. Indeed, presentation similar to 3D with colour curves and perspectives might well enrich the navigation function in future, making it even easier for the driver to find the right way.

The objective of this development process is to ensure clear, harmonious, and standardised presentation of information within the vehicle. Wherever possible, there should no longer be any difference between the presentation of messages in the instrument cluster, in the Central Information Display in the centre console, and in the Head-Up Display. Information will then be presented at exactly the right point, in the same consistent style, with the same world of colour and brightness. This gives the driver clear signals and allows him to respond more quickly wherever necessary, no matter which instrument he receives the information from.

Consistent research for enhanced efficiency.
Following the principle of EfficientDynamics, BMW Group engineers are also working hard in the area of display technology, seeking to reduce the amount of energy required and enhance the performance of the system at the same time. Particularly the consumption of electric power by light sources plays an important role in the choice of displays, since presentation of a virtual image through the Head-Up Display on the windscreen under all ambient conditions requires a very high level of brightness. The information presented must, for example, be clearly visible also in reflecting sunshine on a wet road.

Since the introduction of the Head-Up Display, brightness has been increased from 7,000 to 11,000 candelas. Now, however, the challenge is to provide such a bright display on as little energy as possible.

BMW Group engineers have already succeeded in presenting the colours red, yellow, blue and their combinations in sufficient brightness in order to highlight the colour white with brightness from 10,000-11,000 candelas. At the same time they have significantly enhanced the level of efficiency in presentation by optimising the overall structure of the light source and its surroundings. So that while more than 100 LEDs were originally required in the Head-Up Display in order to achieve the brightness required, enhanced units now require less than ten LEDs.

A further potential in light technology lies in the travel of light from the source to the display providing the virtual image. While so far some light was wasted, going past the display, a sophisticated optical solution now ensures a much better light yield without any energy wasted. This almost halves the consumption of energy down from 13 to just seven watt.

1.3.2 Head-Up Display Max – More than 16:9.

The objective of the Head-Up Max Research Project is to enlarge the projection area and thus provide a larger image for new options in use. At the same time the Head-Up Display is to become more “intelligent”.

On the one hand this means integration of a wider range of functions, on the other it means the adaptive provision of information relevant to driving conditions in specific situations.

Only what is really important is presented on the display. Hence, the display control concept developed by the researchers priorises information individually according to specific conditions, offering the driver exactly the information he needs in each situation. Should the driver, for example, be adjusting the radio by way of the Head-Up Display, and then come close to the next turning in the road, the system priorises information from the navigation unit, overrides the radio menu, and gives the driver the appropriate turning information instead. Once the driver has turned into the next road, however, the system will automatically return to the previous function. At the same time the driver is able to actively interrupt the navigation information with its higher priority and continue the previous interaction.

The particular advantage of the enlarged Head-Up Display is that it not only offers the driver information through the display function, but also enables him to actively influence specific functions in the iDrive menu. Numerous tests have shown in the meantime that, controlling various functions through the Head-Up Display instead of using the Central Information Display, the driver may even benefit from greater safety and motoring comfort. He is therefore able to select and mastermind functions with the help of selection lists such as the address directory, the list of his last destinations or entertainment functions through control units on the steering wheel. And in the process the rule always observed is to provide only as much information as required in as simple a process as possible.

Challenges in the process of implementation.
The larger display area in the test car is formed by simply placing two conventional Head-Up Displays next to one another. The Display thus covers the entire area from the primary vision beam to an angle of 12° to the right, which means the full width of a person’s active area of vision. If it were even wider, the driver would no longer be able to recognise and focus on surrounding conditions at the periphery.

The biggest challenge in implementing this technology is currently the limited space within the vehicle. The main task for the engineer, therefore, is to reduce the dimensions of the image components in future, with solutions possibly being offered through the use of special lenses or laser projection instead of TFT technology.

"In the prototype I can work without air conditioning, which we had to remove in order to fit Head-Up Max. But we can't expect the customer to make the same concession."
(Natasa Milicic, researching options for an enlarged Head-Up Display)

Enlarging the Head-Up Display nevertheless involves a lot of work not only in terms of engineering. For to make the system safe and clear without the slightest distraction, and to ensure a high standard of comfort, the BMW Group is working hard on all of these aspects, long before their possible implementation in series production. Experts in the area of ergonomics, perception psychologists, electrical engineers and software engineers are therefore cooperating closely in order to achieve the optimum result.

Even before the start of pre-development, feasibility studies and various test structures serve to determine and eliminate features, components and systems not able to meet the significant demands of the development engineers. And once an idea has cleared this first obstacle, it must prove to be practical and sensible in various measurements and tests.

The BMW Group's six driving simulators serve as helpful tools in this process, enabling the engineers and researchers to examine and analyse the driving and operating behaviour of the vehicle. Various systems analysing the driver's eyes and visual behaviour are also applied in a number of test scenarios, recognising, for example, through changes in pupil diameter, the degree of cognitive awareness or distraction.

The knowledge gained in these test series goes straight into the ongoing development and technical implementation of the respective idea and is then tested again. Only if a function really offers added value without distracting the driver in any way will it be introduced on the Head-Up Display and, accordingly, in the car itself.

1.3.3 Must Displays Always be Black and Flat? The MINI Center Globe as Inspiration for Series Development.

Presenting a vision – this is the idea behind concept cars such as the MINI Crossover Concept. But it is obvious that such a vision must be based on realistic technology.

The MINI Center Globe is a good example of this philosophy, clearly proving the options and possibilities offered by the ongoing technical development of central display units. Instead of a single flat screen, the MINI Center Globe presents information on a transparent ball and on various levels. Such three-dimensional presentation allows the appropriate implementation of information and entertainment functions geared to each situation and individual conditions. For in addition to the displays currently in vertical and horizontal arrangement, the MINI Center Globe for the first time also uses the depth of space, that is the third dimension. Information is therefore presented on different levels with a higher or lower degree of clarity or urgency, depending on the user's personal wishes or the current situation.

> "Displays always used to be flat, black, and come in a frame. They offered very little freedom of design, particularly when switched off. Now the MINI Center Globe takes us into the third dimension of displays and presentation units."
>
> (Robert Isele, Display Technology)

The combination of Black Panel and laser projection technology in the MINI Center Globe allows crystal-clear and detailed presentation of all kinds of images, even moving pictures and films. Even today, therefore, the MINI Center Globe provides a good impression of the options available in terms of navigation, communication and entertainment in the automobile of the future, using innovative technologies in the process.

One of the technologies developed for this purpose has already entered series production, albeit in a very different form: Black Panel technology is already used in the instrument cluster and climate controls of the current BMW 7 Series. And while other visions still need some time to reach an appropriate level of technical development for use in production, significant progress has also been made here. The best example is laser projection, another feature of the MINI Center Globe

"We believe that the MINI Center Globe revolutionises the world of displays in the car. So the display of the future will be everything but boring."

(Robert Isele)

What makes the world go round? Or: What lies within the MINI Center Globe?

The MINI Center Globe combines the latest laser projection and Black Panel display technologies in the interest of optimum presentation quality. Quite literally, Black Panel technology sets the foundation for the MINI Center Globe, with a frameless Black Panel Display along the "equator" of the Globe using the same technology also featured in the instrument cluster of the new BMW 7 Series. This frameless, high-resolution display blends perfectly with its surroundings and is recognisable as a display only when switched on.

A transparent ball shell spreads out across this surface, comprising two spherically shaped, moving projection areas.

Through its spherical shape, the Center Globe allows three-dimensional presentation of contents, with clear and plastic rendition of "front", "rear", "top" and "bottom". Yet a further advantage is that the driver and front passenger may call up and check out different display contents and messages, the globe sections shifting to give the driver and front passenger different functions and information at the same time, to be seen only from their personal perspective. As an example, the front passenger may surf in the internet while the driver retains his free view of all instruments and displays within the MINI Center Globe.

1.3.4 Innovative Laser Technology – the (Bright) Signs of the Times.

The MINI Center Globe uses cutting-edge laser projection technology in the car for the first time in order to present all information in perfect, easy-to-read quality and style.

Compared with the TFT displays generally used today, laser projection offers several benefits: First, the excellent optical features of the laser projector ensure absolutely clear presentation without any distortion. The image is absolutely clear all round, even on spherical projection surfaces and several levels.
A further advantage of laser projection is the unusually intensive colours as well as a visibly brighter and more detailed image.

While laser projection technology is still in the early days of series development, it is already at least as good as TFT displays on all critical counts such as brilliance, colour, resolution, and the speed of reaction. This alone clearly proves the potential of this trendsetting technology.

Cooperating with powerful partners, the BMW Group is able to offer the latest technology also in the area of laser projection and is able to take new steps in the development process from an early point.

Through intense research, engineers have succeeded in the meantime in reducing the typical phenomenon of “speckles” generally encountered with a laser to an almost invisible minimum. “Speckles” are grains spread out across the entire screen and resulting from coherent light (the laser beam) being reflected by a refracting surface. On the surface the beam is reflected by various particles creating very fine magnification and light-cancelling effects, the latter being perceived as darker spots, the former as brighter spots.

Wherever many dark and bright spots come next to one another, the observer has the impression of a “grainy” image. This phenomenon can indeed be reproduced very well by a laser pointer directed at a wall.

Image with a significant “speckle” effect (left) versus improved presentation today (right); Patent:LBO

Laser projection technology for a brilliant video experience.
A particularly interesting option provided by laser projection is to present moving pictures with a level of quality never seen before. To perceive a steady and fluid image without jitter, the human eye and brain must receive at least 24 images per second. Laser projection already offers 50–60 images per second and, as an additional advantage over TFT displays, laser projection does not require any shifting time worth mentioning. This means no delay in building up a picture, which with fast-moving images may otherwise result in ugly streaks or shadows.

A further advantage particularly in a vehicle is that laser projection is independent of ambient temperature, while even a good TFT screen slows down the image at room temperature by approximately 5 milliseconds and makes the image even slower at colder temperatures. The delay encountered with laser projection, on the other hand, is only about 0.25 milliseconds.

> "As soon as we introduce laser projection, many people will get into their car just to watch tennis or football."
>
> (Robert Isele)

A particularly important point in the projection of images is the brilliance of laser projection. "Brilliance" is the interaction of possible colours (colour range) and contrasts. The benchmark for the range of colours to this day is the NTSC standard introduced by the National Television Systems Committee in the USA comprising all colours a cathode ray television is able to present.

The best TFT displays and, respectively, the best flat-screen TVs available today achieve 70-90 per cent of this standard. The laser, on the other hand, covers the complete range of CIE colours with the full scale of all colours the human being is able to perceive, equal to 200 per cent of the NTSC colour range.

This improvement of display quality is roughly comparable in its magnitude to the transition from the first colour mobile phone display to the display on a modern Smartphone.

Bundled light for optimum use of energy.
The technologies used today have already reached their highest level in terms of brightness, with no potential for further improvement. The laser, by comparison, already reaches this level today and is much better in terms of light contrast.

A problem with conventional TFT screens is back-lighting of the display surface, which also affects deactivated pixels, while the black we see is actually nothing but dark grey. In laser projection, on the other hand, only the pixels actually required are illuminated with the energy needed – which means that black is always black in the case of laser projection.

This makes this display technology far more economical in saving resources.

BMW displays already use much more efficient transflective technology which, contrary to displays illuminated from behind, also use incoming light to illuminate the screen by penetrating the screen and reflecting light beams from the back of the display.

Apart from optimum clarity and readability under all light conditions, the advantage of this technology is its potential in saving energy. And following the rule that everything is open for further improvement, the development specialists and engineers working in this area are constantly in search of new savings potentials.

On a dark background with lines on the surface (letters and writing), laser projection is more efficient by a factor of ten. The Head-Up Display also reaches or even exceeds the factor of ten, while the level of efficiency with video projections is more in the range of four to six. This means that laser projection, despite the increase in brightness and brilliance, is even more economical and efficient than a TFT display.

New visions – Concept BMW Vision EfficientDynamics.
BMW Group designers and engineers are already considering new, even more innovative solutions over and above the technologies presented. So when it comes to displays, a further option in the BMW Vision EfficientDynamics concept car once again sets the standard of technology in the car of the future.

1.4 Active Sound Design – a New World of Sound.

How “maxi” can a MINI sound? Can you hear the joy of motoring? And what is the sound of hybrid? Precisely these questions are being asked by the BMW Group’s Acoustics Department.

Looking back in time, the examination of acoustics in the automobile initially meant the avoidance and suppression of unpleasant noise. No squeaking, whistling, rumbling or rattling was to disturb the driver and query the quality of the product. But soon it became clear that there was an enormous potential in not only making the car not sound bad, but rather in making it sound really good. Ever since, switches have delivered that pleasant “thump” when operated, doors close with the solid sound of quality, and the engine with its sound engineering also enhances the sporting overall character of a premium car.

The optimisation of annoying sound has therefore developed into pro-active sound design, leading to qualities such as psycho-acoustics, brand sound, and the emotionalisation of products. A further point is that acoustic enhancement of the subjective driving experience again offers significant advantages, giving the acoustics engineer a new, interesting challenge.

Active acoustics technologies developed in recent years from active noise control into a powerful tool for active sound design have now become one of the tools used by acoustics engineers in their work. Apart from the extremely efficient modification of sound, simple and convenient adjustment and modification of the acoustic experience is a particularly important feature of this technology.

Sound on demand.
Cruising in town with the throaty chortle of a V8 and, just a bit later, driving dynamically along winding roads with the sporting sound of a BMW straight-six? The MINI prototype developed by the BMW Group’s acoustic engineers is able to offer both at the touch of a button, thanks to active sound design. The idea, quite simply, is that the driver can decide himself whether to enjoy a powerful sporting sound or whether he is currently in the mood for a quieter and more discreet sound from the engine.

Active sound design controls the perception of sound within the interior through a sophisticated electro-acoustic system. To generate the sound impression desired, the actual sound of the engine is modified by the addition of further sound elements selected and fed in by a sound generator. Applying constantly updated vehicle data and sound design data generated in advance, a digital sound processor delivers the additional signal appropriate for current driving conditions. So through such specific control and management of the car's acoustic feedback, the driver and passengers are able to enjoy a new level of motoring pleasure and a truly thrilling driving experience.

The sound of an engine is interactive and, for this reason alone, highly emotional: the engine responds to the driver, the gas pedal, and the speed of the vehicle. We know not only from motorsport that the sound of an engine is able to give us goose bumps. Active sound design therefore offers a significant potential in emotionalising the driving experience with a strong influence on the driver's and passengers' subjective feeling.

But apart from the fun factor, the emotionalisation of the driving experience, this technology still offers a far greater potential. With engines becoming smaller and more fuel-efficient, and with automobiles perhaps not even having a combustion engine any more in the not too distant future, how should an economical but nevertheless dynamic car sound in practice?

The significance of the sound experience in driving:
you can hear driving dynamics.

To understand why the sound of the engine has a strong influence on the subjective perception of driving dynamics, we must first take a closer look at the process of human perception. Processing information, the human brain first picks up individual perceptions, compares these impressions with past experiences, and processes the results obtained in this way to generate an overall experience. A further point is that individual sensory perceptions come together to set off any possible lack of information and ensure that we understand what we perceive. This means that many impressions are combined with one another and that the human being can hardly decide consciously between individual forms of perception.

What does this mean in our perception of driving dynamics? With all sensory impressions supplementing one another in forming the overall experience, driving dynamics is always an auditive phenomenon. Apart from the straight-line and lateral acceleration we feel, there is also the acceleration we hear, that is the sound of the engine under load and when accelerating, all this contributing to the subjective experience of driving dynamics.

Depending on the engine sound pattern, we perceive a vehicle as dynamic – or we do not. The important point in either case is the right combination of all sensory perceptions, with an engine that sounds good not necessarily conveying a dynamic driving impression.

To verify these theories, BMW engineers took two completely identical cars and then varied the sound inside the passenger compartment by means of active sound design. The driving tests then conducted confirmed precisely the phenomenon described above, test persons firmly believing that the car with a more dynamic engine sound accelerated faster and was more dynamic in its behaviour, while they perceived the other vehicle as “calmer” and “more discreet”.

Why does an engine sound the way it does?
To appropriately adjust the acoustic driving experience, the engineers first had to identify the components responsible for the respective engine sound, since every type of engine has its own and characteristic sound effects. While a straight-six sounds more sporting and “throaty”, a four-cylinder has a more refined and gentle sound. But what, in the first place, makes an engine sound the way it does?

Every engine comes with specific sound components creating its individual sound pattern – components referred to as various levels of engine order. These sound factors the frequency of which is always a multiple of the respective engine speed show characteristic lines in the sound spectrum and make a significant contribution to the sound actually experienced. Depending on the type of engine, these characteristic lines come in a different frequency range and vary in their magnitude. In the sound of a four-cylinder, for example, the second engine order plays a particularly dominating role (frequency = engine speed x 2), while in a six-cylinder the third engine order is the decisive factor (frequency = engine speed x 3). Depending on these levels of order and their surrounding conditions, the sound of an engine shows different levels of modulation ranging from rough to smooth or powerful to gentle.

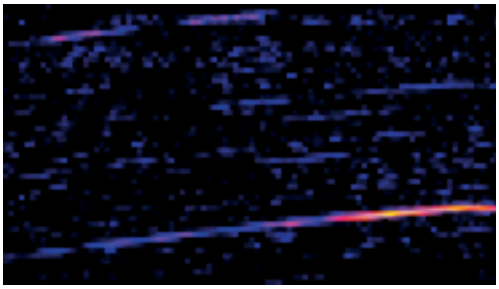
Depending on how the respective orders respond in their amplitude to changes in driving conditions (gas pedal and load), the engine is regarded as “powerful”, “dynamic” or more “reserved”. This creates important aspects in the subjective impression of driving dynamics, which may be influenced specifically and directly through active sound design.

How does active sound design work in practice?

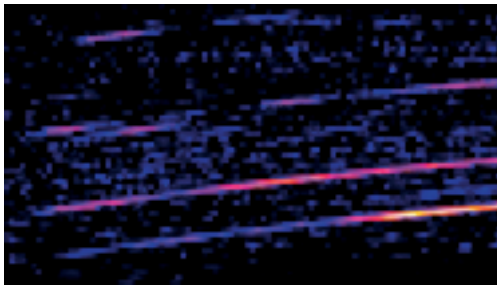
Classic sound design is based on the selective transmission and amplification of desired sound components and the absorption and damping of unwanted components. In the sound of an engine the sound experience is modified in the intake area and on the exhaust system and optimised through appropriate body damping and interior acoustics reflecting the character of the respective vehicle – quite simply, the sound must live up to the promise of emotional BMW or MINI design and the sophisticated substance of the product.

Sound design these days is required to meet increasing challenges: The need for minimum space and lower weight, the use of modern powertrains optimised for greater efficiency, as well as more restrictive exterior noise legislation are just some examples.

This is where active acoustic processes, in combination with conventional optimisation, offer completely new solutions through direct management of the sound perceived largely independent of the transmission path and the particular characteristics of the original sound.

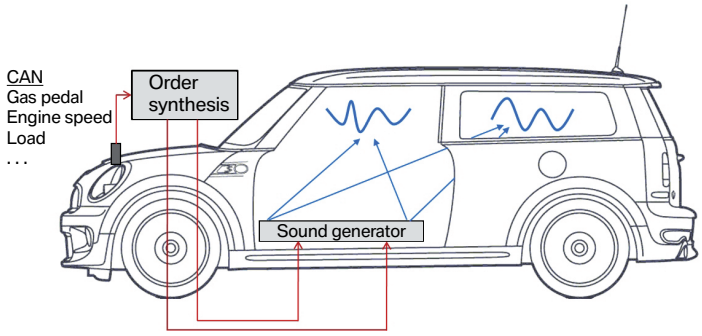


Engine order of the original sound pattern



Engine order of the modified sound pattern

Applying vehicle data such as road speed, engine speed, engine load or the position of the gas pedal permanently determined and made available by the CAN (Control Area Network)-bus, specific order components enhancing the character of the respective vehicle are added to the perception of sound through active engine sound design. Proceeding from these parameters as well as the sound data already saved within the system, a digital signal processor generates the desired order signal in real time, combining this sound signal in the interior with the original sound to provide a smooth, homogeneous and authentic experience in sound.



Block diagram active sound design

Given the wide range of vehicle data considered and the synthesis model used, the software is very flexible, allowing the sound engineer to intervene in a manner either quite impossible or at least extremely complicated with conventional technologies. In all, active sound design is an efficient weight- and space-saving philosophy which may be integrated relatively easily in existing vehicle architectures.

Creating good sound is hard work.

While active sound design is based on a relatively simple idea, the actual process of implementation creating a well-functioning sound system is highly complex. So while the block diagram looks relatively straightforward, the engineers are faced in reality with big challenges. The objective is to supplement the original sound so that the newly generated sound pattern is superimposed perfectly on the original signal, the two signals supplementing each other as an ideal match.

A particularly important point in this process is to provide the new sound pattern with virtually no delay, since any lack of harmony in feeding back the sound will immediately be perceived by the driver as “fuzzy”, failing to convey the experience of dynamic power and create the thrill of driving pleasure desired. To convert movement of the gas pedal directly and authentically into the sound desired, the transfer of data must be particularly quick and latent periods must be reduced to a minimum. The challenge, among other things, is to correlate the experience in sound with specific action not foreseeable and different every time. So regardless of how fast or slowly the driver accelerates, the audio signal must always be smooth and harmonious, being perceived at “the same time”.

The human being is very sensitive in this respect, recognising any delay as a kind of interference and realising that the sound is not authentic. The human brain registers such disharmony even down to the two-digit millisecond range.

The design of the optimum overall sound pattern for the vehicle as a whole is likewise anything but a trivial process, with the wide range of different parameters making sound management particularly difficult in this case. To achieve optimum results, the engineers therefore cooperate with specialists in psychoacoustics and ergonomics, as well as designers. For while machines can provide a lot of support in the process of development ranging from analysis all the way to simulation and driving tests, the human being is ultimately the crucial yardstick. So man and machine must work together to provide the optimum all-round experience.

Active sound design in the MINI prototype.
Active sound design in the MINI prototype seeks first and foremost to enhance driving pleasure, giving the driver the opportunity to express himself through the MINI. The motto, therefore, is: MINI – it's me.

Precisely here the system offers brand-new options in personalising and customising the driving experience. Depending on how the driver and his passengers feel, they may choose an appropriate engine sound within the car, a sound conveying the more extroverted character or the current emotions of the driver. In this way one can give the car the sound it needs or the sound the driver would like it to enjoy. This is the right kind of sound design within the interior, the sound the customer would like to enjoy right now – customisation of the highest standard.

With active sound design being based on an electronic system, it may be controlled and deactivated at any time. This gives the customer complete freedom in using the added value and benefits of the system. Like music, active sound design may help to support your inner emotions – whether intense or calm, either boosting your feelings or intentionally doing exactly the opposite.

In conjunction with other innovative technologies, sound design turns the interior of a car more than ever before into a genuine overall experience. The interior is emotionalised, creating, say, a dynamic driving experience full of dedication on several levels.

Since people these days spend more and more time in their car, they should also be able to enjoy this time as much as possible. But even so, emotionalisation of the vehicle will not work the same way in future for every customer. Active sound design enables the customer to decide himself on his sound experience and actively choose what he currently wants to enjoy in reflecting the way he feels.

Outlook – what is coming in future?

Active sound design as the conscious change and management of engine sound – what "sounds" more playful in the MINI prototype offers an enormous potential for the future. Looking even further ahead, this might help to give diesel engines their own characteristic sound of sporting performance no longer associated in any way with a truck or commercial vehicle. A diesel, therefore, with sound characteristics truly reflecting the dynamics and torque of the engine.

> "BMW design promises a certain sound. The customer gets into the car and expects an appropriate sound experience when he starts the engine. The key to this experience in future is active acoustic systems."
> (Albert Kaltenhauser, Head of Airborne Sound, Acoustics and Vibrations)

Although active acoustic systems may also be used for the exterior, all of the sound experiences presented so far relate to the interior. This option to create a different sound experience outside and inside is indeed another important feature of sound design and engineering. It means that the driver may create his own specific driving experience within the car as he desires, without in any way harming or disturbing the environment.

Over and above active sound management by the driver, active acoustic systems may also be used for a more subliminal effect. Indeed, studies are currently being conducted in the context of BMW EfficientDynamics on how the gearshift points in today's cars may be enhanced and supported by an appropriate acoustic effect.

2. Infotainment of the Future.
2.1 MINI Gets Connected – the New World of In-Car Entertainment.

A very special idea has been making growing inroads into the MINI world ever since the year 2001 – the vision of intensifying the interaction of man and the machine, allowing two-sided communication of car and driver, and thus making the time the driver spends in his car as pleasant as possible. The question is how can information from the car be converted into exciting experiences and new functions for the occupants? The problem at the time was that the technology required for making this project reality was not available.

With technology and society having developed to a higher level in the mean-time, the vision of 2001 is now becoming reality: MINI Connected is introducing the modern world of communication into the MINI, opening up brand-new perspectives in the process. In other words – MINI Connected shows what is possible when integrating an internet-compatible consumer electronics (CE) device such as a Smartphone into a MINI and consciously giving this device specific data from the car.

Serving as an innovative spearhead in technology, the MINI Connected proto-type and other technological test-beds for the first time offer comprehensive integration of CE equipment within the car, bringing together the vehicle itself, mobile information, and entertainment.

MINI + Smartphone = MINI Connected.
Everything you need for MINI Connected is a MINI equipped with MINI Connected and an iPhone, as well as the right software application. The Smartphone is connected directly to the MINI through a special interface. As soon as the customer starts the MINI Connected application on his Smartphone, brand-new functions are provided and made available in typical MINI style.

> "MINI Connected combines the currently most popular technology with the most exciting car in the market."
>
> (Dr Ralf Hoffmann, MINI Product Management)

The idea for MINI Connected has been considered within the company for quite some time – and now progress in technology, economy and society allows (and even demands) the introduction of this concept.

Particularly the MINI customer wishes to enjoy his or her world of mobile entertainment and readily available information also in the car. The various features of MINI Connected therefore serve to fulfil this need in innovative, informative and entertaining style.

The MINI 50 Camden already offers the first application of Mission Control in a production model, even though this model is not yet "connected", meaning that it does not yet have a Smartphone interface.

The bottom line, however, is that MINI Connected is already making significant progress towards its introduction in series production.

The MINI customer has a strong penchant for technology and is trend-minded, which is also why he or she tends to use the latest CE equipment. And the MINI customer wants to use these devices everywhere, also and in particular in his MINI. We know that the MINI customer is very modern. This is precisely why we are the first to introduce these technologies and interfaces in the market, so that MINI will set the standard also in the long term with new functions based on sophisticated Smartphones."

(Dr Christoph Grote, Head of Development of Information and Communication Systems)

Why Smartphone?

What added value is provided by integrating CE equipment in the car? First, integration of such equipment makes the car independent of vehicle development and lifecycle periods, while the second advantage is that the car becomes part of a larger world.

"Integrating the CE environment closely into the car, we are participating in and benefitting from the quick and ongoing development of the functions involved. We are able to combine the full innovative power of this industry with our own products."

(Dr Peter Lehnert, Head of Early Phase Information and Communication)

A Smartphone is already a central interface used not only for making phone calls, but also for saving contact data, updating your calendar and downloading data such as music or videos – not to mention the provision of mobile access to the internet. A lot of the information, data and functions available on the Smartphone may also be used in the car at any time thanks to the integration of these systems.

New functions and features are becoming available almost every day, expanding the overall range of functions, upgrading the current systems and making them really appealing also in the long term. Applications specific to the vehicle provide the further option to carry over these benefits to the car itself and the motoring experience.

"We are naturally continuing the development process to offer the driver new features time and again – new and up-to-date every time."
(Dr Peter Schramm, Projekt MINI Connected)

"MINI Connected Live" – bringing the whole world into your MINI.
MINI Connected is subdivided into two basic functions bearing the project names "MINI Connected Live" and "MINI Connected Buddy". The former, "MINI Connected Live", uses internet access through the Smartphone brings applications into the MINI using structures outside the car, whether it is information downloads or access to data outside the car relevant under current driving conditions. This creates a communication channel bringing the world into the car while driving and at the same time putting the driver in touch with the world. In the process "MINI Connected Live" also allows the use of Google services such as Local Search or Send-to-Car. The latest information and all important data is therefore immediately available, everywhere the driver goes, also while driving, in an intuitive process.

"MINI Connected Live" also enables the driver to connect to existing Social Communities such as Facebook or Twitter. Even while driving, therefore, the user may exchange short status reports with friends or acquaintances, communicating specific data such as his current location, destination or road speed as his current status through Facebook or as a tweet through Twitter.

To do this the respective application accesses the appropriate vehicle data and enters the information retrieved in this manner into pre-fabricated messages or status reports. And naturally contact data saved within Communities may also be transferred to the vehicle's directory of addresses.

"I'm on my way to Hamburg and I'm travelling at a speed of 123 km/h."
(Example for a tweet from a MINI on the autobahn from Berlin to Hamburg)

The Web Radio application offers internet radio in the car for the first time. So whether it is news or music, international or regional – the large and well-assorted station database leaves nothing to be desired, offering every kind of music through numerous stations in many countries. Whether it is the latest club hits on Ibiza Global Radio, South American music transmitted by Interactiva FM from Brazil, radio shows or newscasts on local or global stations, Web Radio makes the world smaller and diversity bigger.

"MINI Connected Buddy" – MINI, your friend.
The prototype of "MINI Connected Buddy" also provides access to data via the Smartphone, the only difference being that in this case the data comes from within the car itself, and not from outside.

All data and information in the vehicle comes together in the car's bus systems, normally without the driver even noticing what is going on. Now "MINI Connected Buddy" makes the driver aware of this information in new style again typical of MINI. The driver should therefore participate actively in the "life" of the car and be integrated even more intensely in the entire technical and automotive environment. Conversely, this gives MINI even greater personality, with some functions being implemented most clearly with that "twinkle in the eye" so typical of MINI.

The idea for "MINI Connected Buddy" dates back to the year 2001 and comes from the BMW Technology Office in Palo Alto, California. The vision created there was to revolutionise the man/machine interface within the car and raise the options for interaction to a new, unprecedented level. The objective was to convert vehicle functions into acoustic entertainment, in the process creating

a car with personality and character. And while an initial prototype using elaborate, integrated solutions was even built at the time, technology and society were not yet ripe for such a development.

> "We wanted to leave behind everything conventional. We had a vision, but did not know how to get there. So what started as an experiment, subsequently became more and more specific and down-to-earth."
>
> (Bernhard Schambeck, one of the creators of the idea in 2001)

Mission Control.
Mission Control, one of the MINI Connected Buddy functions, was already part of the first research project in Palo Alto.

The consideration involved in this case is quite simple and straightforward: While the driver's sense of touch and vision are already highly activated while driving, there is still ample capacity left over in his auditory sense. So it was only obvious to consider the option of transmitting messages no longer as a sound or light signal, but also through voice communication. Hence, Mission Control communicates directly with the driver and passengers in the car.

The new generation of in-car entertainment systems is making its debut in the special MINI 50 Camden production model, three characters quite different through their voice alone sharing out the task of communication. While the Coach is responsible for addressing the driver, two Assistants deliver helpful information on the powertrain, driving conditions and the MINI's comfort functions to the Coach.

In all, Mission Control, depending on the car's level of equipment, is able to consider up to 120 different driving situations, operating conditions and other events, with 15–40 different statements available in each case. All together, this means more than 1,500 different acoustic messages offering an ongoing exchange of information in traffic situations frequently encountered.

The messages come in English, the "mother tongue" of the MINI, again with that twinkle in the eye so characteristic of the brand.

Mission Control is firmly installed in the MINI 50 Camden in a special control unit, meaning that it does not yet offer further options for expansion or upgrading which will be provided in future through MINI Connected and the integration of CE equipment.

Added value on several levels.
Apart from straightforward entertainment, Mission Control also comprises a highly functional component offering the driver helpful information over and about the systems already in place in order to interpret different driving conditions and take appropriate action. As an example, Mission Control informs the driver when he is setting off with the handbrake pulled, when the doors are not properly closed, or if he is revving the engine too high while still warming up.

Mission Control considers ways and means to save energy, advising the driver at high speeds to close the windows in the interest of better aerodynamics or to switch off air conditioning when opening the window while driving.

In future Mission Control might also take over further functions, serving, for example, as an "ecological" driving instructor advising the driver, again with that twinkle in the eye so typical of MINI, to drive more smoothly and consistently in the interest of better economy.

The "MINIMALISM Analyser" integrated in "MINI Connected Buddy" would then help the driver analyse his trip after reaching his destination, comparing the journey with former trips in terms of fuel economy, average speed or the time spent travelling.

"Dynamic Music" and sound effects.
The MINI prototype presented at the Innovation Day for the first time enable the driver and his passengers to underscore the driving experience through adaptive music ("Dynamic Music") and appropriate sound effects. So whether the driver is taking a bend dynamically on a country road, driving at top speed on the autobahn, cruising along in city traffic, the music played by the car will change in every situation thanks to Dynamic Music, reflecting the current driving situation and its level of dynamics.

"My MINI prototype gives me the perfect sound track in every situation. The gas pedal, steering wheel, direction indicators, and the brakes are my DJ console and I am the arranger of the music through my style of motoring."
(Bernhard Schambeck, involved in the project from the start)

Depending on driving conditions and the situation in general, the music changes in its rhythm and intensity, with sound effects enhancing the musical driving experience once again in specific situations and incidents. As an example, the sound of the direction indicators is integrated rhythmically in the music played or the music shifts in fast bends like an acoustic mass from right to left and left to right in a stereo panorama.

To accompany the driving experience, a large number of pre-fabricated music files respond in accordance with the parameter settings entered in advance. Which layer is added in which case depends, for example, on how fast the car is travelling, how far the driver has pressed down the gas pedal, or how fast the car is accelerating either straight ahead or in a lateral curve.

The music played adjusts to every style of motoring, Dynamic Music supporting the subjective driving experience by strengthening the bond between car and driver.

MINI Connected turns the inside into the outside and vice versa.
With a fully portable mobile terminal, MINI Connected may be used not only within the car. Indeed, three different scenarios in using MINI Connected are conceivable, each with a broad range of functions.

The first point is that the driver is able to use specific functions through the appropriate control interface while driving. The second and particularly interesting option is the use of MINI Connected outside of the car itself, with the various applications of “MINI Connected Live” being available for use also beyond the vehicle. The driver having found a flower shop through Google Local Search, for example, may not only drive to his destination by car, but also maintain the navigation function when walking the last couple of metres on foot with the help of his Smartphone.

A wide range of other functions is also conceivable in future, for instance with the driver using his Smartphone to check, say, the charge status of the battery in his MINI E, without even having to get into the car. He would also be able to climatise the car shortly before setting out with minimum use of resources as long as the car is still connected to the electric ”fuel pump”.

One-sided becomes two-sided – challenges in the implementation process.

The main challenge with MINI Connected is to integrate the CE device and its many functions “cleanly” and “deeply” into a given process. Since MINI Connected may be used not only to mastermind more Smartphone functions through the car, but also to enable new functions to access data from the car itself, the software development specialists have to meet a particular challenge in developing appropriate concepts and adaptations. The first necessity is to adjust the interface, the second is to develop applications appropriate and specific to the car. Connection to Smartphone and the internet requires particularly high security standards to properly protect both data on the Smartphone as well as, in particular, in the car itself, in the interest of appropriate privacy.

To use the functions available in the car also while driving both safely and conveniently, the next requirement was to integrate these functions in the vehicle’s display and control concept. This is done by the Remote Human Machine Interface, with the processes available in the CE system being conveyed into the car through a specific interface, presented in the Central Information Display, and masterminded by the car’s control logic (MINI Joystick, multifunction steering wheel).

The MINI display and control concept is the result of intense research and is conceived in particular for intuitive control while driving. Hence, only this specific display and control concept fitted at this point in the car ensures optimum ergonomics, user-friendliness and safety.

If a display and control concept optimised for the car is also to allow the integration of infotainment services developed after the vehicle was delivered to the customer, it is essential to bridge the gap between the long service life of the car and the far shorter innovation cycles in consumer electronics.

Model-based development of the Human Machine Interface by the BMW Group meets this demand by opening up the car for re-loadable services, that is mobile terminals, web applications or software downloads. The customer will therefore be able to use these services quickly and conveniently in future, in accordance with the specific features and technologies installed in his car. With the BMW Group, this means intuitive, straightforward and ergonomically perfect use of such systems without distraction. Apart from the comfort of ongoing, consistent use of the equipment available, the main benefit for the customer is enhanced safety and the knowledge that his car and the systems installed are always in line with legal requirements.

Semantic information through enhanced flexibility.
The various control options and types of driver information are made particularly dynamic by services subsequently downloadable and providing a semantic description of their user interaction. Applying generator rules, graphic control elements may then be generated specifically for each vehicle using concepts from the Semantic Web to provide clear terms for describing the HMI features of the service and its requirements for suitable control and operation.

The author of the HMI description service thus provides detailed information on the type of service, its presentation and operation. In the process he need not even know in what model (and, therefore, on what head unit) this information will be applied and presented on a specific user surface. Hence, a music player may, for example, be identified as an “audio play service”, with the HMI control buttons then being provided for the appropriate operations “play”, “stop”, “pause”, etc.

A further advantage is that the user interaction service only has to be described once and may then be used on all models, since the application is the same in each case.

Yet a further benefit of semantic information is that it allows interaction of services which did not know each other before. All they have to know is the service they are to interact with. As an example, a location-based search service may log in as a supplier of geographical addresses, enabling the user to download the search results – that is addresses – at the touch of a button as the final destination in the navigation system. Should the service also supply telephone numbers, these will automatically be downloaded into the telephone function, the dynamic HMI thus enabling the user to combine a random number of services in many different ways, even covering services which did not even exist when the car was built.

2.2 “Rock-Island” or “Jazz-Archipelago”? – the MINI Music Map.

Portable data memories these days offer increasingly large data capacity. The current iPod Classic, for example, offers up to 10 GB memory capacity for music and other files, equal to about 40,000 titles the customer would naturally like to access also while driving. And now the MINI Music Map Research Project shows how such enormous music files may be displayed and made accessible in the car.

New, innovative solutions are needed to ensure quick and easy access to such a large volume of data. Precisely this is why development engineers in the BMW Group Research and Technology Division are concentrating in the Man Machine Interaction (MMI) project on better ways and means of presenting and using information. While the current presentation of such information on text lists is naturally well known and allows intuitive control and operation, it provides only a limited overview of the contents and their general context.

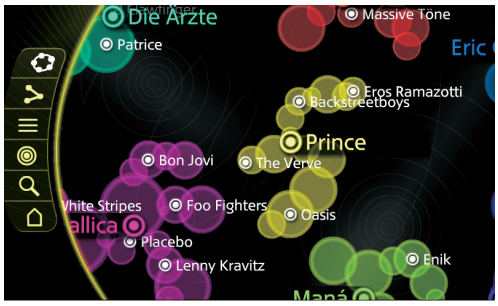
This is a drawback particularly in using files with “fuzzy” or unclear requests. In many cases the driver wishes to enjoy a certain kind of entertainment or genre, he knows roughly what he wants to hear, but he does not necessarily know of a specific album from a specific artist – quite apart from the fact that he does not know his complete music selection by heart.

In practice, therefore, the driver will rarely look for explicit data entries, but rather for certain groups of files meeting certain criteria. Precisely with this in mind, the researchers have developed a visualisation option serving to cut down the driver’s choice to certain categories while nevertheless fulfilling his music wishes – the MINI Music Map.

Browsing through your music files.
The MINI Music Map presents the user’s music files in two dimensions like on a geographical map. Map presentation is indeed very suitable for this purpose, since this kind of display has already been used for decades to provide orientation, for simplification and communication.

Within such maps, the artists and their respective music genres serve as points of orientation. The colour of individual "islands" within a group of islands then stands for specific genres, the size of these groups of islands varying according to the number of titles filed for a certain artist. Depending on the zoom factor, well-known artists stand out as "lighthouses" showing which genre this specific group of islands involves. The further you then zoom into the individual groups of islands, the clearer the separation of islands becomes and the number of artists presented increases accordingly.

The advantages of the MINI Music Map are that, first, this type of presentation offers a comprehensive overview and, second, the driver arrives at the information he is seeking within just a few steps.



This allows the user to make a "fuzzy" choice of the genre covered by a specific artist, the program then putting together a route via the group or groups of islands. And should the driver use the search function, a spotlight will guide him to the artist or genre he is looking for.

After arriving at the proper address, the driver may either stay where he is and hear more from the artist chosen or move on to his next "destination", the next song. Various filters then allow further adjustment, so that the driver hears only music, say, from a certain decade – or the songs he hears most often.

"This allows you to enjoy your music collection in a way you have never done before."

(Dr Verena Broy, Project Manager Music Map)

Meta-data creating clear order within the system.

Apart from music, the music files also provide specific information on themselves, that is "meta-data" such as the artist, genre, the length of a song or the frequency with which it has been played. And since this process is used to automatically assort and arrange titles within the music landscape, the driver is no longer required to elaborately arrange his files.

Even so, the use of meta-data alone does not ensure the final, 100 per cent allocation of artists to specific genres or groups, since such meta-data do not necessarily correspond to the "human" perception of music. So proceeding from the particular know-how of music experts, the specialists have developed an appropriate top graphic arrangement for even better adjustment and a more efficient search process also within the individual genres.

In future the MINI Music Map might by all means be integrated in "MINI Connected Live", providing additional information on the artist and the song through the internet interface. This, in turn, would allow the user to share his current music route with others through communities or to create special editions of music maps for certain events. Another option would be to present the wide range of web radio stations on a map. But at the moment all this is still unchartered territory of the future.

Tried, tested, and approved.

The MINI Music Map has received very good results in its first user tests checking how intuitively this style of presentation and operation may be used in practice versus the usual presentation in lists and whether the MINI Music Map is seen in a positive light. In these tests the individual test persons wore special occlusion glasses with lenses dimmed individually. Restricting visibility in this way, the testers are able to simulate the driving situation and draw conclusions on important parameters such as distraction from the actual operation process, "blind" control of the system as well as the driver's eyes moving away from and towards his task in driving the car.

The tests show that this kind of visualisation requires only four of five tries for significantly faster control and operation of the functions desired and is seen in all to be more attractive. The test persons prefer this kind of visualisation because of its greater practical value, more attractive presentation and greater ease of use, stating that it is even better than the usual presentation on an iPod. And through their three-dimensional memory, the test persons find it very easy after a short time to follow the map presentation.

2.3 Video Always and Everywhere – Personal Video from BMW ConnectedDrive.

Television has become digital ever since the introduction of DVB-T (Digital Video Broadcasting – Terrestrial) and DVB-S (Digital Video Broadcasting – Satellite). But the individual viewer is still restricted in his choice, only being able to change from one station to another. Specific topics, contents or formats remain available only at a certain time of the day, when they are actually broadcast.

Introducing the Personal Radio Research Project in the context of BMW ConnectedDrive, the BMW Group development engineers were already able back in 2007 to take the first step towards the interactive selection of media and individual programming in the car. Personal Radio provides access to a wide range of audio content, IP-based services enabling the listener to receive a broad choice of radio programmes from all over the world – depending on how he feels, and regardless of both his current location and the time of day.

> "We want to offer the customer his own programme he can adjust and change himself. Receiving clear recommendations, he should be able to watch the programme he wants himself in future, wherever he goes and whatever the time of day. Not just when the programme is broadcast. And all this he must be able to enjoy in the car."
>
> (Thomas Helbig, Personal Video Project Manager)

Personal Video for the first time offered the opportunity to access the wide range of video programmes provided in the internet directly in your car. The first step was to link the car to newscasts broadcast by the Bavarian Broadcasting Corporation. And at the moment a brand-new video world is being created based on the mediatheques offered by public service broadcasters and video portals such as YouTube or Clipfish.

The highly attractive asset offered by these providers is their constant availability – individually on demand, whenever the driver wishes. This only requires a sufficiently powerful internet connection in order to provide the data capacity required through a mobile link, as well as the availability of online mediatheques allowing individual access to the contents desired.

The high standard of video presentation quality ensures both informative and attractive presentation of contents – a significant benefit in the case of short reports and information programmes such as the news. Additional video information serves to convey substantial content to the viewer within a very short time, compact and attractively prepared formats meeting the demand in today's world as well as the need for consistently available, up-to-date information. We already see a strong trend towards online use of the media, but at the moment the quality of the videos offered is not always very good.

Video formats at the touch of a button.
Receiving the latest information within 100 seconds – the "Rundschau news" broadcast by the Bavarian Broadcasting Corporation offers a compact overview of all major events during the day. Updated several times a day, the programme always carries the latest news.

Personal Video makes this information format available also in the car – together with many other formats to be introduced soon. With intuitive control by iDrive, the driver is able to pick the video he wishes to see, watch the video and receive comprehensive information on the day's events within just 100 seconds. And he can say himself whether he would like to watch the news shortly before setting off or during the next somewhat longer stop, for example at a railway crossing.

"Personal Video offers me the news from my favourite station even when I'm on holiday at the seaside."
(Dominik Schnieders, research engineer and first test user)

Outlook for the future.
The internet is developing rapidly – and so are many options in using this service. Video portals such as MyVideo or YouTube offer the opportunity to present all contents online and retrieve whatever you wish any time you like. So you can watch what you want when you want, as long as it is available at all.

Personal Video from the BMW Group now offers this option also in the car, just as BMW seeks to offer the customer his own individual programme in future. A programme the customer may put together himself, personalise, adjust and modify. As a further feature, Personal Video shall also provide the customer with individual recommendations helping him make his choice from the wide range of contents offered in the internet.

An important factor in this context is the designation of specific contents by meta-data. With broadcasting contents being digitalised, there is now the option to specify contents through additional descriptions or key terms in order to allocate them to individual themes or categories. And once the driver has compiled his favourite programme several times, the car will gradually "learn" which preferences and viewing habits the driver has. So proceeding from this choice expressed by the driver, the car is able to make specific recommendations the driver is then able to modify and refine, as is already possible today with various intelligent playlists offered in music programmes. And it goes without saying that the driver's personal data is kept private and fully protected at all times.

Wherever a good broadband connection is available, the car would be able to download the driver's favourite contents at an early point in time before the driver even requests such a service. Hence, the driver would always have the latest version of a specific programme or content even before setting out.

This means that the car is able to operate independently of bandwidths, network failures or other kinds of interference when playing the programme desired. A further advantage of the download function (versus video streaming) is that playback quality is independent of the bandwidth available and may therefore be improved accordingly.

First step in networking different world and experiences.
Personal Video transmits functions we already know very well from home services into the car. The entire system has indeed been adapted to the car, so that the user does not have to learn everything anew and benefits as before from simple user guidance. In some cases, in fact, user guidance is even better and more intuitive than in the past.

As a further result of the research process a browser is being integrated in the car offering the latest HTML standard and, in particular, providing integrated video qualities. So here again the BMW Group has recognised the signs of the times and follows this upcoming standard, while everything remains as user-friendly for the customer as before.

To give the car genuine video qualities also on the road, a few more obstacles must still be overcome. The first point is that this seemingly simple idea required a great deal of development and hard efforts to achieve the status we have today. Subsequent integration of the services required in the existing periphery of the BMW 7 Series used by the engineers as a research car was only possible through the know-how of the development engineers and through close and intense cooperation with colleagues in the respective departments.

Making the car broadband-compatible (whether with WLAN, WIMAX, UMTS or other future technologies) is, however, only one side of the coin. The other requirement is to develop and introduce broadband networks available on a broad scale and not failing in, say, a tunnel or amid the skyscrapers in New York City, just as it is necessary to determine economically viable scenarios for the use of such services.

In all, Personal Video is another step in networking the various worlds we live in today. The car of the future will be able to use broadband technologies and will therefore become an integrated part of our networked world. Cars will become more “intelligent” in the years and decades to come, making specific recommendations according to current requirements and context, and offering interesting, highly relevant video and audio content. So the driver will be able to tell his car that he is going on holiday and needs information on a specific region, suggestions for a good hotel or, quite simply, the latest news.

The underlying consideration in this case is that many people spend more and more time in their car every day – and they want to use this time efficiently. So whether the driver wishes to use this time for relaxing, to obtain information, for entertainment or to do some work, is up to him. And whatever his choice, a big advantage is that he can determine his preferences, interests and viewing habits conveniently from home and download such input into his personal profile in the car.

3. Paving the Way into the Future of Individual Mobility.

3.1 Sustainable Traffic Management.

Why is the BMW Group so committed to the world of transport?
As one of the world's leading car makers, the BMW Group takes its social responsibility very seriously, going far beyond the usual activities of a car manufacturer and showing strong commitment to numerous projects for solving transport problems in densely populated areas and, accordingly, reducing the level of CO_2.

BMW Group engineers have determined that the appropriate implementation of traffic management such as an "optimised green wave" or dynamic traffic control would reduce CO_2 emissions by passenger cars in Germany alone by approximately eight per cent, equal to 7.4 million tonnes of CO_2.

Apart from reducing the burden on the environment, the BMW Group, through intelligent traffic management, is also making an active contribution to the enhancement of the quality of life in densely populated areas. In particular the BMW Group seeks to develop sustainable solutions helping to minimise the negative effects of individual transport not only quickly, but also on a long-term, sustainable basis, without depriving the individual of his or her personal mobility.

In particular, the BMW Group seeks to provide ideas and, through intense participation in various projects, is able to shape the overall scenario. In this context the company sees the automobile as part of a complex network of different modes of transport, each of which should offer its particular strengths and qualities. Innovative mobility, telematic and navigation solutions should help to improve efficiency in road traffic.

3.1.1 Cars "Talking" to the Traffic Lights – Traffic Data for Greater Efficiency.

Introducing the concept of EfficientDynamics, the BMW Group has already taken on a leading role in the automotive industry. Throughout all model series, various EfficientDynamics technologies serve to enhance the environmental standard of BMW Group cars. The Auto Start Stop function, for example, is now an indispensable feature of BMW and MINI models, making every stop at the traffic lights an opportunity to save fuel simply by the driver releasing the clutch to switch off the engine. Whenever the engine then remains switched off for more than four seconds, the car is able to save energy, reducing both fuel consumption and emissions in the process.

But how can the driver know how long he will be stopping at the lights?

Precisely these and other questions are studied by the BMW Group's traffic researchers, who also consider what information from the transport infrastructure might be of interest to the driver and the vehicle, and how this information should get into the car.

Cars "talking" to traffic lights and overhead road signs.
One possible solution is Car2X communication by WLAN, the "X" standing for infrastructure such as traffic lights or roadwork markers to give the car (and, subsequently, the driver) extra information.

Another possibility would be to go through traffic control centres gaining, comparing, evaluating and passing on information for greater efficiency.

BMW Group engineers have been working for a number of years on the exchange of information among vehicles, as well as the exchange of information with traffic infrastructure such as traffic lights. Technology of this kind can help not only to avoid accidents, but also to improve the benefits of EfficientDynamics. Just take the Auto Start Stop function as an example: Once the car receives additional information from the traffic lights specifying how long the lights will remain on red, it would be able to deactivate the Auto Start Stop function for a very short stop of less than four seconds, while activating Auto Start Stop for a longer stop. All this in the interest of maximum efficiency.

The engineers at the BMW Group would like to verify these ideas by establishing a test scenario for trying out this principle in practice and gaining further important information. Particularly the optimisation of traffic management through traffic lights operating appropriately is believed to offer a significant potential for saving fuel and time as opposed to driving up to traffic lights and crossing road junctions in a simple non-optimised process. Introduction of "intelligent" green waves and the efficient use of stopping times when the lights are on red, therefore, offers a significant potential for greater economy.

Don't drive faster than allowed, but drive more efficiently.
Apart from optimising efficiency in the inner city through the intelligent management of traffic lights and the car itself, BMW Group engineers also seek to make motoring outside of town more efficient through the provision of traffic data.
A good example in this context is the presentation of speed limits on overhead road signs determined by the traffic control centre and causing the driver to follow the instructions he receives. Should the driver be travelling on the autobahn at a speed of, say, 120 km/h, but knows that in a few hundred metres

the speed limit will be 80 km/h, he can take his foot off the accelerator and capitalise on the momentum of his car, not giving gas and applying the brakes where not necessary and therefore slowing down "gently" to the speed allowed.

Camera systems used for the detection of traffic signs in the BMW 7 Series are already able to retrieve such information today, but only from close up. The idea of the traffic management experts is to transmit such information straight to the car by direct connection to the traffic control centre. Such speed limit information has indeed already been used successfully in a research project, and now the next step is to compile and integrate the data required.

Another typical example is road construction work or other traffic obstacles such as detours, roads closed down to traffic, and traffic congestion. Again, such information may be provided in good time through central interfaces as traffic data, thus ensuring greater efficiency as well as extra safety and in many cases helpful saving of time.

"Being aware of current speed limits, the car is able to give the driver appropriate recommendations for reaching his destination safely and efficiently."
(Martin Hauschild, Team Leader Traffic Technology)

3.1.2 Inter-Modal Route Guidance – the Best of Everything.

The term "Inter-Modal Route Guidance" means nothing but the idea to promote individual mobility by using existing traffic systems networked with one another. Precisely this is why the BMW Group seeks to integrate various means of transport and use them in a synergetic process.

To ensure that the BMW and MINI driver reach their destination as quickly as possible in style and feeling relaxed, use of the automobile is connected intelligently to the various providers of public passenger short-haul transport, even taking parking conditions and the availability of parking space into account.

Choosing the fastest and most convenient means of transport – with and without the car.
The Park & Ride concept offers a perfect starting point for establishing appropriate traffic networks. Particularly in densely populated areas, it may well be more meaningful for the individual to park his car outside of town when driving to the inner city – especially if the underground, bus or tram will take him to his destination faster and more conveniently.

This is the case above all when roads are congested, when it is not possible to reach your destination directly by car, when parking space at your destination is not sufficient, or if parking would be far more expensive than taking the underground.

This enables the customer to save precious time and money, no longer having to look for parking space in town and avoiding any extra – and superfluous – fuel consumption.

Potentially this may benefit not only job commuters, but also tourists or employees who do not drive into town regularly.

The opposite case is also conceivable: Should a commuter who uses Park & Ride every day hear in good time that short-haul passenger transport is currently not available or is severely delayed, he may change his plans and drive to work by car for a change.

To make alternatives to the individual's car really attractive, a high-performance mobility service must provide the driver reliably with information also outside of his car. The key to the combined use of traffic systems therefore lies, first, in the provision of the latest information on public transport as well as parking conditions and, second, in the availability and use of mobile terminals. This means that the driver is able to check his best travel itinerary both before setting out and while travelling. Networked with the car's on-board computer and, accordingly, with the navigation system, the driver's terminal will then be able to present the route desired both within the car and outside of the vehicle.

Important criteria for or against combined use of various means of transport, such as the presumable travel time, time saved, cost benefits, the last opportunity to ride back to the car park, as well as possible delays in the traveller's journey, must be made available to the customer at all times. A further point is that the proposed Park & Ride car park must be readily available and easy to find, with the option to conveniently change to another means of transport.

Practical, clear, and always up-to-date.
The following example shows how inter-modal travel assistance might help the driver in future: Leaving from the Bavarian town of Landshut about 110 km north-east of Munich, the driver proceeds to Munich to visit the BMW Welt. In the late afternoon he has another appointment right in the middle of the city. Due to a major event, downtown Munich is closed to all private traffic and roadworks on the main road leading into town cause severe traffic congestion, with vehicles hardly making any progress and consuming a lot of fuel in stop-and-go traffic.

"Inter-model travel assistance gives you not only the fastest, but also the most efficient and convenient route to your destination, and is always up-to-date. Even with parking space at the end of your trip."
(Dr Markus Mailer, BMW Group Transport Management, Project Manager Inter-Modal Route Planning)

After the driver has entered the various stopovers on his trip, inter-modal travel assistance presents the route to the first destination and advises the driver to use public transport on his ongoing journey to downtown Munich. Once the driver has confirmed this proposal, the navigation system calculates the complete route together with the underground connections required as well as the remaining distance he still has to cover on foot. It automatically checks the occupancy of car parks in the area and looks for optimum connections with public short-haul transport.

The user also receives all relevant information such as the cost of transport, departure times, stations for changing trains, and the last available train back to his car. And since the mobility service constantly receives the latest traffic data, the Travel Assistant also considers possible interferences in a dynamic route planning process and suggests alternatives where required.

Pilot test in Munich.
Inter-modal route guidance will first be tested in Munich. As a provider of mobility service, the BMW Group cooperates closely through the BMW Parkinfo Service with the Munich Transport Authority (MVV). After having successfully passed the first test, inter-modal route guidance may subsequently be tested in other densely populated centres the world over.

The technical features for successful implementation of this ambitious project are already in place today. The challenge in future will be to intelligently network and use the data compiled on traffic conditions and integrate such data into the car.

3.1.3 TPEG – the Data Revolution.

For a number of years navigation systems have been able not only to show the way to the driver's destination, but also to respond to unforeseen events such as traffic congestion, and suggest alternative routes. This is made possible by providing traffic data over the radio on the Traffic Message Channel (TMC). Large-scale communication of traffic congestion by TMC still works relatively well today, but has now reached the limits to its practical implementation.

Having to cater for upcoming traffic information-based travel services such as inter-modal route guidance offered by the BMW Group, TMC no longer meets these new requirements, since the new functions available in the car require not only straightforward traffic data, but also a lot more information with relatively large data volume. And since TMC can be received only on FM radio with its limited bandwidth, it is impossible to receive large amounts of data efficiently and quickly. This creates the need for a new and more efficient transmission standard.

More power, more functions.
The solution to this problem is TPEG (Transportation Protocol Expert Group). These four letters describe a new international standard for transmitting multi-modal traffic and travel information no longer requiring voice communication. The TPEG Automotive Profile (TAP) has therefore been developed as part of the Mobile Info Project for transferring such information to the vehicle. In this project involving various car makers and providers of traffic services seeking to make full use of traffic information, the BMW Group was the leader in particular in developing this extension of TPEG.

TAP offers much greater bandwidth used more efficiently than with other transmission protocols in the past. The special feature of this new transmission mode is that the information transmitted can be processed better and more efficiently by machines and prepared quickly and easily for use by human beings. Specifically, this means that location references, updates and news management are now becoming much better, faster, and, in particular, more reliable.

Interacting with the development of broadband transmission channels such as Mobile Radio, DAB (Digital Audio Broadcasting) or HD Radio in the USA, TPEG allows the customer to conveniently access a very large range of information with utmost convenience from almost everywhere.

"TPEG is the automotive telematics standard of the future. It is a door-opener for new services such as inner-city traffic flow information, weather and danger reports as well as the price of fuel and the occupancy of car parks."
(Martin Hauschild, BMW Group Transport Technology)

More information, more options.
The TPEG Automotive Profile (TAP) provides the framework for numerous applications and functions. While TMC used to cover only individual traffic events such as traffic congestion, traffic jams, accidents, closed roads, and was limited in all cases to the motorway or autobahn alone, TAP also offers traffic information on federal highways and in the inner city. And since both the location of the vehicle as well as the presentation of a specific place or location have been further optimised, the navigation function has also improved.

TAP also offers useful information such as the flow of traffic and traffic speed, weather conditions, parking options and the occupancy of car parks, connections to other means of transport, as well as filling stations and the price of fuel.

The two characteristic applications Traffic Event Compact (TEC) and Traffic Flow and Prediction (TFP) already offer a short outlook at what the TPEG Protocol might be able to offer in future.

"TPEG opens up brand-new possibilities in the traffic-based use of information."
(Robert Hein, BMW Group Research and Technology)

What's coming your way – Traffic Event Compact.
Traffic Event Compact (TEC) follows the original TMC function and specifies traffic conditions. Like TMC, TEC informs the driver of traffic congestion, roadworks and obstructions, but now covers not only the autobahn, but also federal highways and the inner city. A further point is that TEC significantly speeds up the transmission of traffic data through TAP and makes the flow of information more reliable.

Theoretically, TEC is also able to transmit traffic flow information. This information is indeed important, since it shows where traffic is flowing and where it is not flowing. But since the transmission of such information through TEC requires a lot of bandwidth, implementation of this concept depends on the infrastructure available.

In Asia, for example, sufficient bandwidth is available through DAB, while in Europe the infrastructure for transmitting data has not yet made sufficient progress. This is why the presentation of traffic flow information has been further enhanced in the context of the Traffic Flow and Prediction (TFP) Project.

Everything goes – Traffic Flow and Prediction (TFP).
Contrary to TEC, Traffic Flow and Prediction (TFP) allows very efficient encoding and transmission of traffic flow information. The particular advantage of this information is that road congestion reports as such do not indicate whether traffic has come to a complete halt or whether it is still flowing slowly. Traffic Flow and Prediction, on the other hand, shows that, for example, traffic is still moving at a speed of, say, 30 km/h at a certain point along the route. This information indicates the time lost in a traffic jam as opposed to taking an alternative route, and which of the two options is best in terms of time and efficiency.

TFP not only collects current traffic flow information, but also historical data able to provide good forecasts for the volume of traffic at a certain time and at a certain place. As a result, TFP allows intelligent route planning tailored to the time of day and actual traffic conditions. Clearly, when the driver sets out what is now happening at a place he will only reach in one hour is not really relevant. It is far more important to know what conditions will be like there one hour from now in order to plan the best route accordingly.

The first field test with the new TAP transmission protocol and the TFP application was successfully concluded in the USA in November 2008, promising positive results. In cooperation with ClearChannel, a provider of traffic information, traffic data was broadcast on HD Radio, the counterpart to the future European DAB format, the tests proving that the TPEG Automotive Profile and TFP are ready for series development and introduction into the market. Further test series are currently being conducted in Munich.

Challenges in regular use.
The technical infrastructure for using the TPEG standard is already in place. What is still missing is the broad foundation of traffic data making all the information required available – simply because the more data is available, the easier it is to forecast traffic events and conditions.

The process of compiling such data is however still in its early phase. While it is already possible today to measure the flow of traffic and its speed at neuralgic points by means of GPS tracking and autonomous radar detectors running on solar cells, only broad-scale or even nationwide surveys will allow valid predictions. With more and more data survey mechanisms being implemented, however, it is fair to assume that the amount of information available will increase significantly in the years to come.

"We are looking for an integrated concept in future. With the driver making only one single entry for his destination, this would give him all the information he needs including traffic congestion, the use of public short-haul transport and even an overview of filling stations taking the amount of fuel in the tank into account."

(Robert Hein)

Networking different worlds and future scenarios.
A point still to be clarified is how the enormous flood of data can be properly handled in future. Information simply showing where traffic is congested or where car parks are available and how full they are, is good but not sufficient. Instead, such information must be efficiently compiled in future, prepared intelligently for further use, and then made available according to specific requirements.

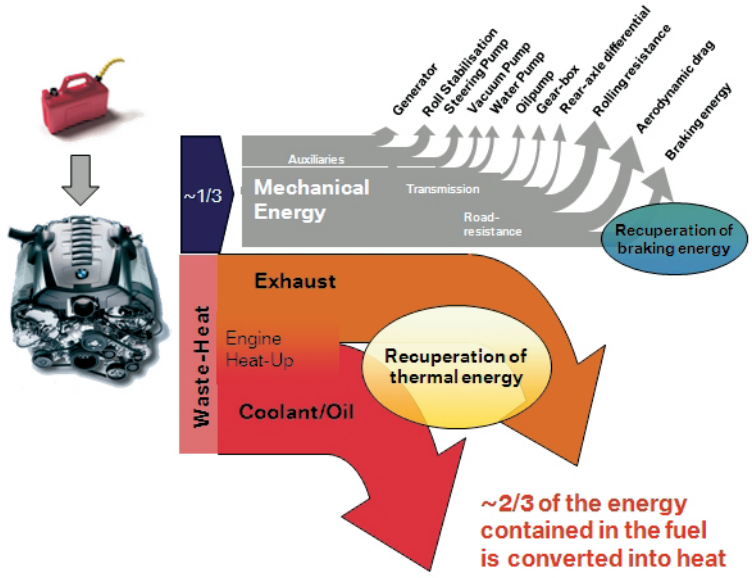
The BMW Group's Inter-Modal Route Guidance Project takes the first step in this direction. TPEG provides the basis for feeding information on traffic congestion, the availability of car parks, connections to public short-haul transport and other important information into the car, thus giving the driver his optimum route through one single entry.

Since TPEG allows several transmission routes and modes, a further advantage is that the information required may be provided either by mobile messaging going to the driver's mobile phone or by DAB going to the navigation system.

3.2 Intelligent Heat Management.

For many years it was important to avoid heat in the car and thus prevent any overheating of components. In recent years, however, there has been a significant change in mind in the process of reducing CO_2 emissions.

Even a highly efficient combustion engine is able to convert only about one-third of the energy in the fuel consumed into traction actually propelling the car. The remaining two-thirds are lost as waste heat going into the environment through the car's exhaust emissions and through the radiator.



Distribution of energy in the car.

Making this energy available through intelligent heat management, the manufacturer has a significant potential for reducing fuel consumption and CO_2 emissions. And while a small share of the thermal energy available is already used today (for example when warming up the engine or through exhaust gas turbocharging), further, specific improvements will serve to reduce fuel consumption and, accordingly, CO_2 emissions once again by several percentage points.

The challenge in heat management, however, is to use the energy contained in heat for practical purposes in the car. Precisely this is why BMW Group development engineers are working hard on promising projects for using heat lost so far in order to reduce fuel consumption and enhance motoring comfort. And since not all technologies are suitable for every type of engine, the engineers check

out carefully what objectives can be reached best through which technologies and in which context. Three development projects presented here as examples show how this may be done.

3.2.1 No More Cold Starts.

Starting the engine cold is a critical phase in fuel consumption, with the engine consuming the largest amount of fuel at this point due to greater internal friction and the high viscosity of the engine oil as long as it is still cold. Compared with an engine already warm, fuel consumption may therefore increase under such circumstances by up to ten per cent.

Since this obviously offers a very significant potential for reducing fuel consumption and, accordingly, avoiding CO_2 emissions, the engineers are working all-out on largely avoiding cold start conditions through intelligent heat management and significantly shortening the warm-up period.

> "We want cars to warm up as quickly as possible, since higher temperatures mean less friction, less friction means less fuel consumption and, therefore, less CO_2."
>
> (Dr Andreas Eder, Head of Heat Management Pre-Development Projects)

The solutions considered include technologies for improving heat insulation on the engine in order to retain heat built up in the engine and engine compartment as long as possible. A lot of thermal energy is generated while driving and is available after coming to a stop – energy stored in components such as the engine and transmission. The engineers are therefore seeking to prevent the engine from cooling down quickly and to retain as much residual heat as possible so that the engine is not completely cold when started the next time. Particularly under realistic customer driving conditions, this ensures a significant reduction of fuel consumption.

Please keep warm!

To keep temperatures within the engine compartment at a high level for as long as possible and to avoid having to warm up the engine from the regular ambient temperature, the engine is fully encapsulated. In addition to the air flaps behind the BMW kidney grille already introduced in 2007 in the context of BMW EfficientDynamics, the engine on the prototype already developed is completely surrounded by fully clad walls and panels, the engineers using proven materials from the underfloor of the car for insulation purposes.

Since the cooling system on a BMW is highly effective from the start, there is no risk of overheating despite this insulation. On the contrary: Components in the engine compartment which previously had to be cooled at a great effort are now protected better from engine heat by the encapsulation.

Thanks to encapsulation, an engine running at a temperature of, say, 80°C or 176°F now cools down much more slowly after being switched off and still has a temperature of approximately 40°C or 104°F after 12 hours. And studies show that customers park their car for more than 16 hours in a row only in 12 per cent of all cases.

With each degree of temperature having a significant influence on fuel consumption, this improvement alone provided by encapsulation reduces fuel consumption by up to 0.2 per cent for each extra degree of temperature (in °C).

More comfort on less fuel.
This method of maintaining temperatures is equally suited for all kinds of vehicles and in all climate zones, although it is somewhat more effective at low temperatures. A further point is that such highly efficient dampening of heat on the drivetrain has some positive side effects: First, many measures previously required to dampen noise in the engine compartment are no longer required, since now the source of noise is insulated directly. This not only saves weight, but also audibly improves the acoustic behaviour of the car. Second, the customer benefits from such innovative insulation of the engine compartment not only through lower fuel consumption, but also through additional comfort, since, apart from acoustic improvements, the insulation also helps to warm up the interior faster in cold weather, as the coolant is also kept warm.

3.2.2 Heating with Waste Heat, Avoiding Emissions.

Apart from heat storage, the use of the thermal energy contained in the car's exhaust gas also offers major saving and comfort potentials. Using such heat to warm up the interior helps to reduce fuel consumption by a diesel engine, for example, by up to 10 per cent, depending on the outside temperature and the driver's driving profile. With petrol engines an exhaust gas heat exchanger would be very effective in warming up the drivetrain more quickly to the right temperature, avoiding friction in, say, the gearbox. Such a heat exchanger conveys heat or thermal energy from one flow to another, in this case the heat of the exhaust gas going to the oil in the automatic transmission, with additional heat being pumped in consistently from the start.

Extra heating energy without extra fuel consumption.
Modern direct injection diesel engines are now so efficient that the energy going into the coolant circuit and, therefore, to the heater is no longer always sufficient to meet the customer's requirements. It has therefore become quite normal these days to fit cars with an additional electric heater providing such extra heat on up to 1,000 W of electrical energy.

To deliver such energy for additional heating, the engine has to develop up to 2,000 W – since about twice the amount of mechanical energy is required to provide one watt of electrical energy. In all, therefore, such additional heating involves an increase in fuel consumption of up to one litre.

To avoid this extra fuel consumption the hot exhaust emissions may be used by means of a heat exchanger positioned as close as possible to the catalytic converter and diesel particulates filter, thus providing an additional source of heat for the interior. Heat otherwise lost on the exhaust system therefore serves to warm up the interior as an additional source of driving comfort. Properly designed and engineered, such a system may provide the same heating output as an electrical heater, avoiding the need for electrical heating modules consuming additional fuel.

Savings potential varying from case to case.
Not every technology is equally sensible for each type of engine and may be used at random on each type of vehicle. Precisely this is why BMW Group engineers carefully consider which objective can be reached best with which technology and in which context.

The exhaust gas heat exchanger, for example, is used in different ways in the BMW Group's various development projects. It has a greater potential for saving fuel with diesel engines by additional heating of the interior, while on the petrol engine the exhaust gas heat exchanger serves to shorten the warm-up period required.

A further point is that the benefits of intelligent thermal management depend not only on the outside temperature, but also on the size and power of the engine, the size of the car and its main use (city traffic or long distances). In the EU test cycle the potential offered is not really noticeable, since here the engine is required from the beginning to start at a temperature of 20–30°C (68–86°F). Under realistic everyday driving conditions, on the other hand, the customer will feel the greater fuel economy at the latest when he is required to fill up the tank next.

3.2.3 Electricity from Waste Heat – the Thermoelectric Generator.

The thermoelectric generator (TEG) offers a completely different option to use heat in the system, generating electricity out of unused thermal energy in the exhaust gas.

After having presented the function principle of the thermoelectric generator last year, the BMW Group is now presenting the next level of development in this project. Shown originally as a stand-alone underfloor solution developed since 2004 also as part of a project promoted by the US Department of Energy, BMW Group engineers are now presenting the thermoelectric generator as an integrated component in the exhaust gas recirculation cooler. In this new stage of development, the TEG is able to deliver up to 250 W of energy under typical customer driving conditions, reducing CO_2 and fuel consumption by up to two per cent.

Generating electricity in the car: a process chain with substantial loss of energy.
The degree of electrification in the car, the range of features and, accordingly the consumption of electric power are constantly increasing. Depending on the model, the level of equipment and the route profile, generation of electric power is now responsible for three to eight per cent of the total amount of fuel consumed by the customer. This is attributable to the high losses resulting from the various levels of efficiency and transmission ratios in the vehicle.

To provide this energy without additional consumption of fuel, BMW Group engineers have developed the thermoelectric generator on the basis of a technology used since the 1960s to generate electricity in space probes. This technology uses the effect of the temperature gradient in thermoelectric semi-conductor elements generating electrical voltage (the Seebeck Effect). The bigger the difference in temperature, the higher the voltage generated.

Since, depending on load conditions on the hot side of the generator, exhaust gas temperature is between 300 and 900°C (570–1,650°F), the TEG connects high- and low-temperature modules to generate electricity over as wide a range as possible. And as before, the engine coolant is used for the cold side of the thermoelectric generator.

Simply clever – the integrated approach.
A special feature of this new development is the elegant integration of the TEG in the existing cooling structure for recirculating exhaust gases. Such integration of the TEG with its particular functions requires only a minor additional effort, without impairing the recirculation of exhaust gas.

Exhaust gas recirculation (EGR) serves first and foremost to keep temperatures in the engine low during the combustion process, thus minimising the generation of nitric oxides. To do this some of the exhaust gas already burnt is fed back and added to the fresh intake air, the mixture burning in the combustion chamber therefore being made up not only of fresh air and fuel, but rather fresh air, fuel, and residual gas. This residual gas takes up combustion heat and thus reduces the peak temperature in combustion as well as the generation of nitric oxides.

To cool the residual gas and recirculate it as required, EGR comes with a water cooler (operating through the engine coolant) and a control flap, thus offering ideal conditions for enhanced efficiency, since, apart from water cooling on the cold side and a flap controlling the flow of exhaust gas, the EGR-TEG only requires thermoelectrical material. This material is taken up by the hot exhaust gas directly downstream of the exhaust gas manifold (upfront of the exhaust gas turbine) where the temperatures available are a lot higher and electricity can be generated more efficiently in the TEG.

A particular challenge in the integration of the thermoelectric generator is that the thermoelectric materials used have an insulating effect. While this increases the space required for the EGR, it continues to cool the residual gas with virtually no loss of pressure, even generating electric power in the process.

The power level aspired here in series production is 250 W, equal to about half of the on-board consumption in a BMW 5 Series. This again means a fuel saving under the customer's driving conditions of up to two per cent.

"With the number of components limited to a minimum, the exhaust gas recirculation cooler is a very elegant solution which may quickly reach production level."
(Dr Andreas Eder, Head of Heat Management Pre-Development Projects)

Reaching production level.
Engineers at the BMW Group are continuing their efforts to further improve the TEG. Currently they are looking for the best technology for integrating the thermoelectrical material efficiently into the EGR cooler and, with the steel housing on the heat exchanger, to make the TEG solution as light as possible.

A further potential lies in the improved distribution of heat through the thermo-electrical material. The challenge in this case is to develop an intelligent structure providing as much heat as possible without at the same time losing too much pressure within exhaust gas recirculation. Precisely this is why the development engineers are currently checking out a number of variants to determine which solution offers the highest surface temperature on the thermoelectric material with the loss of pressure in EGR remaining acceptable.

Further potentials for the future.
Since only some of the exhaust gas is available within the recirculation process, the integrated TEG solution does not yet use the full potential for generating energy through heat. It is however an important project in the implementation of future TEG concepts, ongoing research and development giving the engineers valuable information and experience which goes directly into the further development of TEG.

Like in the prototype presented, a larger thermoelectric generator is to be fitted in the exhaust system in future – either as an underfloor solution or directly integrated in the catalyst. However, this solution is a lot more elaborate and involves a far greater design and construction effort than the integration of the TEG unit in the exhaust gas recirculation system.

Integration in the main exhaust gas pipe is nevertheless an attractive option for the future, since here, due to the greater mass flow, a lot more electricity could be generated. Turning the energy generation process around, with electricity going from a battery into a semi-conductor (the Peltier Effect), the electric power unit might also serve to heat the catalyst in order to reduce untreated emissions when starting the engine cold. Then, once the exhaust gas has reached the temperature required and the catalyst is operating at its regular temperature, the process is turned around in order to generate electric power. In all, this offers a potential improvement of fuel economy under the customer's typical driving conditions of up to five per cent.

Thermoelectric generation of electricity is also receiving increasing attention from the public. In September 2008, for example, the thermoelectric generator was awarded the EcoGlobe for particularly ecological innovations. This prize is awarded by the DEVK, the German Automobile and Transport Club, and the Center Automotive Research at Gelsenkirchen College in Germany.

The ideal combination: heat management and BMW EfficientDynamics.

While some features of BMW EfficientDynamics such as Brake Energy Regeneration or the Auto Start Stop function serve to reduce fuel consumption when applying the brakes or when the car comes to a somewhat longer standstill, intelligent heat management serves to reduce fuel consumption also while driving. In future, for example, insulation of the engine compartment will largely maintain the temperature of the drivetrain even before setting out, making the cold start period a lot shorter. Warming up the transmission fluid, the exhaust gas heat exchanger will help additionally to minimise friction and maximise fuel economy. The main point is that a TEG provides the electrical energy required by the on-board network and offers its benefits where it really counts most – while driving.

Depending on the specific situation and route profile, heat management offers various solutions. Both on short and long distances various technologies serve to reduce fuel consumption, insulation of the engine compartment, heating of the transmission fluid by an exhaust gas heat exchanger on the petrol engine, or the heating function of the exhaust gas heat exchanger on a diesel engine, for example, providing benefits above all on short distances. On longer journeys, on the other hand, the thermoelectric generator will offer synergy effects, with heat management helping to significantly reduce CO_2 in future.