BMW GROUP THE NEXT 100 YEARS

Corporate Communications

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Connected, flexible, autonomous: BMW Group expands use of innovative technologies in production logistics

Many Industry 4.0 innovations already used in series production
Collaboration with universities, research institutes and start-ups speeds up development

Munich. The BMW Group is increasingly relying on innovations from the fields of digitalisation and Industry 4.0 in production logistics. This will ensure the company's global production network continues to receive the parts it needs in a timely and reliable manner in the future. The focus is on applications such as logistics robots, autonomous transport systems at plants and digitalisation projects for an end-to-end supply chain. Staff can control logistics processes from mobile devices such as smartphones and tablets and use virtual reality applications to plan future logistics. Innovations coming out of many pilot projects are being implemented worldwide in logistics at BMW Group plants.

"Logistics is the heart of our production system. Our broad spectrum of ground-breaking projects helps us run increasingly complex logistics processes efficiently and transparently," according to Jürgen Maidl, head of Logistics for the BMW Group production network. "We are taking advantage of the wide range of available technological innovations and working closely with universities and start-ups. We are already working with tomorrow's Industry 4.0 technologies today."

Around 1,800 suppliers at more than 4,000 locations deliver over 31 million parts to the 30 BMW Group production sites worldwide every day. Digitalisation and innovations help the company organise logistics more flexibly and more efficiently. At the same time, almost 10,000 vehicles coming off the production line daily must be delivered to customers around the globe. Digitally connected delivery, so-called Connected Distribution, ensures that these transport routes are also more transparent.

"We always have several pilot projects running at our locations worldwide," explains Marco Prüglmeier, head of Innovations and Industry 4.0 for BMW Group Logistics. "We

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ourselves operate like a start-up within the BMW Group, with agile development methods. We leverage various forms of international cooperation to make sure we always have access to the latest findings and technologies. We learn the most from these pilot projects. We already transferred a number of projects to series production, with further implementations planned for the future."

Connected Supply Chain: Full data transparency in the supply chain

The BMW Group supply chain relies on a global supply network and close cooperation with numerous logistics service providers. The Connected Supply Chain (CSC) programme significantly increases supply chain transparency. It updates the plants' material controllers and logistics specialists on the goods' location and delivery time every 15 minutes. This transparency enables them to respond immediately if delays appear likely and take appropriate steps early to avoid costly extra runs. The digital connection between suppliers, transport service providers and the BMW Group is through the so-called CSC portal, which, for the first time, in addition to sending a transport notification, now also provides material numbers with GPS data and realistic arrival times. Since mid-2018, several hundred suppliers and transport service providers in Europe and Mexico have been integrated into the system. By the end of 2019, several thousand partners will be connected to the system. CSC also lays the basis for predictive analytics and artificial intelligence (AI) in supply chain control.

Autonomous transport systems both inside and outside

Autonomous transport systems such as tugger trains or Smart Transport Robots are increasingly used to transport goods within production halls.

To allow tugger trains to now also be used for the sophisticated process of supplying assembly lines, as part of a pilot project, BMW Group Plant Dingolfing has developed an **automation kit**, which enables conventional tugger trains of any brand already on hand to be upgraded to autonomous tugger trains. The capabilities of these driverless tugger trains go beyond automation of earlier solutions. It is possible to create dynamic route guidance according to delivery priority and for them to avoid obstacles by themselves.

Independent control and navigation of the tugger trains is via laser signals, which continuously scan the environment and create a corresponding room profile.
Another future technology is also being piloted alongside autonomous tugger trains at the Dingolfing plant. A **Smart Watch** supports logistics staff during the container change process and announces approaching tugger trains via a vibration alarm. The employee can also read which containers should be unloaded and send the tugger train on to its next destination by tapping the display.
BMW Group Plant Dingolfing is likely to be using 20 autonomous tugger trains from next year.

The BMW Group is also pioneering the use of autonomous transport systems outdoors. As part of a pilot project, the BMW Group is using an autonomous outdoor transport robot for the first time at its Leipzig plant to bring truck trailers from where they are parked to the unloading and loading bay on their own. A mobile platform drives underneath the trailer, connects it and steers it through the plant. The so-called **AutoTrailer**, with a payload of up to 30 tons, navigates by laser, without additional guidelines or markings, through the plant's outdoor areas. Sensors and cameras provide a 360° all-round view, which forms the basis of the safety concept.
Next year, the AutoTrailer will go into real operation at BMW Group Plant Leipzig. The Spartanburg (USA) and Dingolfing plants are also planned as additional locations. The huge potential of this transport system is particularly evident at the BMW Group's largest plant in Spartanburg, where about 1,200 of these trailer-shunting manoeuvres take place every day.

AutoBoxes are another variant of the autonomous outdoor transport system: These autonomous platforms can manoeuvre multiple lattice boxes with components between plant halls. With a payload of up to 25 tons, they can transport up to 20 lattice boxes at one time. In spring 2019, a pilot application will be launched at the Dingolfing Dynamics Centre. The AutoBoxes will also be introduced at the plants in Shenyang, China and Berlin next year.

Back in 2015, the BMW Group joined forces with the Fraunhofer Institute IML to develop the first self-driving **Smart Transport Robots** (STR) for transporting roll containers through logistics areas within production halls. The second generation is now in operation at BMW Group Plant Regensburg. The flat robots carry roll containers weighing up to one ton and transport them autonomously to where the goods need to be. They calculate the ideal route independently and move freely through space. The new SLAM (Simultaneous Localisation and Mapping) navigation method does not require permanently installed navigation transmitters in buildings and can therefore be used quickly in a new environment. A built-in battery module from the BMW i3 powers the STR for a whole work shift.

For delivery of urgent small parts, a smaller version of the STR is used, the so-called **miniSTR**. This robot transports small load carriers weighing up to 50 kg and calculates its route independently.

The body shop at BMW Group Plant Regensburg has successfully piloted autonomous lift trucks, so-called "**ants**", over the past twelve months. These autonomous ants bring components from the "supermarket" to the right installation site. The safety concept includes personal protection and obstacle avoidance, as well as interfaces to other automated industrial trucks. Going forward, a total of eight autonomous ants will supply other areas of series production.

The BMW Group uses a cloud-based operating platform, named BMW Services, for central coordination of autonomous transport systems. The platform simplifies logistics processes significantly. Staff enter driving rules and workflows through an easy-to-use user interface and receive the latest data on all vehicles. Going forward, the platform will support autonomous transport vehicles built by different manufacturers. The BMW Group is therefore actively involved in the German Association of the Automotive Industry (VDA) and Mechanical Engineering Industry Association (VDMA) to establish a standard that will enable communication between all autonomous transport systems in the marketplace.

Regardless of the manufacturer, every autonomous transport system should be able to exchange data with BMW Services.

Loading and unloading of goods containers:
Robots take over arduous tasks and relieve staff

After delivery to the plant, the goods are transported to the assembly line in containers and parts containers of various sizes. For the tiring job of reloading containers from pallets onto conveyor belts or into storage, employees will be assisted in the future by logistics robots specially developed for this purpose. Four different types of robots, referred to as "Bots" by logistics experts, are currently being tested or have already been integrated into series production.

Stationary "**SplitBots**" can take full plastic boxes from the pallet in the incoming goods area and place them on a conveyor system that transports the boxes to a warehouse. The SplitBot also makes sure the containers are lined up correctly for automated storage. Using artificial intelligence, the SplitBot can detect and process up to 450 different containers. Following successful completion of the test operation, plans call for SplitBots to be used in series production at BMW Group Plant Dingolfing from 2019.

The BMW Group is currently testing the use of a mobile "**PlaceBot**" directly on the assembly line. The movable PlaceBot unloads tugger trains and places boxes loaded with goods on a shelf. It uses an image recognition system to classify these small load carriers and determine the ideal grip point from the combined input of sensor technology, camera and artificial intelligence. It can also move autonomously in a predetermined area.

Another logistics robot, the so-called "**PickBot**", collects various small parts from appropriate supply racks. Different parts are recognised by a self-developed, self-trained artificial intelligence. The PickBot then calculates the right grip point. Over the long term, the PickBot should be able to recognise and handle up to 50,000 small parts and will likely be used in series production at BMW Group Plant Leipzig from 2019 on.

The "**SortBot**" already deployed in series production at Plant Leipzig stacks empty containers on pallets before they re-enter circulation. Three SortBots will be in use at BMW Group Plant Leipzig by the end of the year.

Smart devices support logistics staff in paperless logistics

Gloves with integrated scanners and displays, data glasses and smart watches are increasingly used to support logistics employees. The transition to paperless logistics, with digitally labelled containers and shelves, opens up new areas of application for mobile devices. Glove scanners read the electronic label and indicate the exact contents of the small load carrier on a small display that can be worn on the arm.

One aim of paperless logistics is for all containers to have a single label. This "**unique container ID**" will contain just a single QR code and a number. All information relating to the supplier, content or storage location is stored centrally and can be called up by various scanners. A special logistics app shows the employee all relevant information for their tasks on a smartphone – for example, the position of a small load carrier and whether it has the right content.

The use of augmented reality glasses helps the employee sort parts into the right order. They see which component goes into which shelf in the data glasses' field of vision. Correct work steps are confirmed in green, while errors are visually highlighted. The use of data glasses therefore helps staff keep track of the large number of different components and avoid picking mistakes, i.e. when putting together certain parts.

Virtual reality and artificial intelligence

The use of virtual reality already plays an important role in planning logistics spaces. In a virtual environment, planners can quickly and efficiently lay out future logistics areas completely and assess how much space is needed, for instance. Planning is based on 3D data representing the real structures of a logistics hall. For the past several years, the BMW Group has been capturing its plants in digital form with millimetre accuracy, using special 3D scanners and high-resolution cameras. This creates a three-dimensional image of the structures, so that manual recording on site is no longer needed. When planning future logistics areas, BMW Group experts can now combine existing data with a virtual "library" of shelves, lattice boxes, small load carriers and around 50 other widely-used operating resources.

The selection, placement, movement and removal of logistics structures and areas, as well as distance and area measurements, can be simplified in the virtual environment.

Several planners can also work on the same area design at the same time, regardless of their location.
To ensure the data used is exactly right, the BMW Group is also relying on artificial intelligence. Artificial, neural networks are first "trained" by presenting the computer with tasks and results to learn from – for example, the system familiarises itself with the appearance of different container types from photos taken from different angles. By training the network in this way, it becomes capable of recognising the container types it has learned from new photos reliably and independently. Applications incorporating neural networks require enormous computing power. To secure this, the BMW Group is investing in state-of-the-art computer hardware.

Modern small load carriers and pneumatic gripper robots in testing

Storage areas and their aisles occupy a great deal of space at any plant. In conjunction with two external partners, BMW Group Plant Regensburg is currently testing a modern small load carrier that also comes with a pneumatic gripper robot. What is unique about this approach is the idea of simply stacking same-sized containers in a grid construction above and next to each other, thereby reducing the amount of space needed. Small transport robots drive on top of the grid and remove the goods needed by rearranging the containers. As a result, containers with frequently requested goods automatically land higher up and other containers lower down. A pneumatically-powered lightweight robot then removes the parts from the containers. Using a special gripper, it also takes sensitive parts out of boxes and gets them ready for use as a pre-configured assembly package. Thanks to a well thought out safety system, the robot is able to work alongside employees without a protective barrier.

Connected Distribution:
Vehicle delivery transparency from plant to showroom

Like delivery of parts to plants, the transport of vehicles to the dealership is now also digitally and transparently traceable. The former Connected Distribution pilot project was fully integrated into series production this year. The system uses the same IT built into BMW Group vehicles to track the location of finished vehicles once they are ready to

leave the plant. The vehicle transmits its current geolocation and status to the logistics centre via a mobile connection every time it is switched off. In this way, the vehicle serves as an intelligent sensor that is able to send or receive important information. This data helps assembly staff, distribution logistics and colleagues in the markets improve delivery reliability and reduce lead times. In the second phase of development, the vehicle's interior display will be used to confirm that the car has been handed over.
Prior to transferring the vehicle to the dealership, the Connected Distribution function is disabled and the ConnectedDrive function activated. This means the vehicle can no longer be tracked, and its status data is no longer documented.

Focus on sustainability: Natural gas, electric and future hydrogen trucks will reduce CO2 emissions

Logistics can help the BMW Group achieve its sustainability goals. The focus here is on continuous expansion of CO2-efficient modes of transport. More than 60 percent of all new vehicles now leave production plants by rail.
Nevertheless, it is still necessary to use trucks on certain in- and outbound logistics routes. To reduce emissions from these truck journeys, the BMW Group is already using natural gas and electric trucks in cooperation with logistics service providers. The aim is to reduce truck emissions by 40% by 2030 and to be completely emission-free by 2050.
Nine battery electric trucks are already in use at the BMW Group plants in Munich, Regensburg, Landshut and Leipzig for in- and outbound logistics. The current range available to electric trucks makes them ideal for transporting items within factory grounds or over short distances.
Trucks running on liquid natural gas (LNG) will also be more widely used in the future. Initial runs between the BMW Group plants in Steyr, Austria and Regensburg have shown positive results. LNG-powered trucks can reduce CO2 emissions by up to 25%, while trucks fuelled by bio-natural gas can achieve a reduction of up to 95%. Due to their long range of up to 1,600 km, LNG-powered trucks are ideally suited for long-haul routes.
Over the long term, hydrogen-powered trucks may also be used to achieve the goal of emission-free logistics by 2050. This technology is currently still under development.

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The BMW Group production network

Strong customer demand and the launch of new models resulted in very high capacity utilisation for the BMW Group's production network in 2017. With 2,505,741 vehicles produced for the BMW, MINI and Rolls-Royce brands, production volumes reached a new all-time high. This figure included 2,123,947 BMW, 378,486 MINI and 3,308 Rolls-Royce units. The company's German plants, which produced more than one million vehicles, are responsible for roughly half of production volumes.

With its unparalleled flexibility, the leading-edge production system is in excellent shape for the future. Based on Strategy NUMBER ONE > NEXT, it is characterised by a high level of efficiency and robust processes. The BMW Group's production expertise represents a decisive competitive advantage and contributes to the profitability of the company and its sustainable success.

Quality and speed of reaction are key factors in the BMW production system, as well as flexibility. Digitalisation, standardised modular concepts and intelligent composite construction testify to the high level of expertise within the production network. At the same time, the production system offers a very high level of customisation and allows customer specifications to be modified up until six days before delivery.

The BMW Group

With its four brands BMW, MINI, Rolls-Royce and BMW Motorrad, the BMW Group is the world's leading premium manufacturer of automobiles and motorcycles and also provides premium financial and mobility services. The BMW Group production network comprises 30 production and assembly facilities in 14 countries; the company has a global sales network in more than 140 countries.

In 2017, the BMW Group sold over 2,463,500 passenger vehicles and more than 164,000 motorcycles worldwide. The profit before tax in the financial year 2017 was € 10.655 billion on revenues amounting to € 98.678 billion. As of 31 December 2017, the BMW Group had a workforce of 129,932 employees.

The success of the BMW Group has always been based on long-term thinking and responsible action. The company has therefore established ecological and social sustainability throughout the value chain, comprehensive product responsibility and a clear commitment to conserving resources as an integral part of its strategy.

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