

A high-angle, wide shot of a modern industrial factory floor. The scene is dominated by several large, orange and white robotic arms, likely KUKA, positioned on a complex network of metal frames and conveyor systems. The lighting is bright and even, highlighting the metallic surfaces and the intricate machinery. The overall atmosphere is one of precision and automation.

DECIPHERING INDUSTRY 4.0 PART III SMART LOGISTICS AND MASS CUSTOMIZATION





OBJECTIVE

The future of making things will depend as much on smart logistics – supply and delivery – as on the smart technology in the factory. Factory technology has been developed to save companies money and resources, enable more flexible manufacturing, increase speed and offer product variation. But there seems little point in making products more intelligently to save money if the delivery process is flawed, losing money down the value chain.

Smart logistics can be seen in two broad ways: 1) the intelligent hardware that delivers material within a factory and 2) connecting customer and factory data to the tools of logistics to make them more efficient, especially in areas such as predictive maintenance.

► Intelligent factory delivery

Automated Guided Vehicles or AGVs, and the laser-guided LGVs, are well established as a means of replenishing stores, especially in the automotive sector. What is new is the ability for AGVs to use new “machine learning” technology, learning where to go, what to collect or pick and how to pick objects that they have not seen before.

► Connecting existing data

Data is collected and held within enterprise IT such as ERP, Manufacturing Execution Systems and Demand Planning. But many companies keep this data in their own silos and don't share it with the whole enterprise or the supply chain. Connecting data – such as asset condition monitoring – fully in the network can reveal substantial inefficiencies.



This paper also explores **mass customization**.

This is the technology and business systems that are required to personalize products for the individual buyer but still make them in high volume, economically.

Mass customization is about clever manufacturing technology but is also about where and how the personalization is applied. “Most people's views of mass customization seem to be limited to production, but the reality is that mass customization is about the smart application of advanced design and manufacturing technologies so that things can be personalized to a level where they add the greatest value where it matters most,” says Autodesk's Asif Moghal.

We will see how some companies have become successful by applying the personalization to the product or service in one area, keeping the cost of modification down.



SMART INDUSTRY NEEDS SMART LOGISTICS

Intelligent logistics tools and systems are developing fast, and are probably more mature than intelligent factory technology.

A logistics system delivers parts and materials efficiently. Decades of manufacturing systems have fine-tuned this to slick, lean systems – think just-in-time, kanban, poke yoke, lights and “dashboard” systems for prompting parts replenishment in the automotive industry.

Now, with Industry 4.0 technology, delivering and preparing parts for assembly is reaching the next level. Typically in a car production line, a wide range of parts arrive, often in plastic boxes, to a supply point on the line. Here they are manually sorted, picked and delivered on the line at the assembly point. This – **line side supply** – is often a manual process, but it is being automated.

“We are starting to see robotic systems that receive these plastic boxes on a pallet, it unpacks and delayers them, and stores them as single boxes in an automated high density store,” says James Sharples, managing director of SwissLog UK. Boxes are brought out directly or via a robotic sequencer automatically, then transported by a trolley or an automated guided vehicles or AGV to the line. “Where it used to need a man at the line it can now be delivered by AGV, that is, robot replenishment.”

Where is the Industry 4.0 here, you ask? This process has been maturing for many years, especially in automotive.

The difference today is in the data being analyzed. “Big data” capture and IoT allows people to make more efficient decisions on how your supply chain is affecting the production. For example, Swisslog provides parts tracking for Jaguar Land Rover (JLR) on the up-time of equipment. JLR measures stock in the system constantly and autonomously. An example of IoT is that it can count more units in the stores autonomously, previously a manual job done with handheld scanners, which have some element of error.

SMART LOGISTICS EQUIPMENT

Smart machines are being used for a wide range of tasks in factories and warehouses, especially for FMCG and high volume warehousing applications.

Robots are used for layer de-palletising, end of line palletizing and pallet transportation, with increased use of AGVs and LGVs, and warehouse storage and picking systems using modified AGVs to select boxes from closed racks with no (direct) human access, to save space.

The **AGV** is the standard device for smart material replenishment. As industrial output has increased and manufacturing employment has fallen, demand for AGVs has risen – IBISWorld says by 17.1% average annual rise between 2012 and 2017.

Increasingly sophisticated **camera systems** identify correct parts, and more importantly, reject incorrect parts. Handheld scanners also identify that boxes are correctly selected for that next operation.

The next step, **vision picking**, is a relatively new technique using smart glasses, such as Google Glasses and Microsoft HoloLens. The glasses show augmented reality images of additional information about the box, tray or trolley, such as progress of the order, aisle number, location and next pick. The picker can “see” what needs to go where, providing a faster, more accurate and user-friendly system of order picking.

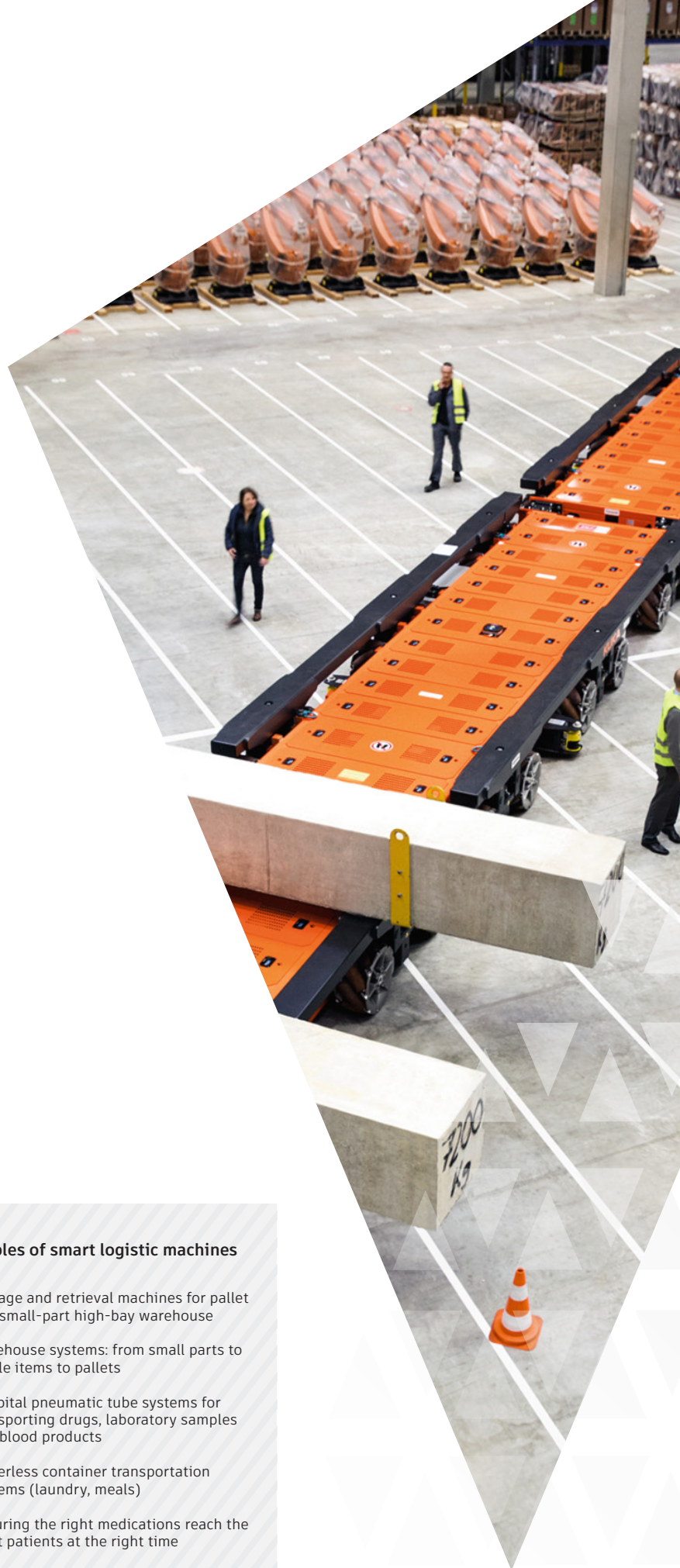
“The idea is, where possible, to bring the products to the human operator, or at least reduce the walking time for the operator,” says Swisslog’s James Sharples.



KUKA’s **omiMove robot** is designed to move heavy loads across a factory autonomously, such as trains and large aircraft parts, again responding to a pull command from the assembly station that needs the large component for fit out.

Now, AGV technology is being integrated with **collaborative robots**, or cobots, to deliver more tasks at the assembly point than was previously possible. AGV mounted cobots can be used for line-side supply to avoid having a person simply removing materials and placing them on a rack.

A growing trend is also the use of **product identification** technology. The ID device absorbs product information and uses “machine learning” to work out what to do. “Industry is trying to reach the point where you can show a robot something and it learns how to pick up an item autonomously having never seen it before. This is being termed ‘alternative intelligence’ more than artificial intelligence,” says Swisslog’s Sharples.



Examples of smart logistic machines

- ▶ Storage and retrieval machines for pallet and small-part high-bay warehouse
- ▶ Warehouse systems: from small parts to single items to pallets
- ▶ Hospital pneumatic tube systems for transporting drugs, laboratory samples and blood products
- ▶ Driverless container transportation systems (laundry, meals)
- ▶ Ensuring the right medications reach the right patients at the right time

MONITORING & PREDICTIVE MAINTENANCE

Condition monitoring

Predictive maintenance – detecting a fault before it occurs – is an essential part of smart logistics.

Increasingly, condition monitoring is helping smart factory logisticians to make key decisions about where to locate conveyors and when to change them.

Today, information about the speed, age, temperature, and wear of conveyor motors can be captured, and assessed for when it is likely to fail.

“You can plan for when it will fail, take it out of service before then, and manage production around that, so you are not dealing with an emergency breakdown where the line can’t get the material it needs. All that can be planned in to pre-empt a critical failure,” says James Sharples.

Companies are sharing this information beyond the factory. By measuring equipment continuously, and then sharing data about equipment performance across multiple sites, operations directors can start to see performance patterns on multiple sites. “This builds up a profile and you can start predicting with more accuracy,” Sharples says.



Predictive maintenance principles are also adopted in logistics. Typically, in a logistics operation with no true predictive maintenance, a broken part initiates a call out report, at which point the company checks if the repair can be made locally or if there is a spare part on site. Critical parts are kept on site, and this would be reproduced across multiple sites, which impacts on working capital and on the inventory of critical spare parts.

“For efficient logistics, like a factory, a breakdown or unplanned maintenance impacts on working capital, the level of inventory and the performance of spare parts, i.e. facilities management costs,” says Erik van Wunnik, Global Business Development Director at DSV Solutions.

Predictive maintenance technology might warn the company several hours or even days in advance that a part is needed on a machine or truck based on data its pulling from the capital equipment. This leads to higher performance of the factory or delivery system, because the right part is always on site and there is automatic replenishment on the line; if something is not working properly, it tells you.

“True predictive maintenance gives a big improvement on uptime and improvement on the whole logistics service,” says DSV’s van Wunnik.

(R) Image courtesy of Briggs Automotive Company Ltd.



MASS CUSTOMIZATION

Adding value where it matters most

Mass customization is the use of SMART design and manufacturing systems to produce custom, or personalized, output without the overheads of traditionally bespoke business models.

We know why Henry Ford famously said “You can have any color you like, as long as it’s black,” – because he could not have made the Model T Ford economically in a full palette of color choices.

But while mass customization involves technology, it does not necessarily need armies of robots swarming over a factory modifying products.

“I believe that most people’s view of mass customization is focused on production,” says Asif Moghal at Autodesk. “Mass customization is really about adding value where it matters the most to the customer”.

If the fourth industrial revolution is about smart design, smart manufacturing and smart processes then mass customization, or MC, represents a huge opportunity for wealth creation, driven by designing and making products in a smarter way. Companies that figure out how to do this will be the drivers of the 4th Industrial revolution.

“MC not only applies to how things are designed and made but how they’re experienced before, during and after purchase” says Moghal. “For example, go to certain websites and you will encounter “My Audi”, “My Triumph”, My Starbucks, and so on, all of which offer you opportunities to experience these brands digitally up-front”

Autodesk conducted research on this for its original *Future of Making Things* study in 2016 which asked around 50 companies about their “readiness” for, among other things, the world of mass customization. MC was in fact the area in which respondents seemed least ready for. Autodesk is doing the same research now to compare how companies design and make products and early results are that MC is being built into designs more and more.

Design automation

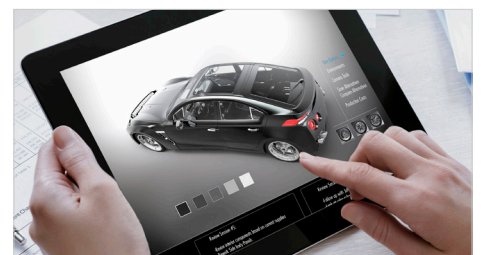
Customization changes product design rules

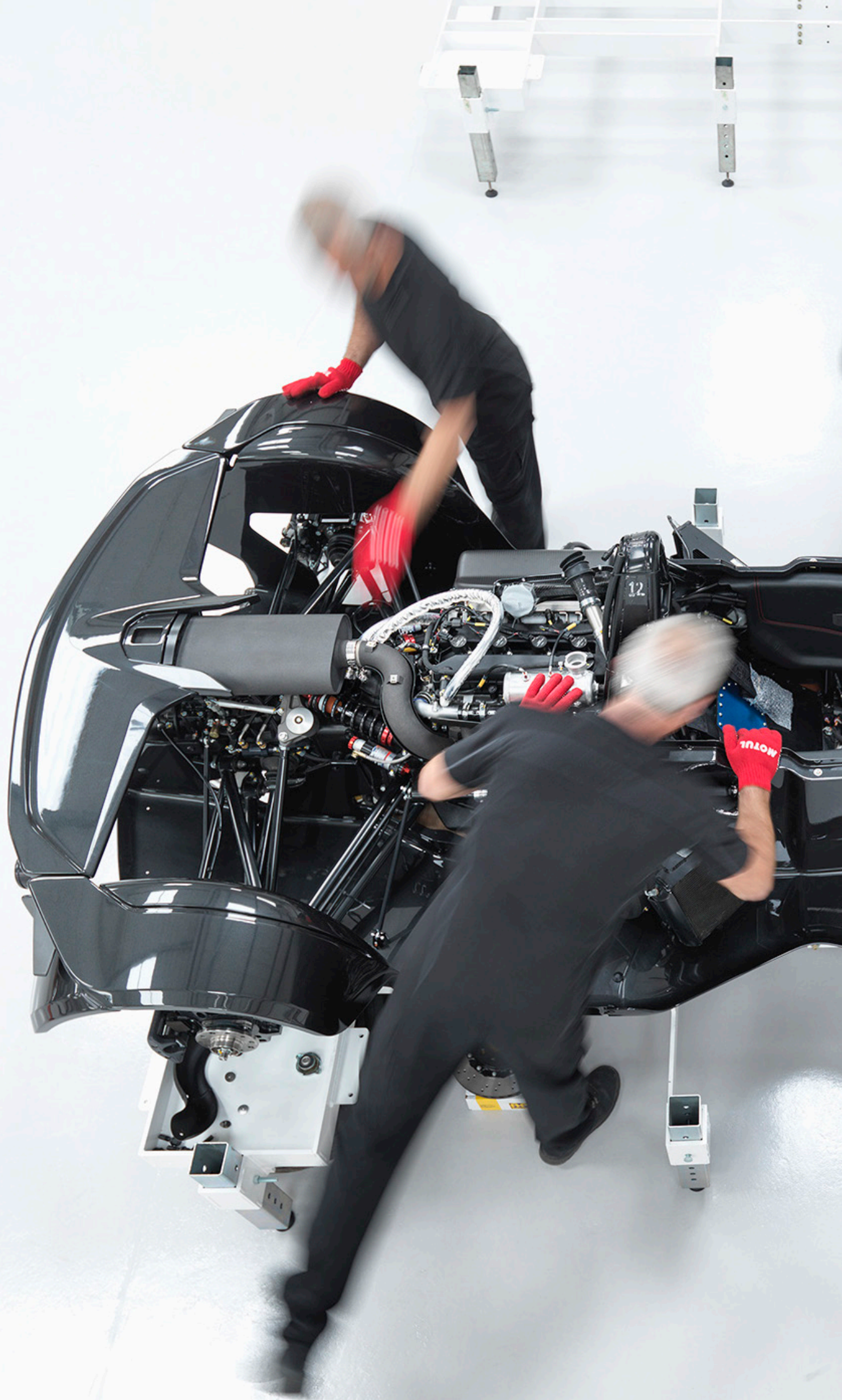
Product design is changing to accommodate MC.

“Some companies are using design automation to allow a product to be configured just by physical geometry or operational parameters,” says Moghal. “For example, give the design tool a space envelope, specify the product function and parameters, for example, an aircraft partition, and the tool customizes the product to specifically meet those design criteria.”

“This approach can be used in any industry, its just a question of defining the problem and feeding the design tool with the right data.”

The terms **topology optimization**, **generative design**, **machine learning** and **A.I.** are being used more commonly to explain this shift.









MASS CUSTOMIZATION

Can “normal” B2B companies customize products?

Customization seems more suited to higher end, consumer goods and luxury goods. What about normal industrial products.

Think of a conveyor system in a factory. The customer wants his conveyor to move 1000 boxes of product per hour, 7 days a week, all following a prescribed route of processes through the factory. But what happens when a new line of business comes in? Perhaps a product that itself is now highly customizable? The customer would need to re-design the line, re-configure and test it, to ensure it handled the new product well and bring it on line as quickly as possible. The company would be looking at a system re-design – but systems are just like products.

“If the system was designed to be more customizable, the conveyor could be re-configured, changed and optimized to deliver the maximum performance throughout the lifetime of that product,” says Moghal. “Designing this in at the front end, it could be reconfigured multiple times depending on the nature of the products it handles.”

The next step: with a truly smart and connected product, the conveyor itself will tell the company it is being under- or over-utilized.

Generative design

Topology optimization and **generative design** are now allowing companies to mass customize for specific design criteria.

EXAMPLES OF MC PRODUCTS

BAC Mono

The British road legal racing car is using generative design to improve the car's performance and increase personalization. This design then modifies the manufacturing process. One example is that the steering wheel is made to measure, where a mould is taken of the driver's grip and the wheel is 3D printed to fit the grip perfectly. "This is mass C customization, adding value where it matters most," says Asif Moghal.



Image courtesy of Briggs Automotive Company Ltd.

Hackrod

A former toy company creative director and film director / motorcycle racer have teamed up to launch a very different car manufacturing company. Felix Holst and Mouse McCoy wanted to make powerful, high performance cars, to their own design – and fast.

Using generative design, virtual reality (VR), 3D printing, and a cloud-based supply chain, the Hack Rod team is challenging the traditional approach to manufacturing. The partners' experience of making "Hot Wheels for Real", life-size versions of the Hot Wheels toy stunt cars, taught them a new, disruptive vision of manufacturing.

The team wired a hand-fabricated race car with sensors and tested it to the max. The finite element analysis data produced was fed into Project Dreamcatcher, a generative design system that uses machine learning to process information and create thousands of new design options.

The project then adopted novel ways of both procuring and fabricating specialist components, custom-manufactured. This was a challenge because generatively designed parts often have complex shapes that can't be easily fabricated with traditional machining. So 3D printing of niche parts could be used on the next chassis, removing the need for new tooling.

The Hack Rod engineers also used more software and digital tools to design the car body, using Fusion 360 as the platform and virtual reality goggles to integrate design changes on a full-size 3D model before deploying them for real, avoiding the need to create an expensive 3D model in clay.

"[Our Hot Wheels' experience] was about the inspiration of kids that wanted what they designed on a full-scale basis," says Hack Rod creative director Mouse McCoy. "From that, the research project was born to really look at these applied technologies converging on each other. . . . And from that, we felt like, wow, the manufacturing company of the future is going to look something like this."

(R) Image courtesy of Hack Rod.

MASS CUSTOMIZATION WHAT NEXT?

Where should the customization happen and how will this affect the supply chain?

“OEMs tell us they would like to produce basic cars, deliver them to the market, have the distributors sell the car, then the consumer would customize it at this stage,” says Erik van Wunnik of DSV. A customization could be a personalized bumper or trim.

But in two years time the customer wants a different modification. The design software and perhaps 3D printing would be a driver of mass customization and a factor of recurring sales in the automotive industry.

“That would impact logisticians like DSV because the method of customization might effect the delivery of goods,” says van Wunnik. “For example, we used to deliver cars but next to this we will have to distribute raw material to the 3D printer studios making the parts, and new parts to the distributors to fit them. It creates a new dynamic market.”

It will also affect the environmental sustainability of the car industry. Customizing a car's appearance might keep the chassis and engine in circulation for longer, reducing scrap, but it might then have five different bumpers in its lifetime, increasing resource consumption. But if those bumpers and parts were designed to be recyclable, the net effect could be lower resource consumption.

New, young companies: Customizing products suits start-ups because they can require relatively low capital and barriers to entry. This will be disruptive and drive economic growth.

“We are going to see the capability of higher levels of MC creep in to the mid-sized and SME companies, so they can offer their customer the full experience to customize what that customer wants,” says Autodesk's Moghal. “Large companies will have more barriers because of their rigid structure and overhead, so SMEs have an advantage.”

This may lead to acquisitions of small, more nimble companies which have developed a service for the OEM who will buy their capacity when it is ready. It will stimulate entrepreneurialism in manufacturing and also encourage the fusion between product design, computer programming, web coding and manufacturing which will appeal to a younger workforce, a demographic that manufacturing badly needs.

Image courtesy of BAC Ltd. / Monty Rakusen.





We hope you have found this whitepaper useful.

Please get in touch with Autodesk and KUKA Robotics if you wish to discuss any part of this report further.

Coming Up Next.....

The fourth & final Autodesk and KUKA Robotics paper in this series on Deciphering Industry 4.0 will investigate:

GENERATIVE DESIGN & MACHINE LEARNING

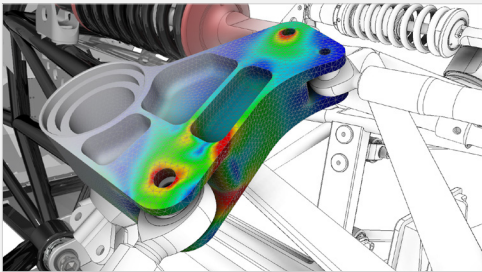


Image courtesy of Briggs Automotive Company Ltd.

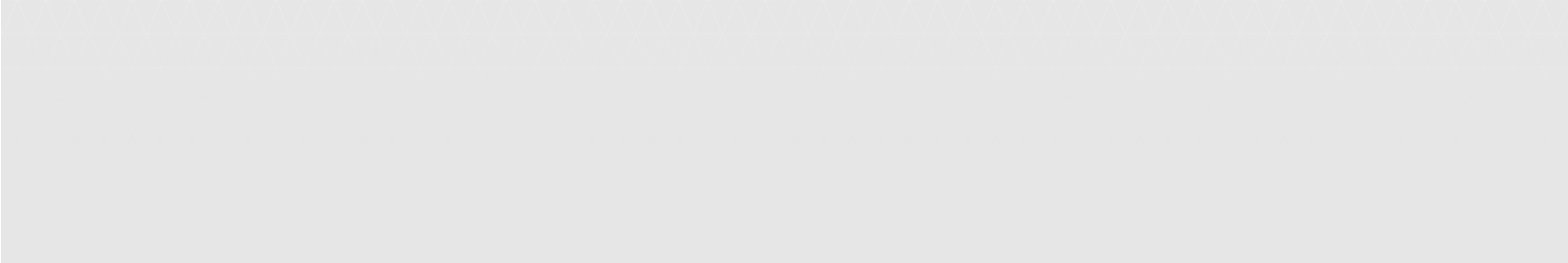
Industrial processes are becoming more iterative and self-learning. The next Autodesk and KUKA Robotics Deciphering Industry 4.0 whitepaper covers **generative design** and **machine learning**.

Generative design, fast becoming the dominant design methodology for smart industry or Industry 4.0, uses algorithms to synthesize design. Hitherto engineers would conceive a design in their heads and transcribe it into a CAD tool. With generative design, designers give an algorithm the goals – such as a clamping force – and the constraints, such as materials, and the code then creates the best design solution to fit the brief. Machine learning is where machines, coupled to computers, are becoming capable of learning without explicit programming. Both are fast becoming more common features in industry and will help accelerate the automation of production tasks.

Reference links

- ▶ **Swisslog & KUKA: Automated item picking**
<https://www.youtube.com/watch?v=MJSITiLi7iA>
- ▶ **Vision picking with DHL**
<https://www.youtube.com/watch?v=I8vYrAUb0BQ>
- ▶ **Hack Rod**
<https://www.autodesk.com/customer-stories/hack-rod>
- ▶ **Autodesk Fusion Connect**
IoT cloud software connecting design, manufacture and supply chain
<https://autodeskfusionconnect.com/>







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