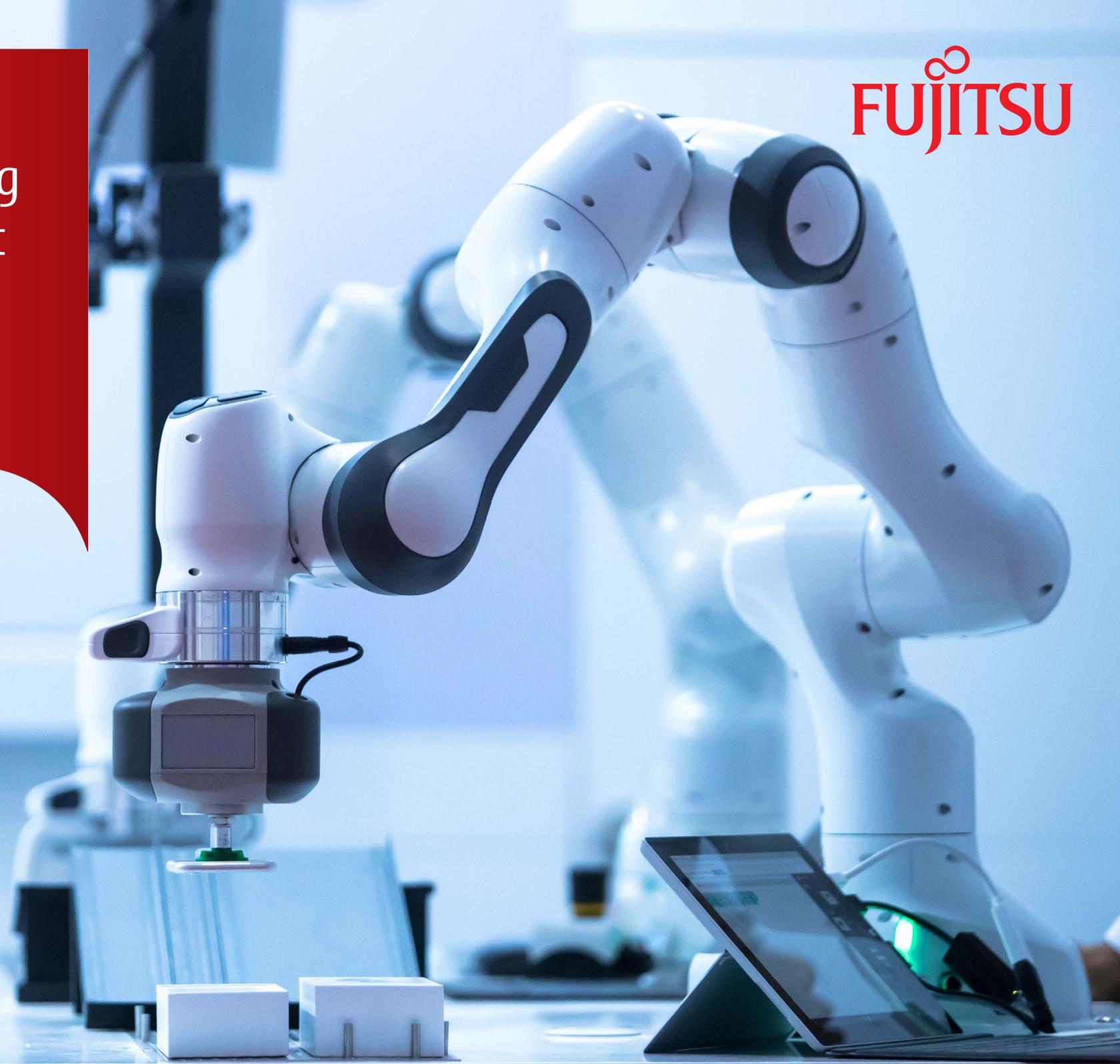


German
manufacturing
and the smart
factory

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Introduction

This eBook takes a look at the current influences the German manufacturing industry is subject to and the direction where it can develop.

Chiefly, this eBook recommends that manufacturers focus on further development of so-called lean manufacturing in the direction of a smart factory. The smart factory, in turn, is influenced by developments including new technologies such as artificial intelligence, and also the changing demands on people.

In detail, the eBook deals with:

- how these current influences will drive the evolution from lean manufacturing to the smart factory
- the role disruptive technologies play
- why digitalization is a fundamental building block, without which these new technologies won't be able to facilitate the brownfield evolution towards the smart factory
- the role humans will play in the smart factory
- where the journey will take organisations in the future.



A changing landscape

The manufacturing landscape is evolving faster than ever. Technologies including Internet of Things (IoT), artificial intelligence (AI), advanced analytics, quantum-inspired computing, and cloud computing are combining to create new opportunities for manufacturers. This is built on top of the cutting-edge technology already used by manufacturers, including robotics, autonomous driving, 3D printing and more.

At the same time, changes in society like climate change, electric mobility, and increasing urbanization have the potential to significantly affect Germany's manufacturing industry. For example, environmental organizations are pressuring cities to ban diesel cars from some streets as a preliminary measure to reduce emissions. This is creating demand for electric vehicles. And, with increasing urbanization, driving into the city center is no longer an option for many Germans, which is creating a challenge. Car manufacturers will need to respond to these megatrends at some point or risk becoming irrelevant. Their response must include new mobility concepts that leverage solutions and services that go beyond pure technology.

While the automotive industry serves as a prominent example, the German manufacturing industry is not limited by the automotive market. In fact, it comprises the entire field of machine engineering and similar challenges can be identified in multiple areas.

The manufacturing industry is feeling the impact of the quickly changing landscape as products become obsolete,

new products arise, and unexpected competition comes from outside the traditional competitor landscape, driven by new technology and shorter product lifecycles.

On the other hand, this type of disruption also holds opportunities for manufacturers to compete more effectively. Plattform Industrie 4.0 is a German government initiative that aims to decentralize control of production processes and introduce final-order-controlled production and smart services. In practice, this can mean that manufacturing organizations no longer sell a product but, instead, an output that's customized to the customer's needs.

This approach puts the customer at the centre of the manufacturing business. Focusing on improving the customer experience by providing new consumption models, data-enriched services, individualized products, and improved quality at a lower cost will all help German manufacturers compete more effectively with overseas counterparts.

For example, Mittelstand companies are the lifeblood of German manufacturing, often supplying larger companies with specialist components or technology. Many of them are hidden champions, meaning they're world-leaders in their sector. However, their small size and traditional approach often means Mittelstand companies find it challenging to adopt the latest technology and embrace the opportunities offered by Plattform Industrie 4.0.

The answer could be found in the smart factory.

From lean manufacturing to the smart factory

Smart factory is the evolution of lean manufacturing, in which the principles of stability, leanness, and efficiency remain important and a number of new aspects also come into play. The smart factory enriches the traditional lean manufacturing in at least six key ways:

1

Stronger customer focus.

3

Support of smaller lot sizes at the same cost as mass production.

5

The enrichment of products by smart services.

2

Decentralized control.

4

The digital twin.

6

Production-cell based manufacturing as an alternative to production-line oriented manufacturing.

These concepts are a direct reaction to the rapidly changing environment and market conditions confronting German manufacturing.

Manufacturing industries around the globe face increased and unexpected competition from global providers. While Asia continues to be a manufacturing powerhouse, non-traditional competitors are also emerging. For example, manufacturing-adjacent businesses can leverage emerging technologies such as additive manufacturing (3D printing) to compete.

Meanwhile, the cost of manufacturing continues to increase and customer expectations are high with little to no tolerance for products that don't meet their standards. Being able to produce in smaller lot sizes that are customized to meet customer needs, at the same cost and quality levels that were possible in mass production, remains a key challenge for manufacturers.

Manufacturing according to customer demand in a highly dynamic environment is now more important than ever.



Disruptive technologies as important enabler for the smart factory

New technologies have paved the way to better address each of these issues and the rapidly changing product landscape forces companies to put more emphasis on these areas. Consequently, a new quality is added to previously-known lean manufacturing topics.

It goes without saying that technology is not the only building block of a smart factory but it is an important tool to further develop and optimize processes. It helps to better prepare people for the requirements of a smart factory.

The following examples show how AI and quantum-inspired computing, among others, are powering the technical foundation of the smart factory:

AI-driven image recognition in quality control

Using AI-driven optical image recognition, like Fujitsu's Advanced Image Recognition, smart factories can dramatically reduce the number of product defects that make it through the production line. Rather than relying on humans to manually examine production line samples, which can take hours and defects may still be missed, smart factories can automate this process.

The system examines photos, ultrasonic pictures, x-rays, and other data that can be converted to images. Based on training images, it determines whether a product has a defect and categorizes that defect.

This approach means that manufacturers can inspect every product that comes off the line, not just a sample. It overcomes the risk of human error and completes inspections in a fraction of the time it would take a person to do it. These systems don't require breaks like humans do, and they free people up to work on more interesting and creative tasks.

Advanced image recognition can also act as a differentiator for manufacturers who can grade their output and sell perfect products at a premium, and less-perfect products for a reduced price, creating more options for customers.

It also forms the basis for an automated feedback to earlier stages in production to optimize production output by re-adjusting machinery in time. Quality control is thus transformed from a cost factor into an active business contribution.



Production optimization with digital annealer

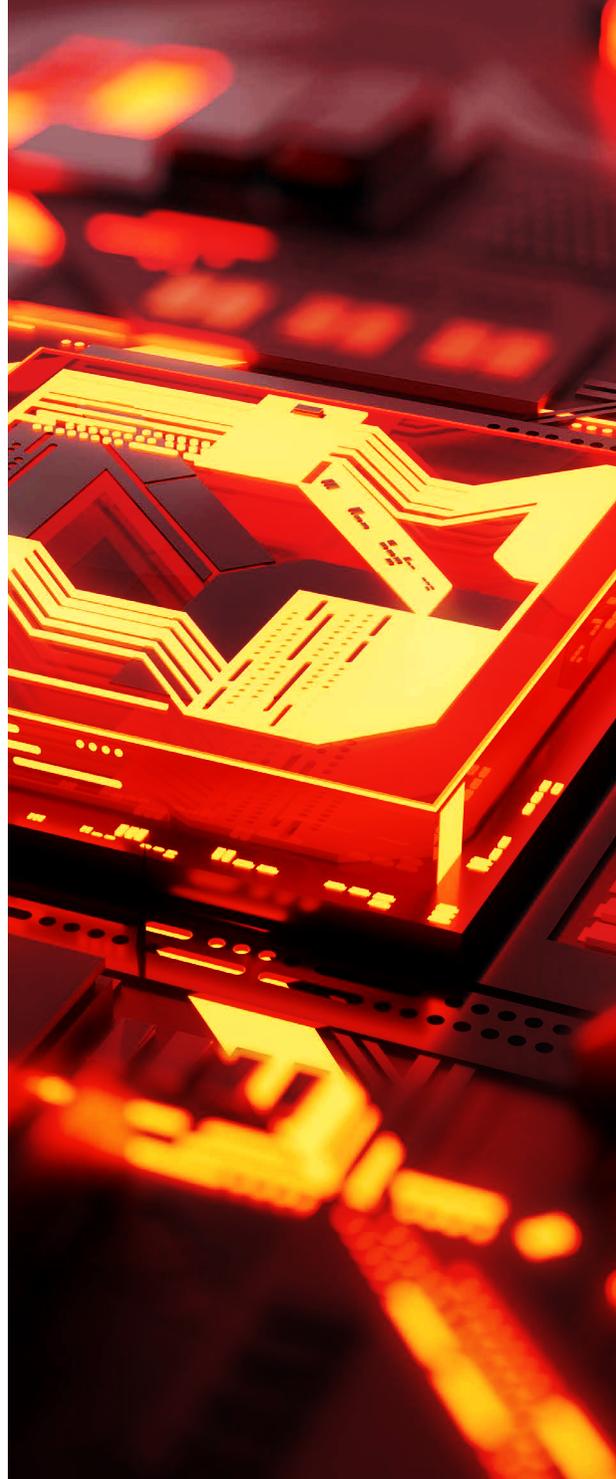
Many optimization problems face the challenge that the optimal solution must be identified from an almost infinite number of different alternatives. Until now, there have been no practicable solutions for such problems, such as job shop scheduling or path optimization of robot movements. Either the calculations took far too long or the solution was far from the optimum.

In the field of quantum computers, there have been first attempts for some time now to achieve significantly better results in a much shorter time with the help of a so-called quantum annealer. However, the problem sizes that can be solved with such a quantum annealer are not yet relevant for the manufacturing industry. With a purely classical architecture, in which the problem is cast in a single CMOS chip, called digital annealer, which works massively parallel in a quantum-inspired way, relevant solutions can already be designed today.

For example, finding the optimum schedule to run production jobs on a fixed number of machines, with different machine sequences and duration times per machine for every job, can be a logistical nightmare for a manufacturing facility. There is no simple equation that can solve this problem. Trying each combination individually would literally take billions of years.

Instead of only relying on rules-based optimization in typical manufacturing execution systems (MES) or even manual approaches, the digital annealer bridges this gap. It can find solutions to hugely complex problems in a short timeframe, for example, increasing the throughput of a production run by 30 percent within one minute.

In another example, in the case of optimizing robot movements, a calculation that would have taken more than 40 hours now takes less than 20 seconds. Consequently, the optimized robot movement time was almost 40 percent shorter than before the digital annealer was used to optimize it.



Major German manufacturers have a strong focus on these technologies, even in this still-early stage of development.

Conclusion on disruptive technologies

These are just two (but very concrete) examples that illustrate how disruptive technologies have a direct impact on manufacturing and the resulting business opportunities.

There are, of course, many other fields where disruptive technologies like AI can be used, such as in the root cause analysis of recurring problems along the production line. Another field of application is the prediction of future behavior. In contrast to the mere visualization of the actual state of a production, these new technologies allow a view into the past as well as into the future and thus provide insights that are not possible for a purely human observer.

In addition to AI, the general discipline of advanced analytics is also evolving. And, progress is also being made in the field of quantum computers, which makes productive use of these technologies in the future seem more likely. At least, major German manufacturers have a strong focus on these technologies, even in this still-early stage of development. In this context, however, the developments mentioned above in the field of digital annealing are particularly interesting, as this would probably not have happened without the progress in the quantum computer environment.

Digitalization as the foundation for the smart factory

The role of digitalization for the smart factory

Digitalization is an important prerequisite for making disruptive technologies, such as those mentioned above, usable in the first place. Therefore, a smart factory depends on digital processes wherever possible. Digitalization, together with disruptive technologies, lets decision-makers know what's happening, why it's happening, how it's happening, and how to optimise as well as how to address issues, in near-real time. When done well, this can mean less machine idle time, fewer product defects, lower costs and, subsequently, increased awareness, decision and action speeds, and productivity.

In addition, digitalization lays the foundation to creating a fully connected facility.

Digitalization, together with disruptive technologies, lets decision-makers know what's happening, why it's happening, and how it's happening, as well as how to address issues, in near-real time.

This concerns the development of centrally controlled machines in the direction of autonomous units, so-called cyber physical systems, which coordinate work processes among themselves instead of central control. But it is also about the connection of the machines with the classical IT systems such as enterprise resource planning (ERP) and customer relationship management (CRM), and, of course, the connection with disruptive technologies like AI, advanced analytics, and quantum-inspired computing, no matter whether these are offered from a cloud or via an on-premise infrastructure.

Not all of these approaches are already a reality or already widely used. However, the requirements for digitalization are now much more tangible and German manufacturing companies are developing their digitalization strategy with these goals in mind.





Challenges and short-term opportunities

A closer look at the topic of digitalization in the manufacturing industry reveals a number of challenges but also opportunities to further develop the current production in terms of the goals just described. They are all related to the fact that manufacturing companies have to start their journey to the smart factory from a brownfield that needs to be carefully developed so as not to damage any currently running business.

On the one hand some of the challenges are:

- integrating operational technology (OT) with information technology (IT)
- overcoming security issues as machines communicate with IT infrastructure
- harmonizing the wealth of machine protocols
- implementing an intelligent edge architecture
- digitalizing legacy machines in a brownfield environment.

On the other hand, some first opportunities are:

- retrofitting machines with limited IT capabilities
- gaining first insights into existing processes by aggregating and visualizing machine data
- gaining insights from the context of data from machines and classic IT systems (e.g. ERP and CRM systems).

The starting point of most digitalization efforts is likely to be the connection of the often still-isolated machine environment (typically referred to as OT) to the existing IT infrastructure.

This opens up potential security issues as systems that were previously not connected to any network lose their air-gap protection and become connected to the internet. However, with the right security measures in place, the benefits of increased connectivity far outweigh the security concerns.

In this context, Internet of Things (IoT) gateways such as the Fujitsu INTELLIEDGE appliance play an important role. This appliance is the transfer point of all machine data from OT to IT. On the one hand, it has all the necessary hardware interfaces for tapping (and, in principle, also for controlling) the machine data and, due to its ruggedized design, it can be operated in the harsh conditions of typical OT environments. On the other hand, it is a device that is fully integrated and managed by IT governance, which fully supports all typical security measures from IT.

In a nutshell, Fujitsu's IoT solution INTELLIEDGE helps organizations to bridge the gap between OT and IT by securely connecting OT systems to on-premise and

cloud IT environments. It offers enhanced security and lets manufacturers embrace the Industrial IoT sooner and more effectively.

The OT world today is still very much dominated by a multitude of different machine protocols such as Modbus, Profibus, Profinet and many more. Standardized and secure communication from the device to the cloud, however, requires open platform communications according to IT standards.

In addition, there is the demand for a uniform view and approach to machines. This involves the standardized representation of machine states, a method-oriented control (analogous to an object-oriented programming methodology) and an alerting system that can trigger events in a targeted manner. The open platform communications united architecture (OPC/UA) protocol combines all these properties. This lets devices communicate with each other in machine-readable ways, sharing data without human intervention.

In a first step, standardized data can be accessed via this interface. The actual idea, however, goes beyond this approach and touches on the idea of cyber-physical systems formulated above, i.e. decentralized, autonomous communication between machines.



But what to do with the newly acquired data, especially where to evaluate them? There are different approaches here. Some see this process completely in the cloud. Others see the necessity to perform these tasks directly near the machine, at the so-called edge. A general recommendation in one direction or the other cannot simply be given. Rather, it can be assumed that hybrid architectures that consistently take advantage of the edge, the core and the cloud will prevail.

In AI-supported quality assurance, for example, it makes sense to evaluate the image data directly on the shop floor to avoid unnecessary data transfer, limited latencies and possible unreliability of the internet connection to the cloud. The training of the data, which requires a lot of computing power and is only necessary from time to time, may be easier to implement in the cloud.

An important consequence of this hybrid model is the need to create an appropriate intelligent edge infrastructure in which the different services such as collecting, aggregating, analyzing data, and then using the insights to make real-time decisions can be effectively managed. Sometimes this intelligent edge infrastructure is referred to as fog infrastructure. The name fog is an allusion to the architectures used in clouds today. Therefore, Fujitsu's INTELLIEDGE appliance implements more than just an IT

governance-compliant gateway function, but rather a virtual machine- and container-based platform that can be orchestrated via a corresponding management platform. In contrast to a pure cloud architecture, the hardware-related services can also be managed here.

The next challenge is to find ways to integrate legacy OT systems, making them ready for internet connection as well as retrofitting them to produce relevant digital data as a basis for new solutions. In contrast to IT, expensive OT equipment often lasts for decades. In many cases, organizations have invested significantly in these technologies and aren't yet ready to jettison them. However, these older technologies are unable to transform to support modern practices or integrate with newer, more powerful technologies.

To move toward becoming a smart factory, organizations will need to consider how they can retrofit legacy technologies. Attaching sensors in a way that does not disturb the previous operation of the machines is a popular retrofitting method. Together with the original machine data, the additional sensor data can be made available to other IT applications, for example via an OPC/UA implementation in a gateway service within a Fujitsu INTELLIEDGE appliance in the form of a self-describing data model.

Hybrid architectures that consistently take advantage of the edge, the core, and the cloud will prevail.

Gaining first insights

Data is a key element of a smart factory. In previous sections, we've seen how to integrate machines into an IT environment, how to retrieve data, and how to process it in an intelligent edge infrastructure. However, before we let the disruptive technologies mentioned at the beginning of this eBook loose on this data, the first step is to visualize this data in a way that allows for valuable insights that would otherwise often go undiscovered. The basis for this is an architecture that allows many different types of data to be stored efficiently and made available to other applications in a structured manner.

COLMINA (Collaborative Monozukuri Innovation Agent) is a Fujitsu toolbox that provides such an architecture. It offers an API for ingesting data in a data lake consisting of databases for structured and unstructured data. The idea is to create an ecosystem based on an open architecture that can be easily and modularly integrated into a manufacturer's existing environment. COLMINA uses all available data sources, such as the machine data just mentioned, but also other production-related data sourced from a manufacturing execution system (MES) or from the classical IT environment, such as an ERP system. In this way, COLMINA works seamlessly with the

One of COLMINA's core application services is the intelligent dashboard, which visualizes data of various kinds systematically across departments.

brownfield and paves the way for using disruptive technologies, as mentioned above, in addition to pure visualization.

After ingesting the data from the various sources, COLMINA's next step is to structure all this data according to a predefined data model, providing a unified platform for applications, which is discussed in the next section. COLMINA also provides the basic infrastructure services for these applications such as container management, storage services, visualization services, authentication services, resource management, and operations.

One of COLMINA's core application services is the intelligent dashboard, which visualizes data of various kinds systematically across departments.

Many dashboards today are quickly created within departments to visualize machine data. This data is often only accessible within this department. However, it makes more sense to collect all essential production data in one dashboard, which is then available companywide.

To maintain an overview, it is a good idea to hierarchically aggregate data on several levels and thus provide access to relevant data for different target groups within the company. This way, a dashboard hierarchy can be implemented for the C-level, which displays all factories worldwide at a glance. In a first zoom into a factory, its structure and its most important KPIs are displayed. On the next level, individual production lines can then be viewed with their most important data, and on another level the status of individual machines can be viewed.

In this way, digitalization and an initial visualization can be used to gain a clear insight into the condition and initial optimization possibilities of the production. For many manufacturing companies, this is the first goal of successful digitalization and also the starting point for further development towards a smart factory.

The further you push the visualization, the closer you get to the concept of the digital twin.





Digital twins

A digital twin is a virtual representation of a physical object. Creating a precise clone of a physical object in the virtual world lets manufacturers manipulate and experiment on the digital twin to gain invaluable insights into product performance.

By gathering data from digital twins and feeding it back into products, manufacturers can improve products, reduce costs, and increase productivity and operational resilience.

The insights gained from a digital twin are vastly more accurate and detailed than product research in the physical world could yield for the same investment. Therefore, digital twinning makes it possible for smart factories to meet and exceed KPIs at the factory, production line, and individual product level.

The ideal of a digital twin, however, involves the consistent linking of all digital data, starting with the product design, the construction data, and the individual product states during production and including the use of the product in operation. This ideal is not yet a reality today, but it shows what significance a digital twin in this form can have for a smart factory.

In any case, consistent digitalization and an initial visualization of the data is an important basis for the further development of production towards a smart factory.

The human factor

The good news first: humans are likely to be significantly affected in positive ways by the transition to the smart factory.

To date, many people are still employed directly in production operations. However, for easily understandable reasons, it is not possible to optimize a human being in the same way as a machine. Furthermore, there are activities in production for which humans are simply less suitable or capable of high-level performance than smart technology. This includes activities such as heavy lifting or repetitive quality assurance activities (as explained earlier in the example of using AI in quality control).

With increasing automation and progress in technology, humans can focus on more interesting and fulfilling tasks. The fulfilling tasks for the future will increasingly be focused on monitoring and controlling the production process as opposed to operating throughput processes.

And here technology can help as well. The factors mentioned earlier, such as the environment, society and new technologies, have accelerated the need for rapid adaptation to new market conditions and the ability to respond to them. People also need to be prepared for these changes. Digital companion systems help (especially younger) people to cope with challenge of catching up on decades of existing know-how and following an increasingly rapid progress in the smart factory evolution.

COLMINA, the Fujitsu toolbox, which we introduced in an earlier section as an example for a digitalization platform, provides a number of these companion systems in the form of applications (or scenarios as they are called in COLMINA).

An example of this is "minimize impact on production". This scenario is about reacting quickly and effectively to unforeseen deviations from a production plan, such as a machine failure. Along KPIs such as "total setup time", "throughput", "production end time" etc., alternative restart scenarios can be simulated. Genetic algorithms are used in this scenario.

Another example deals with an "accelerated response to specification change". This is about an optimal plan for implementing a specification change in a product, for example, replacing a component with a new, better one or one from another supplier. Here, the human worker is given decision support regarding the optimal time for the change to the new component. Inventory, orders and other parameters are used for this purpose.

What all these digital companion systems have in common is that they help people in monitoring and controlling to handle complex knowledge more easily (and at the same time seamlessly integrate in the existing brownfield).

Alternatively to digital companion systems, smart factories can also improve worker safety using wearable technology, IoT sensors, and predictive alerts that trigger warnings when safety parameters are breached.

Selecting the right methodology for implementation

Smart factory solutions are modular and span production lines, operational control centres, warehousing, security and technology and platforms. Solutions can be deployed holistically or in a phased approach.

Before embarking on a smart factory project, it's essential to have business goals in mind. These should be the driving and decisive factors in delivering any smart factory concept. Once this is done, manufacturers can transform step by step. This should never be seen as an overnight change, as a true transformation to smart factory status takes more than a few weeks or even a few months.

Furthermore, it's important to revisit the goal to ensure it's still relevant and achievable. The marketplace could change significantly in the next decade, necessitating a new strategy. With so many factors that are impossible to predict, manufacturers could be forgiven for preferring to do nothing. However, that's not tenable for the long term and it's important to understand the general direction of developments so that the organization can keep pace with the market. It's essential to constantly question and reassess to ensure businesses remain on the right track and the development towards a smart factory remains aligned.

At that point, transforming to a smart factory needs to take into account what new technologies can be adopted in the short and long term, what competencies already exist in the organization (and where gaps may need to be filled), and what economic factors need to be considered.

It's essential to work with an experienced and highly knowledgeable partner that understands the challenges facing the manufacturing sector, as well as the solutions that can help manufacturers begin the journey towards becoming a smart factory.

Future outlook

Fujitsu recently surveyed more than 1,600 senior decision-makers worldwide and found that 90 percent have a clear digital strategy but 70 percent see a clear lack of digital skills across the organization, so they're struggling to deliver on their strategies.¹

The key to successful digital transformation is to have clear goals and be prepared to re-adjust quickly. Small projects with quick wins can help set the table for more comprehensive projects; however, it's essential for the organization to have a culture in which it's permissible to make mistakes and learn from them. It's highly unrealistic to assume that a detailed business plan can address the challenges of a disruptive environment but clearly defined KPIs can help keep projects on track.

The key to successful digital transformation is to have clear goals and be prepared to re-adjust quickly. Small projects with quick wins can help set the table for more comprehensive projects.

As localized trends and megatrends continue to coalesce and their potential impacts take shape, it's essential for German manufacturers to be prepared and to gain an understanding of how smart technology can help them thrive in a new marketplace.

There are numerous companies already making the smart factory a reality today. For example, cell-oriented production

is replacing line-oriented production in some organizations. Cellular manufacturing provides increased agility and flexibility while creating less waste.

Furthermore, organizations are experimenting with smart products that can drive their own production. These products have intelligence built in that knows what the next step in the manufacturing process should be and initiates that next step without human intervention. This creates improved efficiency and less requirement for physical labour in the manufacturing process.

In smart factories, machines can communicate directly with each other. This supports the scheme of decentralized control, in which risk is mitigated and production is flexible because control doesn't rest in a single location.

Tighter integration with ERP systems will let smart factories compete more effectively. For example, a build-to-order system can let customers place their orders directly via an online interface to an ERP solution. That order can then be communicated directly to the shop floor where the manufacturing process can be initiated. The product could be scheduled for production before the customer has logged off the website. This type of ordering process can help ensure that manufacturers have less stock to manage, as it will be manufactured and distributed to order.

With integration a key characteristic of the smart factory, the future will include integrated communications and visibility across the whole logistics chain. This means that managers have visibility not only into what's happening within their own organisation but also in organisations that are delivering parts or components. This can provide early insights into material shortages that could affect production, which would let manufacturers activate contingency plans or inform customers before the delays become an issue.

¹ https://www.fujitsu.com/global/images/gig5/2019_MCS_Smart_Factory_Report_Final_Fujitsu_091019_highres.pdf



Next steps

A co-creation approach that leverages the knowledge and experience of a strong partner can be the difference between a successful transformation and a failure.

Fujitsu has a proven history of helping manufacturers transform their operations to become smart factories. With solutions spanning sourcing, procurement, processing and manufacturing, distribution, warehousing, customer service, sales, and security, Fujitsu can help you become more efficient and competitive by increasing throughput, reducing inventory,

gaining more visibility to processes, and actioning bottlenecks in real time.

The Fujitsu Digital Transformation Center in Munich is a specialized studio where you can explore ideas and develop future visions for your manufacturing business.

To find out more about how our smart factory solutions can help you, [visit our website](#) or contact us today.

[Click here](#) to read about how we've helped manufacturing customers around the world to improve their operations.

Further reading

- [Standardization could be the catalyst powering manufacturing in Industry 4.0](#)
- [Manufacturers eyeing up billion-dollar quantum disruption opportunities](#)
- [How an agile approach will enable manufacturers to make Industry 4.0 work for them](#)