# .experience

# Smart Factories

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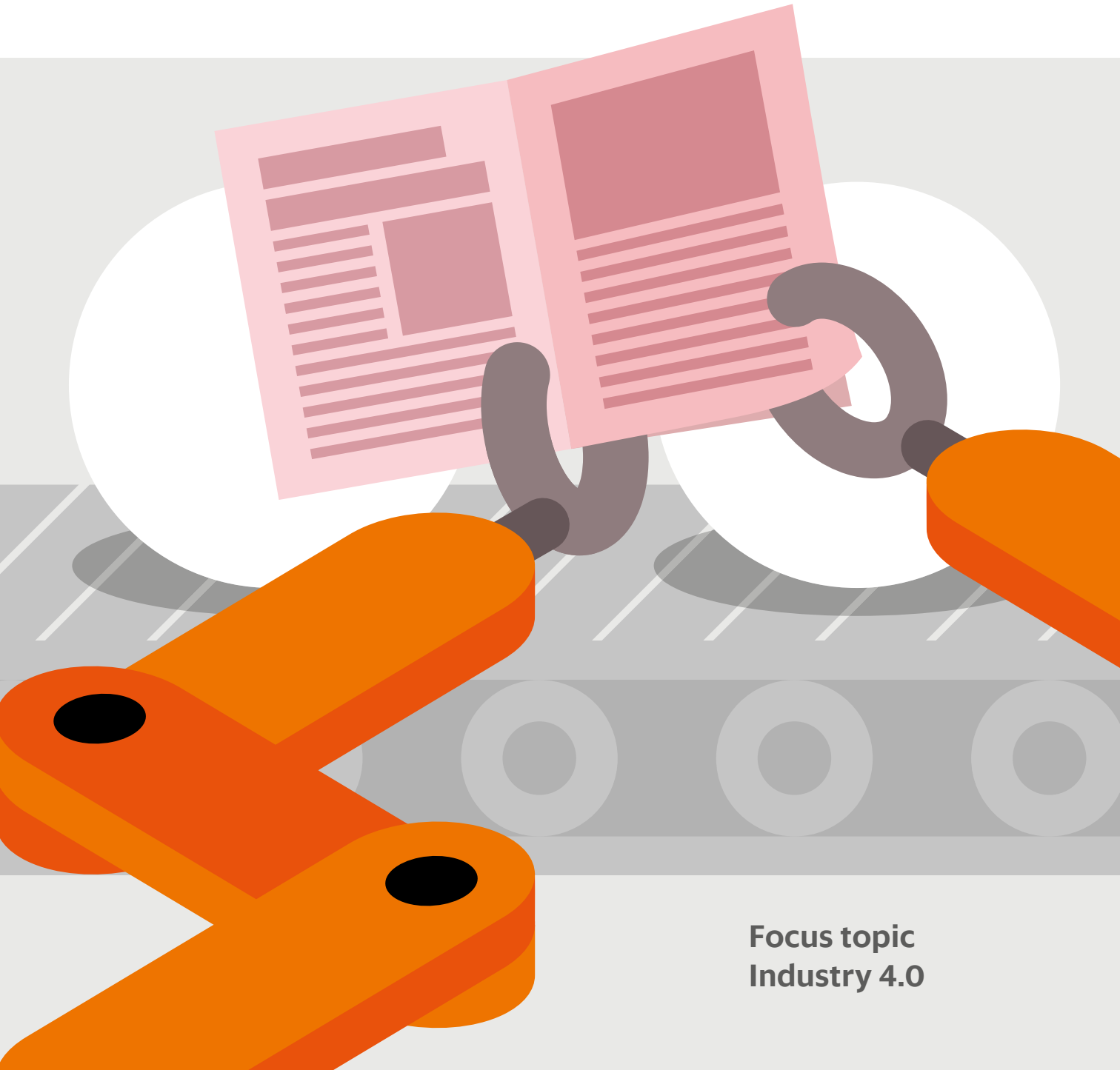

Focus topic
Industry 4.0

# Everything is connected

## In life, in business and with Industry 4.0, and definitely in manufacturing.

**Andreas Gisler**
*CEO*
andreas.gisler@erni.ch

Throughout the whole history of industry, people always tried to become better connected. To communicate with each other more easily, to shorten the distances that lay between them, to travel faster, to get supplies, assemble the pieces and then ship the final product to customers in a shorter time and with lower costs. Our need to connect various aspects of our lives drove humanity towards groundbreaking innovations. Our hunger for progress brought rapidly changing times of pushing the boundaries of what is possible in factories today.

First came the steam engine. Production became much easier and more efficient, which created faster supply chains and distribution. The first industrial revolution was just the beginning of an unstoppable quest for a more connected world. Then came electricity, with wires, lights and engines which made the world smaller by making our reach larger. The second industrial revolution paved the way for a new chapter, decades later, when computers and subsequently the internet would build its lasting impact on our world. The connectivity of the world changed within relatively few years. That's how the third industrial revolution came to be and its new technologies interweaved every part of our lives. As these technologies got perfected and more advanced, they created new dimensions that still influence manufacturing today. And by today, we mean the fourth industrial revolution or Industry 4.0.

The digital world of Industry 4.0 arms factories with technologies that enable us to create seamless connections between people and machines and between machines themselves. They push production to a whole new level of possibilities. Technologies such as Machine Learning, Artificial Intelligence, the Internet of Things, Augmented and Virtual Reality, 3D Printing or Big Data have brought connectivity of the smallest scale into our digital lives, connecting, analysing and interpreting all possible kinds of data.

But Industry 4.0 has introduced new responsibilities and challenges for the mindset in many companies.

What is now essential is the creativity and ability to cleverly combine these new technologies, introducing adaptability, connectivity and transparency to the processes. That's the right way for future-proof success in today's rapidly evolving world. Because Industry 4.0 is so much more than just cool tech gadgets and a bunch of buzzwords.

That is why here at ERNI, we support you by designing and delivering adequate technological approaches for effective, flexible and successful innovations. So, let's dive into the new world of smart technologies, smart production and smart factories and always stay a step ahead.


## About ERNI

ERNI believes in the impact of Swiss Software Engineering to create customer value. Our mission is to boost people & businesses in the innovation of software-based products and services.

The global platform for Swiss Software Engineering combined with a deep market understanding provides the framework for customer success. Our crew manages the complexity of projects, enables people and delivers customer solutions fast. A Swiss mindset with behaviours like consensus-building, pragmatism, integration, reliability and transparency have been deeply rooted in the ERNI culture since 1994. Together with our great crew, they are the basis for successful software projects. Today, the ERNI Group has more than 650 employees at 15 locations.

## About .experience magazine

In the magazine, published triannually by ERNI, we share important lessons learnt in collaboration and technology.

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**Experience magazine contact**
marketing@erni.ch
+41 58 268 12 00

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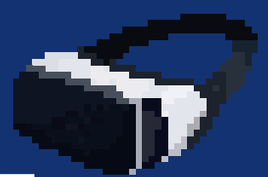
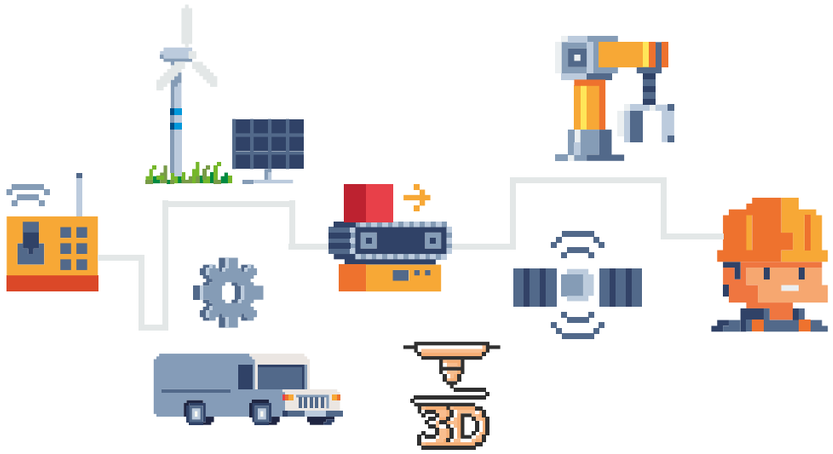



Industry 4.0

# How smart people create Smart Factories




From the steam engine all the way through electricity and computers to robots and data: The fourth industrial revolution has arrived.

Commonly called Industry 4.0, this concept has entailed cyber-physical systems, Cloud Computing, Big Data analytics, IoT and Data Science taking manufacturing to the next level.

With Industry 4.0 come the so-called "Smart Factories", where machines transmit data to each other independently, synchronise with each other, adjust production settings automatically, react to events, plan maintenance and obey safety rules; all this with little or no help from humans. It is literally about factories being smart.

According to Capgemini's Digital Transformation Institute, Smart Factories may contribute at least $500 billion annually to the global economy in the next couple of years.

## What does intelligent production entail?

Traditionally, this requires a great deal of management oversight and detailed planning either manually or by different systems (think: ERP systems, SCM systems, systems to monitor chemicals or machine PLCs, etc.). Smart Factories, on the other hand, are managed by a system called MES (Manufacturing Execution System).

**Contributors:**

**Franziska Grohmann**
*Business Analyst and Agile Coach advising customers in manufacturing and other industries.*
franziska.grohmann@erni.ch

**Carlo Cronauer**
*Lead Shoring & Delivery, Project Manager Industry 4.0.*
carlo.cronauer@erni.ch

An MES is defined by the Manufacturing Enterprise Systems Association (MESA) as "a dynamic information system that drives effective execution of manufacturing operations using current and accurate data." This means that the system guides, triggers and reports on plant activities as various events occur, and can also provide critical information about production activities to stakeholders across the organisation and supply chain.

These systems manage and execute most operations, from placing an order to shipping the finished product to the customer. The MES system does all this by integrating multiple data sources such as the data from sensors attached to the machines, PLC data, ERP data, etc.

In other words, a factory becomes "smart" when it can organise itself almost automatically and with minimal human intervention.

## A Smart Factory has the following aspects:

**– Interoperability**
The computer software, sensors and machines installed in the factory communicate with each other and the workers.

**– Information transparency**
The systems create a virtual image of the physical world through data sensors to contextualise information. All data is stored.

**– Technical assistance**
The systems support humans in making decisions and solving problems as well as assisting or replacing them in difficult and unsafe tasks.

**– Independent decision making**
The cyber-physical systems are able to use the data collected from the factory floor and make simple and complex decisions on their own, becoming as autonomous as possible.

### The differences between Smart Manufacturing and Smart Industry

Manufacturing refers to the making of goods which are sold on the market, while industry (as in "a collection of many factories") is broader in the sense that it includes production of goods, related ecosystems and related services in both the economy and its specific sectors. Although terms such as industry, factory, sector and manufacturing are often used interchangeably in many instances, there are certain differences to consider. As such, Smart Manufacturing refers to fully-integrated, collaborative manufacturing systems that respond in real time in order to meet the changing demands in the supply network, factory and customer needs. In contrast, Smart Industry is a synonym for Industry 4.0 (or industrial transformation) in the fourth industrial revolution, of which Smart Manufacturing is a part.

### What is the 4th industrial revolution?

**1760s**
**First Industrial Revolution**
Human muscle was replaced with iron machines, initially powered by water and then by steam engines.

**1890s**
**Second Industrial Revolution**
Railroads, the telegraph and electricity open the way to modern-style mass production.

**1980s**
**Third Industrial Revolution**
Analog and mechanical devices are replaced by digital controls.

**2010s**
**Fourth Industrial Revolution**
Robots and sensors connect the Internet of Things to flexibly serve connected customers.

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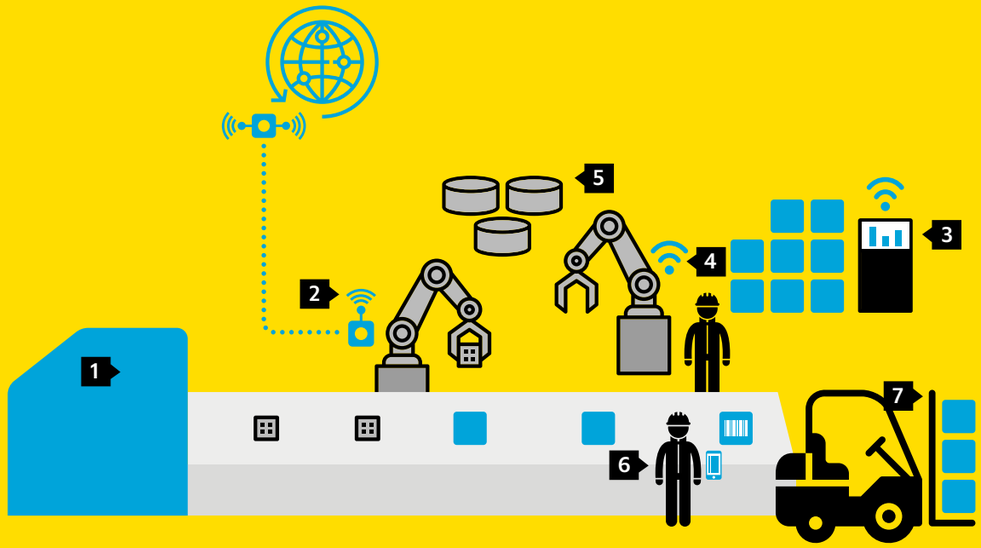
# Mechanical engineering company in Switzerland




**Manufacturing Plant**

**1.** Automated inspection.

**2.** Manage equipment remotely using sensors and limits to conserve energy and reduce costs.

**3.** Monitor production flow in real-time to eliminate wasted time and reduce in-process inventory.

**4.** Implemented condition-based maintenance alerts to reduce downtime and increase throughput.

**5.** RFID sensors identify products and materials.

**6.** Aggregate product and process data, analyse, identity constrains and improvements.

**7.** Production line triggers autonomous material handling vehicles.

## Who?

A mechanical engineering company in Switzerland. A hidden champion and the market leader in the robotics industry. They offer innovative and technologically superior gripping modules and other products.

## The challenge

A need for an interface where the company's customers could operate the machines (gripping modules) easily and intuitively.

## The solution

We were hired to develop a web app that allowed the users of the gripping modules to configure, operate and analyse the data. The web app included a frontend user interface and a backend to communicate with the module's firmware. The frontend user interface was developed in JavaScript using the latest Angular framework. The backend developed by us was used to talk to the module's firmware by interpreting a defined set of parameters that are sent and received via JSON calls. The project was completed with several on-site consulting rounds by our highly skilled developers from the delivery centre in Romania, handling any engineering requirements in real time.



# Benefits of Smart Manufacturing

In our work with clients, we observe many benefits of shifting towards Smart Manufacturing. It offers a new way of monitoring production and getting valuable insights that help make more educated business decisions and becoming more efficient, both in the long and short term.

The old way of managing production just does not fit today's demands when it comes to product quality, traceability, customisation, environmental demands (both from consumers and governments), and optimal production processes.

## Quality control

Often the manufacturing process underlies internal or external obligations regarding the quality of the process itself and the produced part in particular. If it is detected that the production process is running under the quality threshold, it must be stopped immediately and adjusted to ensure the produced goods meet the end customer's expectations.

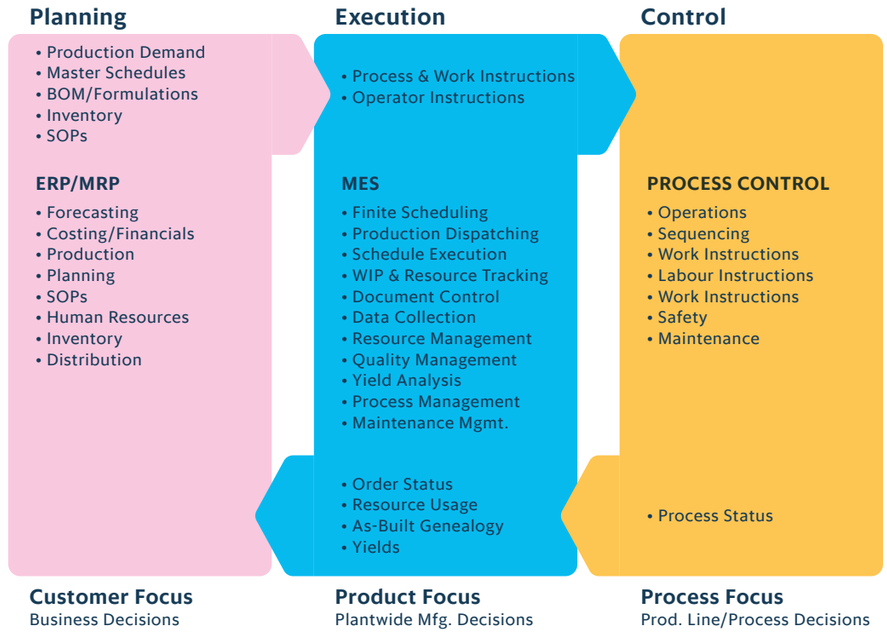
The automobile industry is very well known for its high-quality standards. Another client of ours, a Swiss company in the field of sensor technology, needed to ensure through their software that every car part they produced complied with strict rules. One of the products they make is airbags. In case of a car accident or malfunction, all the production details of that specific airbag need to be available, even if the airbag was manufactured several years ago.

The data that need to be available include production parameters, material used, production conditions (e.g. temperatures), and information about quality control (e.g. measured specification of that piece). In case doubts arise about the safety of one produced batch, they can then find all airbags produced in the batch and recall them.

## Production optimisation

Smart Manufacturing brings the ability to optimise the production, both in the short and long term, be it reacting to changes quickly to avoid downtime or increasing the efficiency of material consumption.

One optimisation task of an MES system that most manufacturers already have in place is accessing and ordering information directly from ERP systems like SAP and calculating which machine will be used for the order and what parts need to be produced. An MES can also schedule and execute the orders.




Source: Industry Directions

In the long term, it is possible to implement more sophisticated optimisations like:

- reducing waste material;
- increasing the efficiency of material consumption by optimising the production processes themselves;
- adapting production parameters automatically in order to ensure quality standards;
- and improving employee assignments, which doesn't necessarily mean fewer employees, but more skilled, better trained employees and a different nature of work.

Let's go back to the case of the Swiss supplier of automobile parts to see how it's done. Automobile parts made of plastic are produced by moulding machines that have up to 2,000 parameters – so finding the optimal settings for all of them can be very laborious.

Misconfigured moulding machines can lead to fragmented parts, lower quality (e.g. too flexible or too stiff) or deviation from the defined product specifications (e.g. length). Finding the optimal parameters is usually a manual process, accompanied by a mix of experience and trial and error technique.

However, this process can be automated by combining sensors that give feedback on the process and quality of the produced part along with smart algorithms. By analysing the quality data of a produced part and the set of parameters used, the algorithm learns how to find the optimal set of parameters for a desired outcome. As a result, the product shows higher quality simultaneously with reduced time and raw material usage. Overall, this translates into significant time and cost reduction for the whole manufacturing process.

In our customer's example, there were even many different moulding machines, sensors monitoring conditions like temperature and pressure, statuses of transporting machines, labelling machines, ordering systems, a staff identification system, etc. to connect.

All this data (several MB) had to be synchronised within a cycle time of as little as 10 seconds.

The biggest challenge is to accumulate all that data for every produced part from all involved systems and synchronise this data in real time.

Therefore, we carefully analysed the current interfaces of those systems, identified areas for improvement and helped design new interfaces in micro service architecture to meet the requirements.

After implementation of those changes, we can see increased traceability of where and how the end product was manufactured.

In order to achieve seamless data collection and storage, we also introduced a plug-and-play approach. This allows data collection even if some systems may be down or offline.

## Predictive Maintenance

Machine Learning also offers another large benefit of intelligent production: the ability to perform Predictive Maintenance instead of reactive maintenance.

The main goal of Predictive Maintenance is to predict when a tool used in production will break down and to schedule its maintenance before this actually happens. This leads to a smooth production with fewer last-minute interruptions should a tool break down during production.

To detect defective tools, the production is monitored in real time alongside the historical data being analysed. Drops in quality can be associated with a given tool and indicate the end of a tool's life.

This can save companies a lot of time, energy and resources, especially in manufacturing.

*Read more about this topic on page 20.*

## Cost reduction

Cost savings in Smart Factories can be achieved directly and indirectly in different areas. When we support our clients in their journey towards a smarter production, we analyse the current situation in the company, identify potential and easily accessible gains and help them make decisions that bring them the fastest and smartest way of how to become a Smart Factory.

Here are some of the main areas we've identified that can see the most significant cost reduction:

- **Overall equipment effectiveness**
- **Real-time order adjustments**
- **Optimal operation environment**
- **Lower energy consumption**

## Utilising data science capabilities

The benefits of Smart Manufacturing can even be advanced by using AI and data science techniques.

Whether it is about calibrating the parameters of a moulding machine, performing Predictive Maintenance or optimising long-term production, a suitable machine learning model needs to be trained on high-quality data before it can be deployed to production, which is a long term endeavour.

How do you develop and integrate data science capabilities into your organisation?

Essentially, there are three options: buy an off-the-shelf data science solution, hire an in-house team to develop one, or outsource it to an external data science team.

What option suits your organisation best depends on the following factors as outlined by the research company Gartner:

- The core problem at hand
- Current analytical maturity of the organisation
- Data science skill level of the IT department
- Potential deadlines
- How critical the solution implementation is to business survival
- The required return-on-investments
- Available budget for analytics
- The availability of specialised tools

We typically work with tools such as Microsoft Azure Machine Learning and Google TensorFlow to support our clients with data science capabilities.

*Read more about Software Sourcing on page 14.*

Although buying an off -the-shelf solution tends to be the least expensive option, it off ers little customisation to meet specifi c needs. A custom-built solution will require a much bigger budget and more resources, but it will prove to be a more suitable solution for Smart Manufacturing transitions because each factory is unique in terms of processes and machines.

Complete outsourcing might be a good fi t for companies that have robust data science capabilities in-house but a lack of time to allocate them to a data science project.

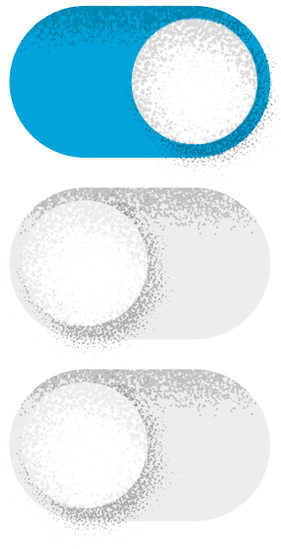
At ERNI, we adapt to your needs and help you analyse which solution is the best for you, taking scale, budget and purpose into account. We deliver solutions that are best suited for your company and integrate the proper data science knowledge throughout your teams.

### Smart Manufacturing and Agile complement each other

As we have seen, implementing an MES and transforming a manufacturing plant into a smoothly running Smart Factory is a challenging journey. It is very important to go step by step on this journey, focusing on the aspects of Industry 4.0 that give the biggest benefit first. In our experience, it works best when development teams as well as management understand and live the Agile mindset.

Being agile allows teams to work in short sprints, which gives space to flexibly react to changes, create closer relationships among employees and departments and allows for people to learn throughout the process and incorporate the learnings into their future efforts. ERNI can help you understand and implement the Agile mindset as well as develop a strategy for transforming your factory in the fourth industrial revolution.

# How to switch to Smart Manufacturing



Apart from the obvious steps of installing the sensors and acquiring new software, there are a few other steps necessary in order to establish a thriving and efficient Smart Factory.

Data is useless unless it's collected, synchronised and analysed in a smart way. For that, you need a well-designed software solution that fulfills the production's timing and data load requirements. The crucial part here is synchronising a large amount of data from different sources, as it may come in different formats, styles or might be difficult to link to other data and at the same time meet timing requirements.

With our knowledge in both MES and software development, ERNI can support you in getting ready for the fourth industrial revolution. We analyse current software solutions, together with all stakeholders identifying gaps, and support you in successfully implementing the next generation of manufacturing software. With our shoring teams, we can even take over the responsibility for developing ourselves if you wish.

# Software sourcing brings valuable knowledge and expertise

In the age of digitalisation, there are demands for functionality that some companies simply don't have. When this need for specialised talent and skills arises, your best option might be external providers that will give you the expert knowledge and incorporate it in chosen topics. Software sourcing is an excellent way of getting the workforce and expertise you need. In the case of manufacturing, we mainly talk about getting software that supports manufacturing processes or products.

## Options for software sourcing

**A company can:**

**Hire a team in-house.**
This can be both time consuming and costly.

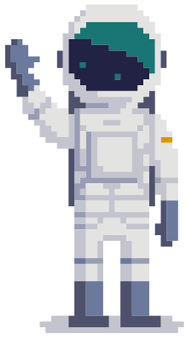
**Work with an external supplier.**
You have the option to hire people on an hourly basis and keep the project management in-house or to outsource both so you have an external provider that builds the key solution and returns it back to you.

It is essential to look at the whole value chain of the products we create. Only through such a systemic view can we get a clear picture of which activities should be outsourced and which should be kept in-house.

### How does it work?

Typically, you have to distinguish between two cases. Is it an already running project where you need to manage maintenance and invest into knowledge transfer? Or is it something that you are starting from scratch? We always start with the question: "What is the ideal setup for the customer?" The answer helps us create a transition plan that details the following aspects:

- Knowledge acquisition about existing solutions
- Defining the processes of our collaboration: distributing responsibilities, managing roles, defining the nature of meetings and demonstrating achievements
- Establishing infrastructure of workstream: communicational infrastructure, tool chain and systems, source code depository, testing tools and devices that people work on.



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**Multinational healthcare company in Switzerland**

**Who?**
The Swiss healthcare company is one of the leaders in the field of pharmaceuticals and diagnostics.

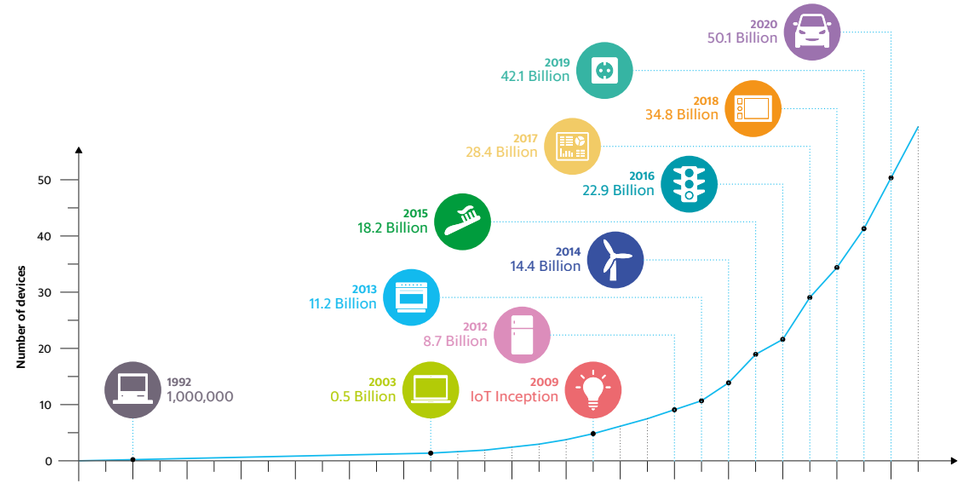
**The challenge**
This company wanted to free up the workforce from lab device maintenance and invest their time into the research and development of future products.

**The solution**
Our Spanish team spent three months with the client, during which we accumulated expert knowledge about the system. At the same time, a laboratory was built for testing the equipment and investigating issues in realistic conditions. We set up the required infrastructure with a business-to-business VPN connection to access the client's systems remotely. As a result of this, ERNI could successfully take over the maintenance of the equipment.



# IoT and a boom of connectedness

**More than 50 billion devices will be connected to the Internet by 2020. Among them refrigerators, wind turbines, smart traffic lights and cars.**




Source: Cisco

Internet of Things (IoT) is the broad term for the interconnectivity of physical objects that enables sending and receiving data. It is also one of the core concepts of Smart Factories that improves manufacturing processes by bringing the intelligence to the table.

With IoT, even the smallest part of a machine can be connected with a single protocol that sends messages, instructions and alerts. In addition, all the data is collected and analysed in a Cloud system that acts as a big, central "brain" of the plant.

For any company just starting out with IoT or simply considering implementing it into their factory, it's important to understand that IoT is more of a concept than a technology that you simply install. This paradigm shift will present a cultural challenge for many organisations as they try to derive the most value from IoT. The cultural issues related to IoT are in some ways similar to those encountered during the adoption of enterprise-based Cloud services, as the Cloud isn´t really a technology as much as a new way of working. Getting the benefits of the Cloud requires a shift towards a self-service or IT-as-a-service mentality. Such changes are often met with strong organisational resistance. Maximising the benefits of IoT data might present similar challenges. A self-service analytic insight creation mindset (for example correlating data from within disparate organisational silos) requires the managers to be willing to tear down territorial walls.

IoT requires a complete change of how a factory is operated and managed. And we are talking a complete change in the company's mindset about how the manufacturing works and what departments take part in it. For example, IoT calls for a much bigger involvement of IT departments and reducing the number of the factory's floor workers.

Here are some helpful questions to ask yourself before implementing IoT in your factory:

- How can your company profit from connecting machines and tools in the manufacturing process?
- What issues and bottlenecks does the manufacturing process have that are important to change?
- Can your current networks and infrastructures support IoT in terms of data storage and security?
- Can your legacy systems and existing equipment be connected through IoT?
- Are all the important stakeholders within your company on board?

Lastly, it is important to start small with IoT. Many are tempted by the promised benefits of these technologies and try to leverage it everywhere. Try to identify the simplest, most beneficial use case within your factory and start there.

# Benefits of IoT

The benefits of IoT are many, but something that is common for most of them is cost reduction. Whether it is through better quality of products, fewer work-related accidents, or better tracking of shipments – the implementation of IoT typically brings in significant cost savings for a company. In our experience with clients, we've identified the following benefits:

**Increased efficiency and quality.**
When all the machines in a plant are connected, a higher level of automation and control is achieved. Predictive Maintenance enables a higher and more stable quality of products, as mistakes due to human error are eliminated.

**Freeing up human resources.**
Routine and mundane tasks can be eliminated and experts can be assigned to more complex tasks instead of everyday work processes.

**Real-time decision making.**
The connectivity of IoT devices allows you to monitor every part of the plant, from the presence of toxic particles in the air to stock levels of spare parts, and make adjustments as the day progresses.

**Safer working environments.**
With IoT, an intelligent camera can monitor unsafe environments or recognise when a light on a machine is indicating abnormal conditions. The same technology can even be embedded in a safety suit.

**Expanding on AI capabilities.**
As mentioned earlier, a Smart Factory gets better at its job the more data it analyses. The benefit of having access to massive amounts of data that are specific to your products and manufacturing processes is creating your own AI model that is curated to your needs.

**More accurate deliveries.**
Adding IoT to shipping boxes and vehicles increases delivery efficiency, both in terms of delivery time and how intact the products are.

# How to implement IoT in your factory

The roadmap to IoT success that we shared earlier might look simple, but IoT implementations are far more complicated than software updates or supply chain integration projects. They require new skill sets and involve multiple business units and operational teams across the company.

Whether you decide to execute the implementation alone or choose to work with an external partner, here are some of the skills that are vital for a successful IoT project:

– **Project management.** As mentioned above, an IoT implementation project has a lot of moving parts and stakeholders. In our experience, really good project management skills are important when working with both hardware and software development.

All of our team members are therefore certified SAFe practitioners, which allows us to manage complex projects with our clients.

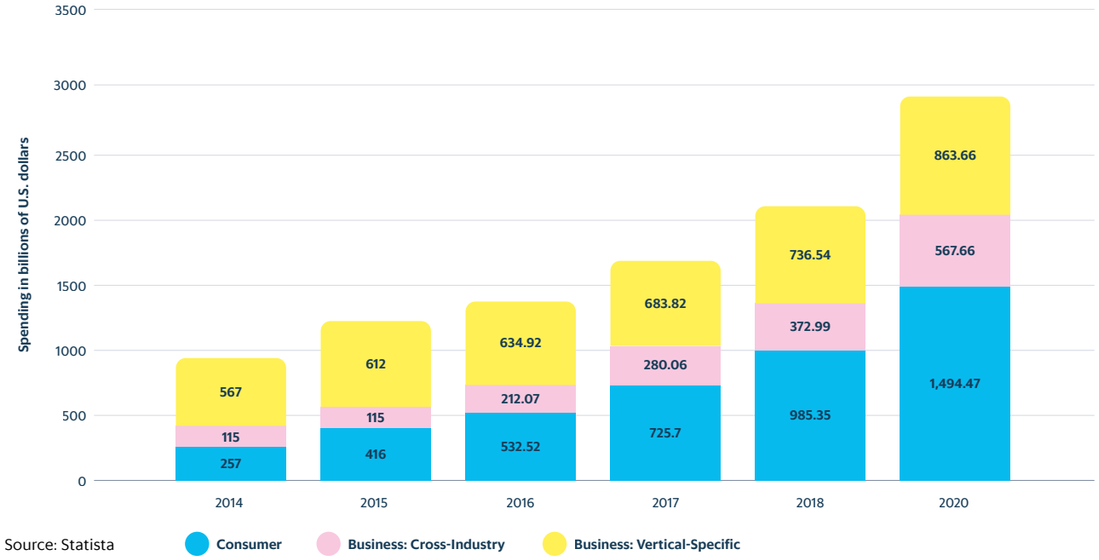
– **Innovative design thinking.** No IoT solutions are alike. To find the right use case and solution, one must be solution-focused, not problem-focused.

– **Robust computer engineer capabilities.** In an IoT implementation, it is important to have engineers to determine which is the right equipment to use, developers/QA for testing, Cloud engineers for the data storage, BI engineers/developers to prepare the Big Data, etc.

– **Data storage and security.** IoT is driven by data, which means proper storage is essential.



## Spending on IoT, by industries like manufacturing, transportation and logistics, healthcare, retail, government, utilities, energy and natural resources, or insurance.

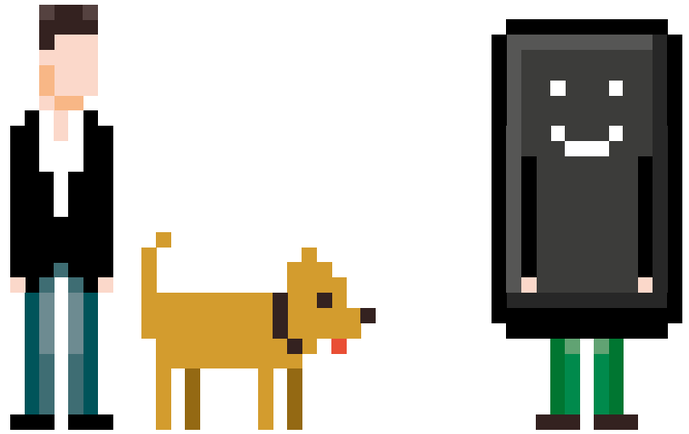



Source: Statista

## How to be successful in IoT and what to focus on:

1. The organisation should have competence in the field of technology and a good business model. The first step to a successful IoT journey is to have a goal and an ROI model, and to understand the market. The best way to initiate IoT is by employing Agile development and systems engineering. Systems engineering practices are vital for managing the complexity and creating the best solutions for the devices. This is connected with system architecture (the overview of the whole system and its components), requirement engineering and system testing. With the Agile methodologies, KANBAN and sprint planning, the teams are able to collaborate better and stay on the right path throughout the whole process.
2. The companies should know what the system requirements are and choose a suitable strategy accordingly. For example, companies will need a cloud solution that will connect their apps with devices. They can either go with proven cloud service vendors, or develop their own cloud-based solution from scratch.
3. Try out the use cases in a real-life setting and also assess the feasibility. The best practice is to work on the IoT solution and use "security by design."
4. A pilot product should be launched to test the product on a small scale.
5. Identify meaningful data. There is noting to be gained from simply collecting data itself; there must be some business value in the insights. In the industrial world, downtime is a major cause of lost productivity and cash. As such, it represents one of the key areas where IoT can help.
6. And finally, after successful evaluation of the use cases and pilot product, the solution should be scaled up so that it can be rolled out for a larger number of consumers or regions.

# Intelligent Apps: A new man's best friend



Intelligent apps are the core of smart businesses. They are, just as their name suggests, AI-enabled apps that use machine learning. The intelligence of the apps is derived from processing vast amounts of data and it has the ability to come to conclusions that are otherwise hidden to a human mind.

The arrival of such apps is slowly changing the everyday lives of consumers and business processes.

For example, Google has recently reinvented the role of virtual assistant. The company introduced Google Duplex, an AI-driven application that leverages natural language processing, deep learning and text and speech recognition. In other words, Google Duplex could call a restaurant to make a reservation without alerting the person on the receiving end that they were talking to AI.

Generally speaking, intelligent apps support workers while AI-driven robots are able to replace them. An app can, for example, support a service mechanic while fixing a machine.

If the maintenance has to be done on a very tight schedule, the intelligent app can suggest quick fixes and safely guide the mechanic through all the necessary repairs.

To ensure it suggests the right measurements and steps, it can provide the mechanic with a checklist and find the solution through the process of elimination. All the necessary information is provided by the mechanic through pictures of the machine he uploads, error messages, etc.

It is also possible to train such app on issues that occur often. This feature is very useful for multinational companies where workers who are facing the same problem are not in the same physical space.

In other words, if you need to reach many people who would profit from sharing specific knowledge or face recurring events that can always be solved in the same way, intelligent apps are the right fit for your business.

At ERNI, we strongly believe in the benefits of intelligent apps, and that's why we have integrated them into our own business processes. Currently, we are developing the "Intelligent Meeting Room", where members of the meeting are recognised by a camera that greets everybody, records their reactions, analyses the outcome of the meeting and distributes personalised notes.



## Intelligent apps in Smart Manufacturing

Intelligent apps have a wide spectrum of applications in Smart Manufacturing. Here are just a few practical examples:

— **Predictive Maintenance**
A service app that suggests the best time for repairing a machine based on the analysis of production data. *(More about this topic on page 20)*;

— **Accident prevention**
A camera app that is able to recognise faces and emotions thanks to computer vision can automatically alert emergency services if an accident has occurred or it can issue a warning if unauthorised personnel have entered the premises;

— **Track and restock inventory**
An app can manage product inventory and send alerts when the stock is getting low, all of this done by image recognition alone;

— **Tracing the product journey**
By reading barcodes, an app can trace the whole product journey;

— **Get real-time feedback**
With intelligent apps and IoT, companies can monitor their production more closely and make adjustments in real time if goals are not met. Intelligent apps can even be trained to make the decisions for them.

Developing an app specific to manufacturing calls for a lot of deep knowledge about the processes inside a plant and industry know-how. An intelligent app can learn more or less anything, but it needs a good teacher. All company data needs to be made available.

# Predictive Maintenance for flawless manufacturing

Having a business that operates 24/7 is no longer uncommon these, and so there are high expectations on the machines to run smoothly without any breakdowns.

As Industry 4.0 keeps pushing the boundaries of data science further, the ability of machines to detect and predict an issue or when the next maintenance is needed has greatly advanced.

According to a study published by the software company PTC, poor maintenance strategies can reduce a plant's overall productive capacity by up to 20 percent; while another study conducted by Industry Week in collaboration with Emerson suggests that total unplanned downtime is costing industrial manufacturers around $50 billion each year.

Traditionally, maintenance companies send repair technicians to the rescue whenever a machine has failed, and maybe every couple of months for regular equipment checks. But in Smart Manufacturing, there is no need to wait for the equipment to actually break down. Instead, the factory itself analyses all data and is therefore able to anticipate when and which component will fail before it actually happens, thus minimising machine downtime.

This way, the company can proactively dispatch a technician who will arrive on-site with the proper spare parts and ready to solve the problem immediately.

Predictive Maintenance is about predicting future failures of machines and selecting the most effective preventive measures. This is done by applying advanced analytic techniques to collected Big Data about technical condition, usage, environment, maintenance history, similar equipment and any other element that may correlate with the performance of an asset.

If any of these variables should change, it means that the performance of the machine is declining and a technician should step in before the asset malfunctions and shuts down the whole assembly line. In a nutshell, Predictive Maintenance allows us to anticipate failures that might catch manufacturers by surprise and can lead to extended uptime as well as decreased lifetime of their machines.

Forward-thinking companies need to consider if they are willing to invest in and implement these technologies and how they will do it because the implementation can be costly. However, the return on investment for such technologies is high, and any manufacturing company with a product that is put under strict safety regulations (cars, medical equipment, etc.) can benefit from it.

### Because Predictive Maintenance is performed only when it's required, it can:

- decrease the costs of labour and spare parts,
- improve safety in the workplace,
- increase product quality,
- increase equipment reliability,
- extend equipment lifetime,
- minimise expenses for storage and purchase of spare parts.

### Learning Techniques for Predictive Maintenance

We always start with gaining expert knowledge. We first talk to the people who designed the machinery to get a pretty accurate idea of what could go wrong and what could fail.

## Predictive Maintenance should comprise the following steps:

1. Predicting faults and deterioration by checking, collecting data and adjusting;
2. Inspection to identify small repairs before they turn into a real problem;
3. Predictive techniques to replace components just before they fail such as vibration monitoring;
4. Replacement of components on a regular basis well before they fail;
5. Correction of potential failures when inspection indicates the need;
6. Overhauling equipment periodically to upgrade general equipment condition;
7. Reliability engineering to reduce or eliminate repetitive failures;
8. Reliability engineering to minimise failures through adjustments to the PPM programme.

The next step is to decide what data need to be collected, based on this expert knowledge.

These can be external environment measurements like humidity, vibrational patterns and the like. The final step we take is adding sensors to the system that will monitor and collect data from the operations.

These sensors enable the detection of small deviations early in the process of failure, which leads to predictive requirements.

For example, if we think of a robot that assembles the exterior of a car, the parts that are most likely to break down are the joints as they are prone to wear off.

As mentioned, we start the Predictive Maintenance strategy by asking the experts about what measures we should focus on. It looks like vibration is the main cause of failure in this case. So we measure the data and analyse them against baselines and control limits to help predict when overhauls will be required. We collect all the other data needed, whether it's temperature or electric current within the system and so on.

Once we have identified, collected and set the initial set of data against the baseline, we can predict the failure of the robot arms.

If we have data sufficient for a failure prediction, we automate the whole process. But if we don't, it is important go back to step one and identify more possible data sources.

It is important to remember that successfully predicting failures requires sufficient data.

## Preventive vs. Predictive Maintenance

Although both methodologies work towards the same goal of extending the life of assets and preventing unexpected breakdowns, Preventive Maintenance (PM) and Predictive Maintenance (PdM) are two different approaches. Here is a short explanation of the types of maintenance:

### Reactive Maintenance

This is an approach based on real problems and malfunctions. Reactive Maintenance, as the name suggests, only reacts to already existing problems, which is time costly, expensive and insufficient in the everyday life of a factory.

### Predictive Maintenance

Predictive Maintenance is based on the actual condition of the equipment. This allows for scheduling of maintenance and a reduction in downtime, directly impacting overall productivity and company profitability.

Predictive Maintenance monitors the equipment's efficiency and uses algorithms to identify trends in data to predict when a failure is likely to occur.

This process is much more complex than Preventive Maintenance. However, this is where we come in, as ERNI will perform condition monitoring tasks and analyse the results for your organisation.

### Preventive Maintenance

Preventive Maintenance is performed while the equipment is under normal operation in order to lessen the chances of that equipment failing. Preventative Maintenance doesn't take place based on wear and tear or the actual condition of the equipment, but based on the manufacturer's specifications. During the specified date and time, the machine is shut down and maintenance tasks are performed. Maintenance is set according to a schedule based on calendar dates or usage, as specified in the instruction manual or warranty documentation.

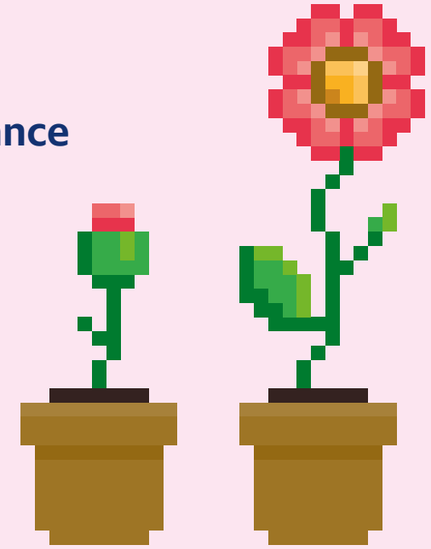
Even though this approach might seem cost efficient, the irregular nature of breakdowns makes it hard to prepare labour and spare parts for repairs, leading to unplanned expenses associated with lost productivity and purchase of spare parts.

### Prescriptive Maintenance

Prescriptive Maintenance is the future. It not only allows us to predict problems, but on top of that, to prescribe a solution. This new technology uses advanced analytics to make predictions about maintenance, and also makes outcome-focused recommendations for operations and maintenance.

# Step-by-step

## What does a Predictive Maintenance solution look like?



Our Predictive Maintenance solution is built upon five layers of analysis.

**1.** Define vision and achievable goals

**2.** Identify data sources and select relevant inputs

**3.** Perform an off-line analysis and prove feasibility

**4.** Rapidly implement a small-scale solution and prove benefit

**5.** Integrate the solution in its full context

At ERNI, we start by creating a model and prediction based on our workstation and show it to you as a proof of concept. We also show you detailed visualisations based on the analysis of the tools.

Once we identify something that works, predictions become inputs that can automate the flow by modelling a good predictor. We deploy it as a web service in order to automatically collect the data and also model some actions based on the model of prediction. It is best to have all these tools gathered in just one tool box. For example, the Microsoft platform is very powerful, but you can also use any other Cloud provider like Google, Amazon or IBM.

### Technology trends are paving the way for a Predictive Maintenance revolution

The science of maintenance is on the cusp of a brand new transformation. The advancements in AI technology combined with Cloud solutions are disrupting the industry the way Predictive Maintenance once did; making room for an easy-to-deploy Predictive Maintenance solution. This new trend is known as the Industrial Internet of Things (IIoT).

The Industrial Internet of Things can collect an impressive amount of data from manufacturing equipment in production and transmit it to devices that can store and analyse it. The main obstacle when trying to implement the technology used to be analysing the data that had been collected. By using an Edge Computing-Servers, this analysis can easily be done on site and in real time. This greatly diminishes the burden on networks and also keeps the costs low.

An Aberdeen Group study found that the best-in-class organisations (top 20 percent) that employ predictive analytics for asset management attained:

- Increase in return on assets (ROA) of up to 24%
- Reduced unscheduled downtime to 3.5%
- Improve overall equipment effectiveness to 89%
- Reduction in cost of maintenance of 13%.

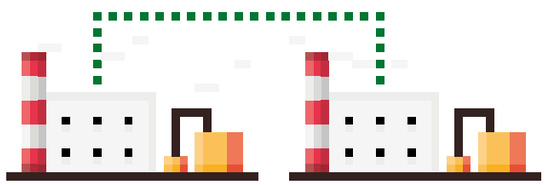


# Digital Twin for real-time problems

Thanks to new technologies, especially the Internet of Things, new concepts such as Digital Twin have been able to make production for manufacturing companies much easier and more efficient. A Digital Twin is a virtual replica of physical assets, whether this is a product, service or process. It collects, analyses and monitors data and simulates any potential problems that might occur before they do in reality, saving costs and time needed for maintenance and increasing productivity. The Digital Twin is an instrumental part of every Smart Factory.

When ERNI experts support our clients on their way towards innovation, there are certain steps that need to be taken. This way, we can be sure where to put the technology in to use and what is the best course of action to take in order to be more efficient and cost effective.

We use a variety of sensors that collect real-time data which are then stored in the Cloud and further analysed. For this, we use a device called “the analyser”, whose role is to examine the systems and give us a full report on how they can become smarter. With the help of this device, we analyse the status of various components of the specific system. This process involves the creation of its digital version and all its individual components – the Digital Twin.



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## Digital Twin for cost reduction in testing

The concept of the Digital Twin is something that we created for a Spanish automotive company in order to reduce their dependency on hardware and to scale the testing strategy. Even then, the client still had a lot of dependencies on hardware. That was preventing us from creating an efficient testing strategy because we got stuck with the amount of hardware we had to test our software on. What we did with this client was to reproduce the environment we had in their hardware in a virtual setting. And then we were able to scale as much as we wanted. We could create 10 different environments and execute the tests that we needed in them. Also, we reduced the cost of waiting for the hardware to test the application because with this method we were able to isolate the software that went into the hardware. The software itself did not need the physical dependency so we isolated the software from the hardware altogether.

For this testing, we used the technology of Digital Twin. As a result, we saved costs, scaling, hardware dependency and a lot of time.

But this technology also has some limitations. In automotive, there are still numerous tests that need to be run on real physical devices. We are able to use virtual representation for about 70 percent of all tests, but the rest needs to be tested on the hardware.

Digital Twin has advantages when compared to other emulators. With Digital Twin, we are reproducing the exact same version of software inside the hardware – a virtual machine. It’s digital because all the software parts are behaving like the real ones. And for specific devices in a field like the one for the Spanish company, we used a Telematic Control Unit. It is a specialised product that enables communication between the car and the systems outside it, which is something that no commercially available emulator can do.

# How AI is solving the problems of the future

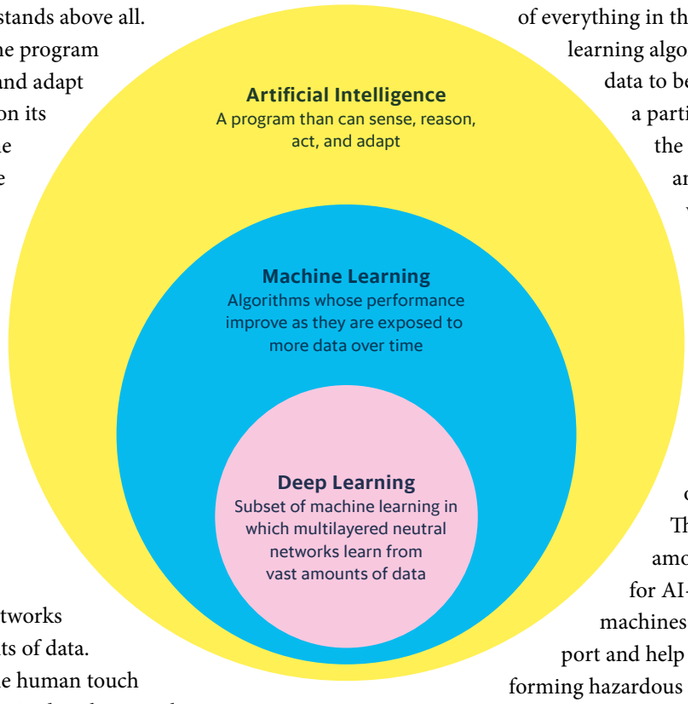
AI and machine learning have revolutionised many industries in the last few years. For someone who is not familiar with these topics, distinguishing between them can be difficult. Let's quickly look at their definitions before diving deeper.

**Artificial Intelligence** stands above all. In AI programming, the program can sense, reason, act and adapt to new circumstances on its own. AI can remove the human aspect from the equation altogether.

**Machine Learning** relies on data input. The algorithm and its results improve as more data come in. Minimum human guidance is required.

**Deep Learning** is a subset of machine learning, in which multilayered neural networks learn from vast amounts of data. In an ideal scenario, the human touch would no longer be required as the neural network would be able to come to its own conclusions about the effectiveness of its path.

Simply put, machine learning is a subset of AI. It is a large group of algorithms that perform different tasks (for example, predict a real estate price, determine what is depicted in an image, etc.) and learn from the data they are given in the process.




Specifically, deep learning is part of a family of machine learning methods that aim to replicate the way the human brain processes and communicates information. This is what makes AI such a disruptive technology.

In the age of Big Data, data is the cornerstone of everything in this field. The deep learning algorithms need sufficient data to be trained to understand a particular topic. The better the data, the more precise and rapid its analysis will be.

Once properly trained, a deep learning algorithm is able to work on its own and tackle new data sets without further human training or interaction. This creates a vast amount of possibilities for AI-controlled robots and machines that are able to support and help human workers performing hazardous and dangerous tasks.

We have experience with many uses of AI in the field of manufacturing. One of our interesting use cases evolved around image recognition. In a customer project, we trained an algorithm for real-time recognition of a company logo. This allowed for tracking of metrics like brand exposure, brand misuse and ROI on marketing investment.

# AI is making factories smarter

What are the specific benefits of these technologies inside a factory? We've seen an array of positive results such as:

- **Shorter development cycles.** With the help of robotics, products can be developed and produced faster and with fewer errors.

- **Higher degree of customisation.** Demand for personalised and unique products is on the rise. With AI, a plant can make rapid changes in its production process and also flexibly create single tailor-made units or "batch size 1" and stay competitive in the manufacturing field.

- **Better Predictive Maintenance.** One of our client's projects involved a solution for predicting failure of semiconductors. The lifespan of a specific part depended on a long list of smaller factors. To better predict this, we employed a deep learning algorithm that took into account factors such as: when the part was manufactured, from what materials, what process was used, etc. This way, the factory could optimise their processes and get a faster feedback loop on their product and so lowered the cost of testing and production.

- **Real-time results and improvements.** Smart Factories are all about iterative processes where learning from past experiences allows for the optimisation of processes. AI enables this setup thanks to the real-time data analysis that these technologies offer.

  A lot of the data science happens in the Cloud, which is our preferred method of working at ERNI. For example, when a Swiss medical company appointed us to take over the administration of medical instruments, all data collection and storage was done in a cloud-based system.

- **Increased productivity.** While robots and machines work alongside human workers, technologies like IoT, AI and machine learning allow for more productive work. According to an estimation of Bank of America Merrill Lynch included in the report Robot Revolution – Global Robot & AI Primer, adoption of robotics powered by AI could increase productivity by 30%, while lowering the cost of labour by 18-33% by 2025.



# Artificial Intelligence helping in the real world

AI and data science are both relatively young fields, but there is no question that they are here to stay. Those who work in these fields still need to learn a lot to master it fully.

That is why we keep investing in extending our knowledge on AI, and research different use cases that promise value for our clients. Currently, we have two promising projects in the works.

- **Water treatment.** In collaboration with an American water treatment plant, we are working on cost efficiency analysis and treatment diagnostics that analyse water demand, water quality, etc.

  Before AI, such analysis would have required a whole team of people. But with the help of machine learning, we can teach an algorithm to conduct the analysis and exponentially get better at it.

- **Fighting diseases.** In a project we got access to data from specific research and tests of diseases in some countries in the developing world. We are working on collecting and analysing the data in order to achieve more efficient distribution of medical care and pharmaceuticals based on the frequency and geographical spread of infectious diseases.

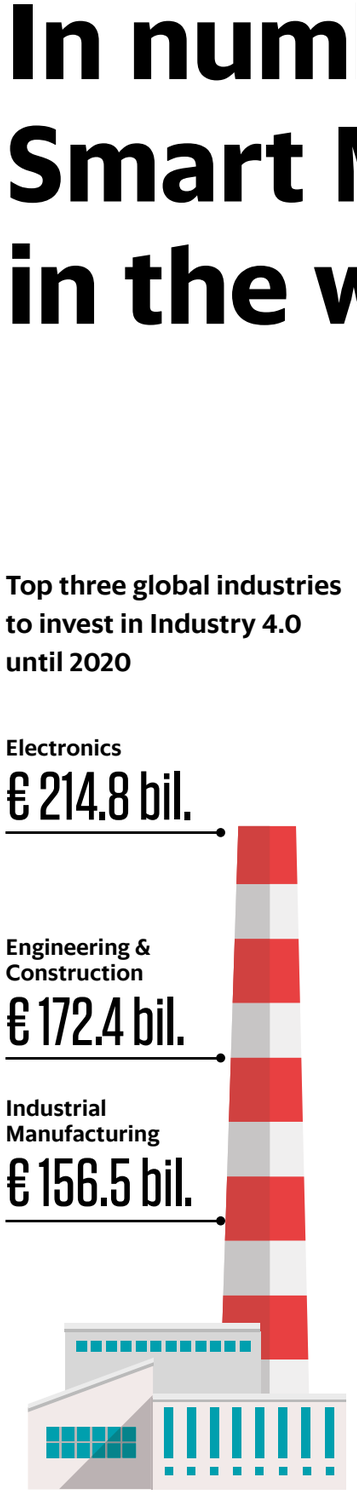
# In numbers: Smart Manufacturing in the world

**Top three global industries to invest in Industry 4.0 until 2020**

**Electronics**
**€ 214.8 bil.**

**Engineering & Construction**
**€ 172.4 bil.**

**Industrial Manufacturing**
**€ 156.5 bil.**



Source: Statista.com

## OBJECTIVE NUMBER ONE

Gaining better visibility into and control over business-critical equipment is the number one objective in using IIoT (Industrial Internet of Things).

Source: Bsquare

First movers are almost three times more successful in combining high revenue increases with significant gains in cost reduction.

Source: 2016 Global Industry 4.0 Survey, PwC

## 48%



Global robotics startups have increased a lot in the past years, especially in the enterprise sector. Around 48% of the deals went to startups building enterprise robots, including those used in heavy industry and manufacturing. Consumer robots accounted for 28% of the total deal share over the last 5 years, and the medical sector received 13% of deal share. A small percentage of the deals, around 6.5%, went to start-ups focused on security and rescue applications.

Source: CB Insights, 2012-2016

**Technologies that are driving Industry 4.0:**

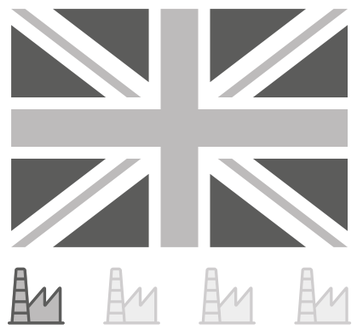
- IoT
- Cloud computing
- Robotics
- AI

## 20% INCREASE

Thanks to data science and AI, Smart Factories with integrated IT systems are providing relevant data to both sides of the supply chain more easily, increasing production capacity by 20%.

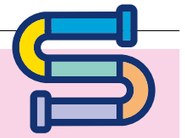
Source: General Electric

## 25%



Only 25% of UK manufacturers feel they have sufficient understanding of the issues, implications, threats and opportunities of Industry 4.0.

Source: The Manufacturer, HSO, The Annual Manufacturing Report, 2017



Smart Manufacturing enables a “flat” business structure, meaning that technology in factories connects all levels of manufacturing from the plant floor to business planning and logistics.

Source: Maverick Technologies

**KEY CHARACTERISTICS OF A SMART FACTORY:**

- Connected
- Adaptive
- Responsive

Smart Factories will require greater levels of judgment and on-the-spot discretion from workers, which can lead to greater job satisfaction and reduction in turnover.

Source: Hannele Lampela et al., Identifying worker needs and organizational responses in implementing knowledge work tools in manufacturing, 2015

## Lack of digital culture and training is the biggest challenge facing companies.

**50%**
Lack of digital culture and training

**40%**
Lack of a clear digital operations vision and support/ leadership from top management

**38%**
Unclear economic benefit and digital investments

**36%**
High financial investment requirements

**25%**
Unresolved questions around data security and data privacy in connection with the use of external data

**25%**
Insufficient talent

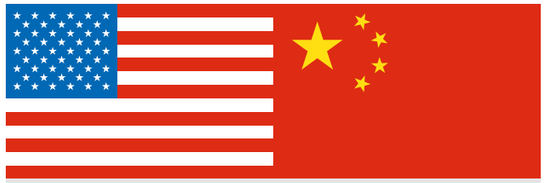
**21%**
Lack of digital standards, norms and certification

**18%**
Slow expansion of basic infrastructure technologies

**16%**
Business partners are not able to collaborate around digital solutions

**14%**
Concerns around loss of control over the company's intellectual property

Note: Included as one of three possible responses
Source: 2016 Global Industry 4.0 Survey, PwC



# THE BIG PLAYERS

## The U.S. and China are the two largest investors in Industry 4.0

Source: Industry 4.0 Market & Technologies. Focus on the U.S. – 2018-2023, report

# TOP 4

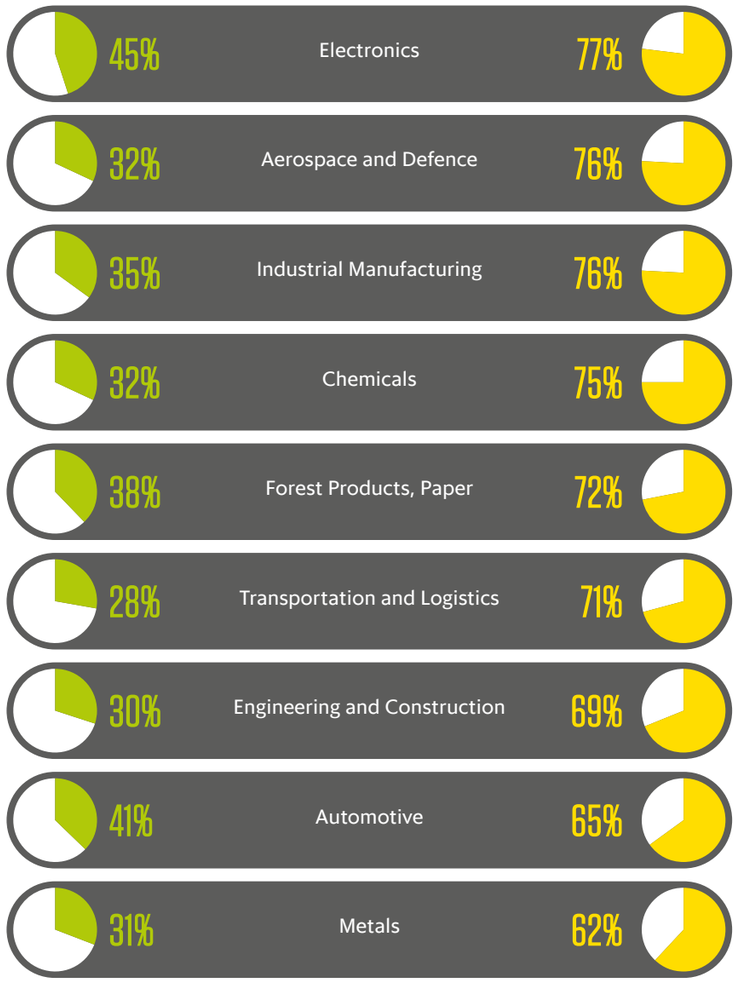
## reasons why IoT projects fail

1. Failure to capture business opportunities
2. Missing critical data
3. Skills or capacity gap to build IoT
4. Failure to ensure market fit

Source: Seebo

## Adoption of Industry 4.0, by Sector

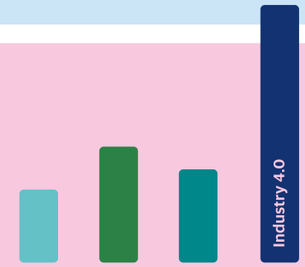
Respondents were asked: "How would you classify the current level of digitalisation and integration (in operations, supply chain, and related activities) in your company? What levels are you expecting in the next years?"




Source: "Industry 4.0: Building the Digital Enterprise", PwC, 2017

28% of the manufacturers in a Cisco survey experienced a loss of revenue due to cybersecurity attacks in the previous year.

Source: Cisco – Midyear Cybersecurity Report (MCR), 2017




Based on overall equipment effectiveness (OEE), world-class manufacturers work only at 85% of their theoretical capacity, while the average factory works at 60%. The rise of Industry 4.0 can change that.

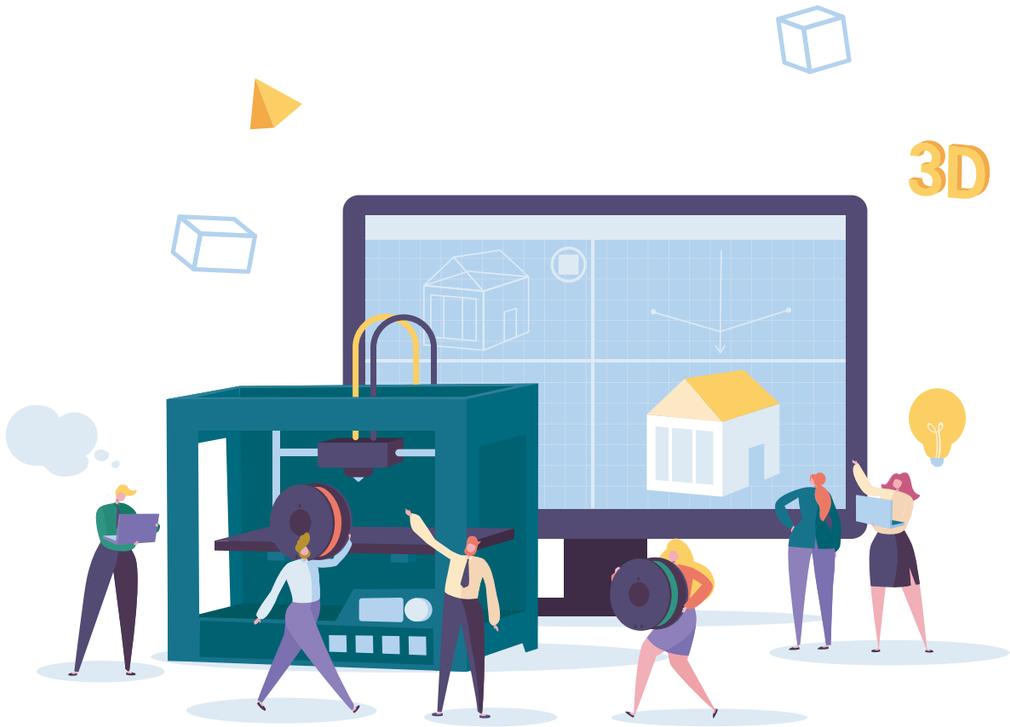
Source: CB Insights

**90%**
↓
**2020**

By 2020, 90% of large enterprises will be generating revenue from data-as-a-service.

Source: International Data Corporation

# 3D Printing: Paving the way forward for Industry 4.0




3D printing has taken the manufacturing world by storm. Also known as Additive Manufacturing, this technology was invented by Charles Hull in 1983, back then as a process called "Stereolithography." From toys to foods, construction sites to body organs and aircraft parts to disaster management, 3D printing is so versatile that it is poised to dominate the trillion-dollar manufacturing industry soon enough.

Technology is enabling the 4th industrial revolution by making production more local, more customisable and more cost-effective. 3D printing or Additive Manufacturing is different from other manufacturing processes like casting, forming or subtractive manufacturing. Not only does 3D printing enable businesses to make complex shapes but it also uses less materials and less time than the traditional methods.

It is safe to say that the technology has the capability to disrupt the global supply chain. With 3D printing, it is becoming more and more possible to create products with any design, any geometry and almost any complexity.

The fundamentals of manufacturing thus have been changed. Companies are embracing rapid prototyping and the software tools are allowing engineers to understand the technology and maximise it for superior production capabilities.

Companies are tinkering with new materials and new workflows to adopt the technology. But the technology is still in its early days, so there is a need to build software solutions capable enough to handle the design and manufacturing stages.

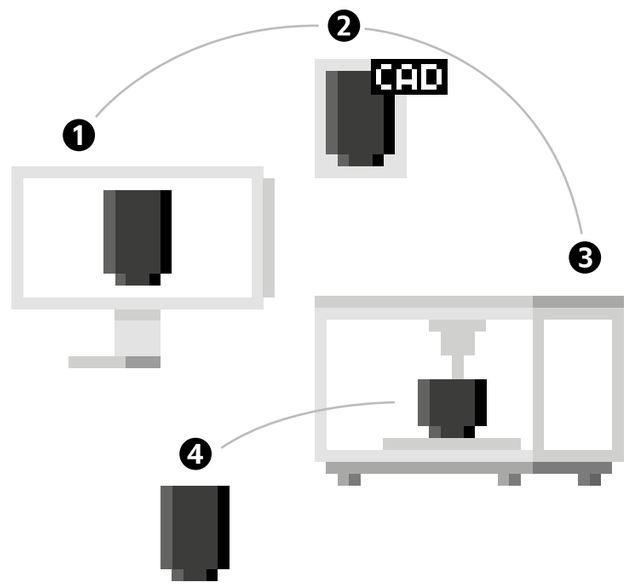


## Basics of 3D Printing

In a nutshell, a physical object is created from a virtual design, i.e. the digital design is converted into a physical three-dimensional object by adding material layer by layer until the object is formed. The digital designs can be created from scratch by using 3D modelling software like Autodesk, a 3D scanner, a digital camera and photogrammetry software.

**There are different techniques and different types of 3D printers. The materials also vary – for example, plastic, rubber, metals, alloys, etc. – but the basic approach remains the same.**

1. The first step is to make a virtual design of the object in a Computer Aided Design (CAD) file using a 3D modelling program (for a new object) or 3D scanner (copying an existing object).
2. In the 3D modelling software, the output model is spliced into many thousands of horizontal layers (2D image).
3. The file is uploaded to the 3D printer where the 2D image is read and the object is created by blending the layers together to create a 3D object.
4. The 3D object is made by melting plastic and depositing it onto the printer platform, as specified by the design, where it instantly cools.



# Which industries can benefit from this technology?

**According to the 2018 Wohlers Report, 3D printing has evolved into a 7 billion USD industry, while according to other estimates, the additive manufacturing industry is already worth 12.8 billion USD. Between 2017 and 2030, the shift will be towards mass production and the companies will be able to produce finished products on a large scale. Here are the main industries that benefit from 3D printing.**

**Automobile Industry**
From prototypes to finished products, 3D-printed products are being used extensively in the industry. For instance, in Formula 1 cars, the car parts are being tested and built using 3D printers. With 3D printing, the manufacturers can optimise the weight and endurance of the components.

**Architecture**
3D printers are capable of producing large structures which can be used in the industry. The architects or engineers can design and print objects directly on site if required. It could also help in mitigating disasters as shelters can be customised and made quickly. There are also many experiments with 3D-printed houses and furniture.

**Education**
The technology offers students a great way to test their designs and learn concepts in a practical way. Many universities across the world have purchased 3D printers and included their use in learning. With 3D printers, the visualisation of a product becomes easier.

**Medicine**
There are millions of hearing aids worldwide and they can be customized and manufactured in just a day shortening the process to merely a few steps.

- The hearing aid, for instance, is a major part of the 3D printing industry. There are more than 15.000.000 of hearing aids worldwide, according to Phil Reeves (author of a report on the 3D printing industry). Hearing aids can be customised and manufactured in just a day, shortening the process to merely a few steps.
- Another major example of the 3D revolution is in prosthetic limbs. 3D-printed prosthetic limbs can be as cheap as 50 USD and manufactured in a day. Regular prosthetic limbs, however, take months to be produced and calibrated. The main advantage that 3D printing brings to the table here lies in the possibility to customise the limb to suit the owner and specific activities like running or biking.
- 3D printing is also being used to fabricate human tissue, braces, chemical compounds, bones, skin (for burn victims), organs, cranium replacement in case of brain damage, heart valves and dental implants.

**Food Industry**
Food production using 3D printers is evolving and has many applications. By using edible ingredients, the users can customise their foods as per their nutritional requirements. Currently, 3D printing is being used for bakery products, chocolates, ice cream and confectionary items. The company Natural Machines launched a 3D printer called Foodini to manufacture food items.

**Retail**
3D printing is a smart technology capable of enhancing the consumer experience and cutting down on inventory and warehouse costs. Retailers can eliminate the complex supply chain and produce products directly in their stores or warehouses. Retailers can also predict consumer demands and manufacture products accordingly. This ensures that the inventory is not wasted, and the consumers can get customised products. With Print+, users can get fully customisable and upgradable headphones. Adidas has a 3D-printed midsole in a shoe. The shoe can be customised to meet the user's need and manufactured when needed. Imagine walking down to a store with a dress in your mind and getting it in a matter of hours. This is the future of the retail industry.

**Manufacturing**
The technology has reduced the time and costs associated with conventional manufacturing. The waste material is reduced and components can be constructed in a single build. It removes the need to use moulds, tools or extra machines, allowing time for designing, testing and manufacturing.

- SpaceX utilised 3D technology to create the SuperDraco engine by using Direct Metal Laser Sintering (DMLS) technology the superalloy Inconel. The conventional manufacturing method is difficult and challenging for producing a complex structure like SuperDraco, but with 3D printing, the time was reduced significantly.
- GE has printed fuel nozzles for jet engines which are lighter and boosts the jet engine's fuel efficiency by 15%. "Fuel nozzles are an intricate and highly sophisticated engine component that are key to delivering industry-leading fuel efficiency and lower emissions for next-generation jet engines," the company said.
- NASA has been using 3D printing technology to manufacture aircraft optimised for savings in weight, fuel consumption and costs. Also, astronauts are able to manufacture components during their long missions.

.e ERNI .experience

## Our involvement in the 3D Industry

At ERNI, we have different and broad activities connected to development of quality and coordination in the field of 3D printing. We are especially working on connectivity between printers/other devices as well as the connections within the printer and also on networking development – communication with external devices. Our interest is in programming and developing the user interface and drivers, predictive analysis, writing system engineering printing 3D models, front panels of computers (managing printing jobs, defining printing parts), software quality assurance, support for current software (software maintenance) and control tools development.

We also experiment with different printing materials. As an example, we have worked with metal, plastic and thermoplastics to create 3D Boxel, a cube derived from a 2D pixel, which is a new kind of technology.

It is essential to have a team specialised and experienced in technology, so no matter the project, a platform, methods and talented people are available for the process.

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# Innovation in Building Automation Applications

# Personalised Air Conditioning

One of our clients developed an innovative product that connects existing products via the cloud to a new solution. They developed this Internet-of-things (IoT) solution using existing component, but struggled with the integration and delivery of the whole solution. ERNI experts were called in to analyse and find the root causes for the problems. We needed to figure out how to put this project back on track and how to speed up the whole process of the development of this new air conditioning (AC) system. By rethinking and addressing some of the pain points of our customer's customer, the developed solution generated a significant competitive advantage.

Smart air conditioning is a trend in building automation that has made controlling the climate in homes and offices easier than ever before. Thanks to using smartphone apps and other cutting-edge technologies, the user-friendliness of such systems can be significantly improved.

Working closely together with this client, we delivered an innovative solution for zone-based air conditioning. This solution does not only control the air conditioning in office buildings but can also support technicians in configuring and customising the solution during its installation and setup. In addition, it allows the end user to adjust individual settings of the air conditioning to their personal preferences via an app on their smartphone.

This innovative product is a rather complex system consisting of various components, such as the air conditioning unit, a cloud solution and the app, which all need to work together.

Each room or zone in a building is equipped with its own actuator that controls the air flow and it has its own associated room device that enables the user to manually adjust the temperature and other settings. All this is a very unique and forward-thinking setup for an AC system. It was designed specifically for Asian markets which fostered a demand for individual air conditioning solutions for rooms or a collection of rooms within a building.

## Control Over Installation Status

As a pilot project for this particular AC product, the company chose one of the most innovative office buildings in Asia. The end users working in the rooms equipped with the solution could adjust and set the settings themselves via the room device and they could also use a mobile app that allowed them to see the status of the AC system on their smartphones. As mentioned, one of the important features of this equipment is the support during the commissioning and installation process.

The system enables the building construction teams to have all configuration data managed centrally in a cloud-based solution which allows downloading of the individual settings directly via the technician's mobile phone to the respective actuator. Some of the currently manual configuration steps of such systems can be automated with this solution.

From a technology point of view, our client decided to choose a very straightforward solution that involves a cloud service, an app that connects to the cloud and a web application on a PC where the AC system configuration can be accessed and edited.

## The Need for Agile Project Management

Implementing Agile methods for project management was crucial to speed up the processes in this project. We introduced Agile and LEAN practices such as sprint-based planning, daily standup meetings, KANBAN and retrospective workshops to the project. We implemented a Scrum-of-Scrums setup which makes sure that the collaboration between the teams is also working well. Agile development is often deemed best for projects with variable scope but a prioritised backlog; it is one of the best approaches for complex system projects.

In Agile settings, a strong focus is put on customer orientation, teamwork, trust, transparency and technical excellence. Agile methods are based on the idea of iterative and collaborative system development. Its core idea is that successful collaboration leads to better results: fewer misunderstandings, less rework and ultimately a more efficient delivery of the product.

Collaboration is a key aspect of the Agile methodology that encourages information sharing across deparments in a company.

## Mastering the Complexity

This project was quite complex as the AC solution involved several components that needed to be integrated into a single solution. In order to make this happen, ERNI experts had to not only apply systems engineering practices (see graphic on right) but also make sure there was a close collaboration between all teams working together; therefore the decision to introduce Agile practices was made. It helped us master the complexity both on the technology and the collaboration side of the project. Besides our client's local teams that were involved in the project, we also had to make sure that we included appointed external development companies located in Switzerland.

We have introduced the client to several collaboration formats that helped us to visualise the workflow and working progress. We have also implemented collaboration platforms for planning.

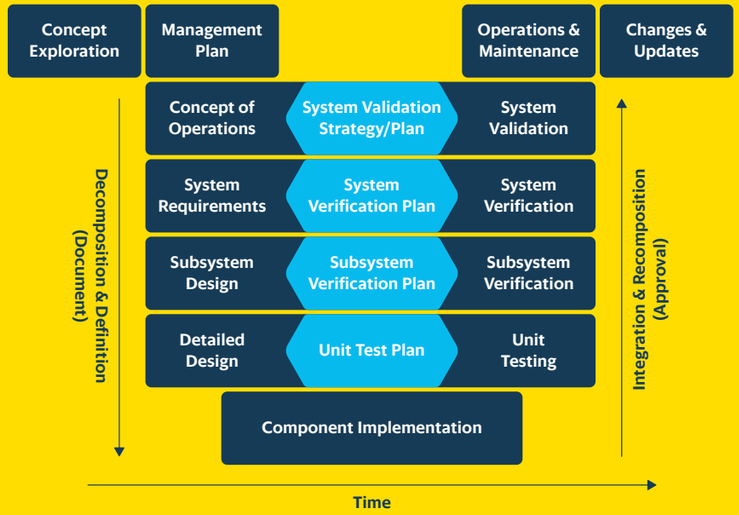
## The Importance of System Testing

Later in the project, the client noticed some gaps in the testing area. The project was lacking an overarching system testing approach. That is why we added a system test manager to the team. The test manager defined a system test strategy and defined several system test cases that were derived from the system requirements. By executing several system test campaigns, we could significantly improve the overall product quality, reliability and performance. A special focus has been put on the interaction between the system components involved such as the room device, the actuator, the app and the cloud.

Testing plays a very important role in the system development life cycle. By acknowledging the advantages of system testing and making it one of the early steps in the implementation process, the software will be more performant and will be of much better quality and improve the customer experience. That is why every project should define a system test strategy upfront and make sure all the necessary resources for implementing it are available and appointed.

Developers and testers are usually perceived as two separate teams with limited interaction by most companies. Now, this is one of the fundamental problems that the Agile approach tries to resolve. By implementing the Agile methodology, developers and testers are no longer considered as two separate teams but rather as two sides of the same production coin.

**Vee Model for System Engineering Process**

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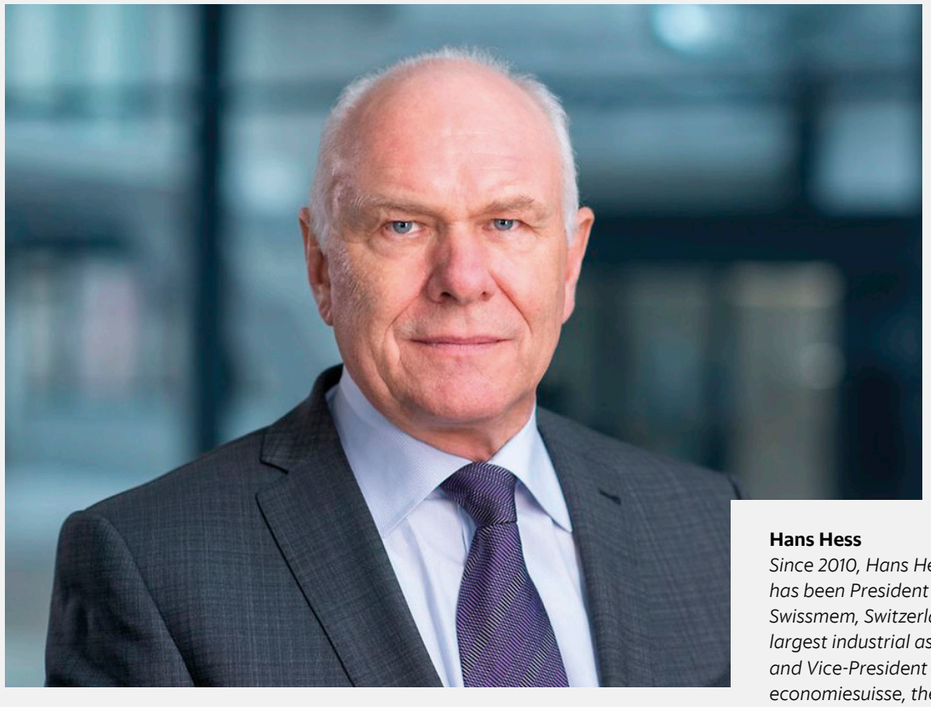
# Opportunities and challenges of digitalisation in industry



**Hans Hess**
*Since 2010, Hans Hess has been President of Swissmem, Switzerland's largest industrial association, and Vice-President of economiesuisse, the Swiss Business Federation.*

When we talk about digitalisation of industry or Industry 4.0, the general perception is that the focus lies mostly on new digital technologies. However, this approach does not go far enough. New approaches, new ways of internal and external cooperation and an adaptive corporate culture are equally important. Only when all these factors work together can innovative approaches to products, processes and business models be implemented with new digital technologies in a sustainable way. Digitalisation will lead to profound changes in the industry. However, for the "Internet of Things", we not only need the internet but also the "things", i.e. physical products. New business models or "smart products and services" only work with the combination of digital technologies with physical products. Even in the future, the "things" will still be developed and manufactured by industrial companies.

Industry 4.0 is not a system or method that can simply be applied to a specific problem. Industry 4.0 is more of a conceptual approach that opens up a multitude of possibilities based on digital technologies. The companies have to decide themselves in what business areas they want to apply digital solutions. It's advised not to focus on company strategy and end-to-end digitalisation in the beginning but to start with selected applications. It is best to first identify suitable processes or activities where digitalisation solutions can provide immediate added value.

## Focus on the value chain and customer benefits

It is difficult to predict where the digitalisation projects will lead and how quickly the progress will be. To start with such projects, the company needs courage and a culture of experimentation. It must build up the know-how gradually, gather more experiences and apply the solutions profitably on an ongoing basis. Typically, industrial companies initially aim to make their value chain more efficient, faster and more agile. The key technologies in this area are automation, robotics and additive manufacturing. But e-commerce solutions, ERP integration of customers and suppliers, Augmented Reality in the service sector and the "Internet of Things" are also playing an essential role.

However, companies must always bear in mind that the use of digital technologies is not an end in itself. The ultimate goal is to define new offers that bring added value to customers or make the company more competitive. "Smart products and services" and innovative business models are becoming increasingly important.

## Interaction of physical products and digital technologies

The use of digital technologies is essential for improving performance and securing a company's future. Successfully paving the way to becoming a digital company is a challenging task as it requires new ways of thinking, changes in the corporate culture and often organisational changes as well. Basically, this is an evolutionary development. Step by step, the company needs to decide which technology is relevant and which projects will move the company forward. Digital technologies are only one side of the coin. One must not forget that the "Internet of Things" requires not only the internet but also "Things". Autonomous vehicles still need wheels, batteries, seats, windows, sensors and ICT components. "Things", i.e. physical products, will never become extinct and so must be developed and produced accordingly. Digitalisation helps to connect them in order to achieve greater customer benefit or better efficiency. It may even create the basis for completely new business models. But you can't do this without the physical products. They will remain in the industry's field of activity also in the future.

## Cyber Security as a basic requirement

The concepts of Industry 4.0 bring together technologies and systems that were previously used independently. In the past, machines, plants and end products operated in isolation and without any data exchange with the environment. Their networking creates major security challenges. Cyber security is one of the critical conditions for companies to successfully exploit the potential of Industry 4.0. This dimension receives too little attention and companies must keep an eye on it.

## Effects on people and work

Digitalisation will trigger profound changes in the medium-to long-term period. These are changes not only in products, processes and business models but also in the activities, structure and culture of an organisation. Various professional fields will continue to develop dynamically, as a result of which some professions will disappear and new ones will emerge. At the same time, the requirements and skills needed will increase. Lifelong learning and further training at all levels of the company hierarchy is indispensable in order to maintain the skills and employability of employees. Switching to a new profession will become part of the professional career path for many people.

The use of document management systems, intranet portals, collaboration tools and applications on smartphones and tablets will forever change the way work is done. Also, the collaboration within teams and throughout the company will change significantly. This, together with mastering the technological development will bring new challenges for corporate management. The managements must do everything possible to enable rapid changes and promote agility within the company, which also includes introducing a culture of pragmatic experimentation and learning. To do this, the companies must create heterogeneous networks in which the original hierarchy levels dissolve to a certain extent. This means a shift towards participation and a more personal responsibility of employees while managers increasingly take on the role of coaches.

The digitalisation of the industry brings great and exciting challenges in all areas. But it also opens up new opportunities for companies and their employees. It is well worth actively seizing this opportunity.

# Plastic fantastic:

## Smart Manufacturing meets plastic research

**Allow us to introduce you to the future of manufacturing. The fourth wave of industrial revolution, also known as Industry 4.0, is already changing the world of manufacturing in many ways. Intelligent connection of all machines involved in the manufacturing process, automated data collection and analysis, autonomous decision making based on the current data from the environment – these are just some of the hot topics that manufacturers are talking about.**

One of ERNI's clients, a business leader in the field of sensor technology and software for manufacturing processes (MES), asked us for assistance with designing suitable software architecture that will meet the high demands of the process requirements of their clients. Today we are meeting in Germany, at a company that already uses our client's products.

Overview of parts in the production hall

We are at an institute that is well known for its extensive research and experiments focusing on improving the processes of plastic manufacturing. It is the biggest player in the field of plastic research in Germany and was founded in the 1960s as a part of the local university.

We are here to learn if the latest developments in the MES product have improved the institute's benefit of it.

Manufacturing plastic is a very complicated process that requires up to 2,000 parameters to be set up correctly in the moulding machine. Errors in doing so may result in anything from faulty products to damaging the production machine.


Raw material / Granulated plastic

### What advantages does the institute see in using our client's MES system?

The biggest win is that data is acquired automatically from the very first step until the end of the production process, making the monitoring of the process very easy. The data is linked together, which allows analysing the process in much greater detail.

Another advantage is that the software can process the input data of a wide variety of machines – and the institute owns many different brands and versions necessary for the experiments.

We are lucky to experience the moulding process live at the institute and monitor the process on the MES system.

First of all, the raw material is loaded into the machine.

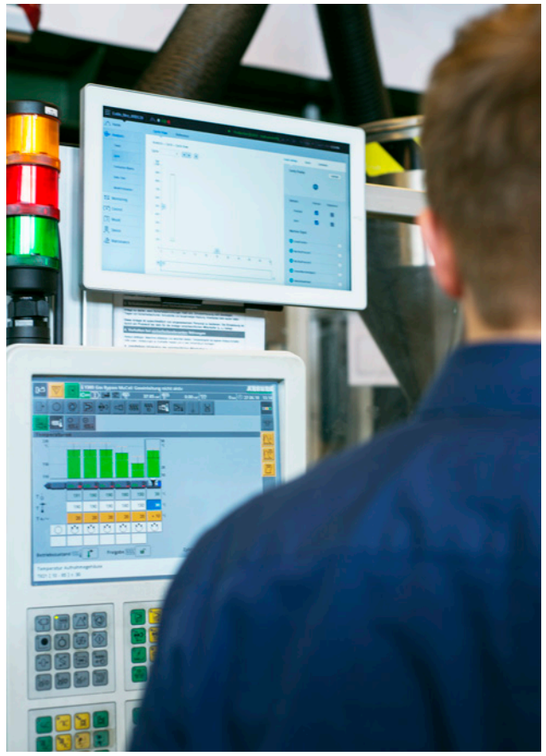

Input of the raw material

### 1. Input of the raw material

Then the machine is heated up in order to melt the granulate. Before starting the melting process, all parameters of the machine have to be set correctly: They depend on the raw material used, the desired product characteristics and the tool (mould) used. Traditionally, setting up these parameters has required expertise and experience of the researcher operating the machine. But thanks to the data gathered from past processes, the machine learning algorithms can support this step.

## 2. The assistants run the machine directly through the machine's SPS

In the institute, this process is monitored closely by the researchers in order to make sure the machine set up is working flawlessly.



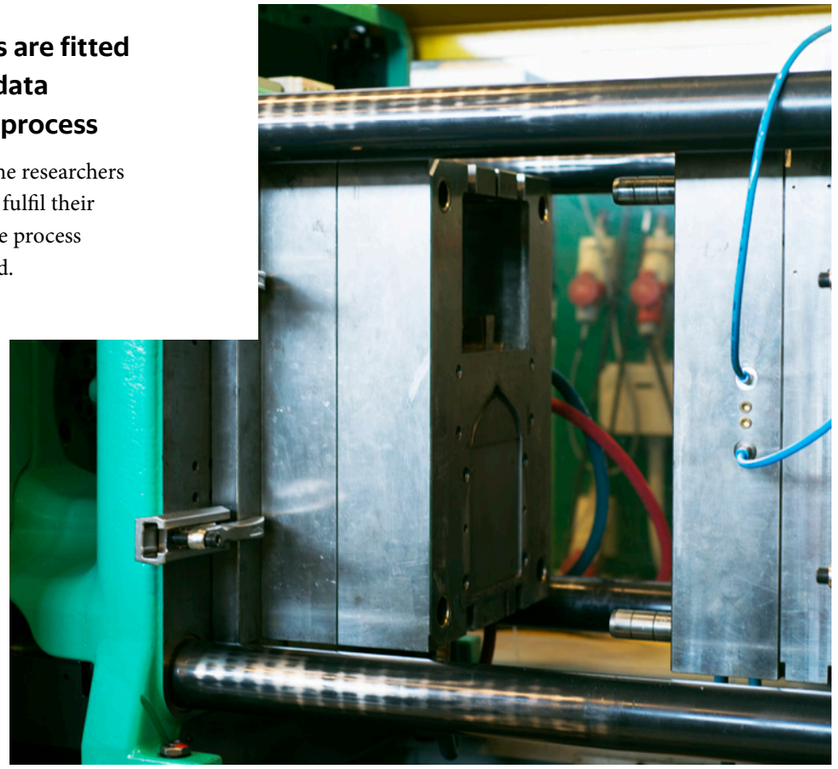
## 3. The process is monitored by the researchers

In our example, data is gathered from two different sources during the moulding process. On one hand, the machine gives us information about the status of the machine (e.g. current production mode, temperature of the machine, etc.). On the other hand, we have information from the sensors that are directly built into the tool (mould). They measure process characteristics (e.g. current pressure in the tool) in rapid intervals.

We observe that the MES system of the new version is synchronising these data sources correctly, which is a difficult process as the data sources are completely independent.

## 4. The moulding plates are fitted with sensors to allow data acquisition within the process

These combined data enable the researchers to check if the produced parts fulfil their quality expectations. If not, the process parameters need to be adjusted.



### 5. The end product can have all kinds of forms

All data from all the connected machines and devices (which can number in the several hundreds) can be seen in the MES. With the help of smart algorithms, a deeper analysis can be made regarding the process, plant efficiency or other metrics.

These in return can then help the institute find better production methods and reduce plastic waste, which then can help to declutter our seas of plastic garbage.

With the support of ERNI, our client was able to analyse their MES product and identify individual areas of work. Together we defined a new system that allows smooth integration of multiple data sources and their synchronisation and has moved the processes towards a lightweight microservice architecture.

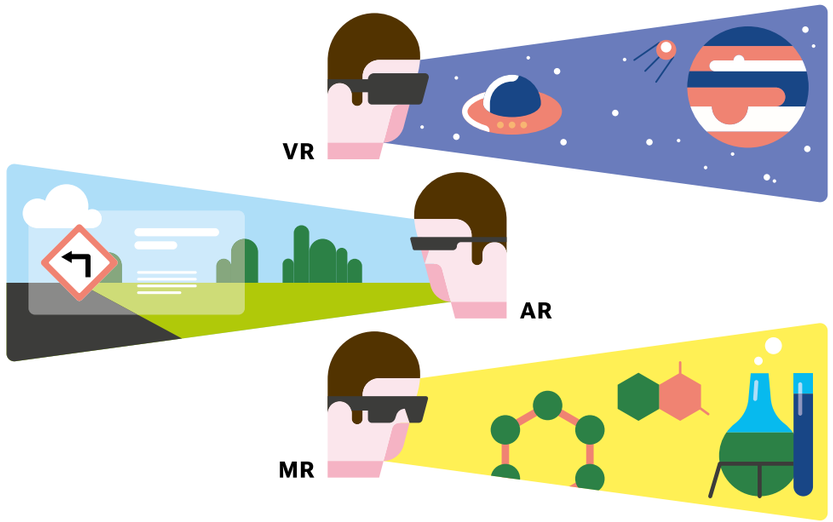
These improvements allow the researchers at the institute to work efficiently with a wide variety of machines, analyse the data synchronised over the whole process and improve the industry's manufacturing processes – with regard to reducing our ecological footprint.

Smart Manufacturing is evolving extremely fast, especially in Germany. Our client confirms that the demand for fully integrated systems is growing steadily.





# Even in Augmented Reality, your mindset will set the tone of innovation




**Augmented reality has been a part of "the real reality" for a while now. It was predicted that AR would reach its peak in 2019. Would you agree?**

**Leon Carruyo Miura**: We can't really say that AR has reached its peak yet. It's ready to be used and already providing many businesses with benefits. But I also think that it will only get better with time. I expect this trend to continue to grow in the coming years, instead of reaching its peak soon. Adoption of this technology has been increasing fast, with more affordable and convenient options available such as ARCore and ARKit (AR frameworks for Android and iOS, respectively) with regard to end-consumer reach. This indicates that in the next couple of years, the technology will become widely spread and virtually (pun intended) everybody will know it and be comfortable using it.

**Arnau Roca**: I can see that a lot of companies are becoming aware of the technology and starting to see its benefits. However, most of them are still investing in POC (Proof of Concept) only. Augmented Reality can optimise any production in pretty much each industry field. It helps you create a new environment where you can interact immediately and don't depend on other people. You don't need any other support and so can solve emerging issues immediately. In manufacturing, this helps you to be very flexible and quick.

**Leon Carruyo Miura**
*Senior .Net Developer and Leader of the Virtual and Augmented Reality Service working as a full-stack developer on a mobile project and VR/AR pre-sales.*
leon.miura@erni-espana.es

**Arnau Roca**
*Business Unit Leader and Account Manager of several customers at ERNI Spain.*
arnau.roca@erni-espana.es

**Creating an added layer of information to our world is a part of creating optimised, digitalised Smart Factories. How can AR enhance the production and what benefits does it bring to companies?**

**Leon Carruyo Miura**: Its key benefit is the ability to present in-context, real-time information to workers, which can help them and the machines around them work more efficiently and accurately. Another field of use is, for example, Predictive Maintenance. In factories, you have a table of data or IT numbers of all devices on site and you can check their statuses.

But when you have hundreds of devices, it can be very inconvenient to read the tabular data. With AR, you take the device (a headset, phone or tablet) around the factory and you easily and quickly visualise the status of everything in view. You can point the device at machines and have them recognised automatically (without needing to search for machine IDs). Then you can visualise a machine's readings; for example, you would see the scanned values such as current temperature or pressure directly over a valve on your screen, not in a separate table. If the values are outside their ideal ranges, you get a visual warning. For example, a device will be highlighted in red if maintenance is needed urgently, together with the predicted date of failure. While a table of machine IDs and measurements is difficult to process, this way is much more efficient.

**Arnau Roca**: It's very similar in the Medtech industry. Except you don't work with machines, but with human bodies. Some companies are using the technology to check on the body status. They use radio sequences of inner organs and are able to see any changes through a patient's smartphone, for example. They can find out when a patient needs a surgery or experiences some health issues. The technology can also help visualise the process of recovery, e.g. virtual recreation of a bone fracture. This has an amazing value for doctors. They can use AR to plan and train for the surgery before they enter the operating room.

AR helps you optimise all sorts of processes in warehouses. If an employee wants to move a lot of products, AR system helps optimise the transport and shipping. The technology can send a warning if traffic jams occur, tell you if you are using the space in trucks efficiently, etc. In manufacturing, it allows you to create virtual objects first, arrange them in the virtual space and see if they will fit.

**Leon Carruyo Miura**: As mentioned in the example with doctors, training is one great use of this technology. Using virtual machinery allows for safe, effective and autonomous training. It's much more engaging and tangible than having the staff read a book manual. This way, more senses are used to take in the information, which makes it more memorable. Additionally, the AR is great for prototyping, improving safety of day-to-day operations, quality control or reducing errors.

**What about the companies that don't have any experience with this technology but would like to try it? What predispositions do they need for successfully implementing AR? What are the steps of implementing AR in a company?**

**Leon Carruyo Miura**: What a company needs depends on the type of project. They'll want to start small and first gain confidence in the technology. Normally, the first step is for our ERNI experts to help the company acquire more knowledge about AR in order to understand its capabilities and how it has been helping other companies.

With that new knowledge, we guide them while they generate ideas on how it can be useful for their company. And this step is very important: the ideas come from the client, not the consultant. But the customer would not have been able to generate them without first understanding the basics of the technology. The client then chooses one of their ideas and we work with them to define and implement a proof of concept.

With the proof of concept in hand, the client can then make a very informed decision about making a sizeable investment in a full project. By then, they will know how the experience feels, how much time it can save and how easily the workers can adapt to it.

**Arnau Roca**: Yes, the point is that we always start in a training centre where the employees learn about VR. Everyone is using mobiles and iPads today, but they need to understand that they will be interacting with something that does not actually exist but only gives them information. We then create a test room that acts like the real factory where they can try out the technology. After the training session, they choose people to use the device on a daily basis. Then the time when the automation will be launched is specified together with a plan of evaluating the employees' responses to it. We create a schedule for when the employees will be using AR and using information from the app to talk to other employees. It's like a normal working day, but one guy will be two to three steps ahead of everyone. That will show the employees that the device will help automatise certain processes but won't solve all of the problems. It's more like a central server that is helping everybody out.

**How expensive is this solution for companies?**

**Leon Carruyo Miura**: These devices have many levels of functionality, so the investment can vary. Normally, we start with simple concepts and suggest inexpensive devices, just to show our clients that it really does work and bring benefits. Once the clients start to use these small solutions and get used to them, they can think of improvements and define what the complete solution should consist of. The complete solution can then also vary, depending on many factors such as complexity of the business logistics, connectivity with existing systems, amount of training needed, etc.

**Are there any challenges that you have to overcome when working with companies interested in AR?**

**Arnau Roca**: The mindset. Nobody will accept change or step out of their comfort zone unless they understand the benefit the change brings. We let them experience it first hand so they see the positive outcomes and improvements of the daily tasks. People are more relaxed about it afterwards.

**Leon Carruyo Miura**: It depends a lot on the clients. It can be easier with larger enterprises, as they already have some budgets reserved for innovative projects. In smaller companies, you really have to work on getting the client to trust the technology. We always offer the option of starting with a proof of concept, where the risk is lower. This way, they can get a feel for it first and validate the solution before moving on to the full solution, meaning a full project with a large budget.

**Is this technology for everyone? How can companies find out if they really need this kind of investment?**

**Leon Carruyo Miura**: Well, let's take the example of its use for enhancing the training of employees. Absolutely everybody in every field of manufacturing needs to train their employees. Here it is even more important that our clients understand the technology. As we have already mentioned above, we put a lot of effort into educating our clients about the technology. We do workshops first and once they understand it, we help them define how they can use it. They decide what is a priority for them and if the benefit it brings is really worth the investment. Another point is that even after the workshops, they keep generating new ideas – this happens almost automatically – so sometimes they even find a better option outside the setting of the workshops and we revise the original plan together.

**How important is data for this technology?**

**Leon Carruyo Miura**: More data can make the solutions more meaningful. You can have an implementation where the amount of data is minimal, but given in context and at the key moment, so it can still be very useful. Or you can gather all data from your entire warehouse and visualise it. This can also be very powerful and open up many possibilities. There are solutions that work with less data perfectly well, but usually more data can multiply a solution's value.

**What devices do you use in companies? Who is the leader in this field?**

**Leon Carruyo Miura**: The flagship in the industry is the HoloLens, developed by Microsoft. Currently, it is the most powerful device and it does not need to be connected to a computer to run. It is also the most expensive one.
With this example, we can start with a smartphone (which everybody already owns) in the proof of concept and then switch to the HoloLens in the second stage of the project. Another expensive device is the Magic Leap One; it's not on the market just yet, but it is due out soon and supposed to be the closest competitor to the HoloLens.

Google, Samsung and Apple are the market leaders in the smartphone segment. They are the first ones out that have introduced the broadest range of AR-capable smartphones. Google and Apple have their own AR software frameworks.

**Let's talk about some other, quite similar technologies. What is the difference between AR, Virtual Reality, Mixed Reality and Immersive Reality?**

**Leon Carruyo Miura**: We have a global meaning of virtual that describes everything that does not exist but you can still interact with. For example, if you only create a 3D image with which you can interact – that is VR.

With AR, you have a device that will give you a virtual representation, but you need to scan the real object first. For example, I am using a mobile app that can recognise a glass and there will be a popup saying if the glass is empty – according to the recognition, it will give you a meaning.

Mixed Reality is when the app does not have to recognise anything, but it creates virtual surroundings and digital objects that will interact with you. You don't need to scan anything and these digital objects follow the rules of physics.

The last one on the list, Immersive Reality, is when you only interact with the virtual. So, for example, when a headset creates a whole new world which does not have to be connected to your real environment. It's all virtual. You don't see outside of the headset; everything is inside.

**Which one is the most beneficial in manufacturing?**

**Arnau Roca**: I'd say Augmented Reality.
You need to see real interactions with daily tasks.
But really, we are talking about both VR and AR.
You can create an object in VR and then use AR to simulate different scenarios and uses.
This way, you don't have to be inside of the machine, you only need to scan the machine and get a hint of where the problem is.

**Leon Carruyo Miura**: There will always be room for VR, but I see more immediate uses in business for AR. With AR, you see everything that you would see without any device – just with your own eyes, plus you have the experience and interaction with the information you need at that particular moment. If your physical location limits your interaction with the intended environment in any way, you can use VR and experience a complete switch – you are not just adding to what you see. Your eyes do not see anything around you besides the virtual world. This can be great for training purposes. You sit at your desk and at the same time train to be a pilot. However, this is not that useful for everyday tasks in a factory. Usually, you just want to enhance reality with AR.

better ask ERNI