The road ahead for Scandinavian industry

The pitfalls, opportunities and keys to success in the next digital age.

Outlook Report by TietoEVRY and KTH.

tieto EVRY

Contents

Computer revolution goes full steam ahead

Since the dawn of the Industrial Revolution, many manufacturers have recognised the need for renewal to keep pace with market demands.

Today, however, the concept of change in the 21st century has taken on a whole new meaning. Industry is facing the prospect of a technological leap that will rival the impact of the steam engine.

As digitalisation picks up momentum, getting onboard with the new technology is a matter of survival. Those who embrace it now will have a chance. Those who bury their heads in the sand may just as well close up shop. These are the findings of this outlook report, put together by TietoEVRY and KTH, The Swedish Royal Institute of Technology.

Although this reality may feel like a large pill to swallow, this radical shift has been years in the making, as the following recap of events and trends reveals.

Marking the new millennium, the National Research Council in the U.S. released its report

"Visionary Manufacturing Challenges 2020" as the first internationally recognised digital roadmap. It introduced the term "pervasive computing", or the ubiquitousness of computer control systems. A few years later, the term "ambient intelligence" became the new talking point exploring the responsiveness of electronic environments to the presence of people.

The carousel was set in motion. Early notions about the Assembly Net led to Augmented Reality and then to the well-known Internet of Things. Along the way, concepts such as EUPASS (2008), FutMan (2008), ManuFuture

(2010) and Industry 4.0 (2014) have all reiterated the same ideas, some with more creative terminology than others.

But the point is this: for more than a decade the message has been crystal clear. Computers and computing power are dramatically changing the way we work, live and, most importantly, how we develop our systems. As such, manufacturers have no choice but to join the computer revolution, but are unable to do so while maintaining their current aging systems, which are largely based on PLCs (Programmable Logic Controller) and conventional mainframes.

The modern factory.

The report turns the spotlight on business- related issues of concern and provides a roadmap for the radical shift that is needed to support tomorrow's production system. From a broad palette of trends and scenarios, the report covers a wide range of topics including:

- **Sustained economic viability:** the importance of matching technological know- how with adequate business models.
- **Environmental sustainability:** minimising the use of resources and unwanted materials, waste disposal and pollution, and how to meet new regulations.
- **The dawn of a new technological society:** how automation will both replace manual labour and create new employment.
- **The impact of globalisation:** a revision of our ethical image is required in industry and society as a whole.

Assuming their role as thought-leaders in the realm of technology, TietoEVRY and KTH

share the view that the future is by no means insurmountable and well within the grasp of all companies regardless of size. The need for a common vision and organisational leadership is a core conclusion of the report.

The idea that excellence stems from a dedicated and unified culture is perhaps best summed up by the renowned management consultant and educator Peter Drucker, who wrote: "culture eats strategy for breakfast."

> **"Vision without action is a daydream. Action without vision is a nightmare.**
>
> **Japanese proverb**

Beyond Industry 4.0

In a world where climate change, dwindling resources and shifting demographics are all major concerns, it is evident that technology alone will not solve all of the world's problems. When it comes to industrial production, now is the time to re-think, re-design and re-create – and Internet 4.0 will not be enough.

Mass-customisation and personalisation are just two examples of how customer demand is fundamentally changing. A new industrial paradigm needs to be created where not only environmental sustainability is safeguarded, but also new business models that secure long-term competitiveness.

This report explains why such a transition is important and how business operations, production lines and corporate structures will be affected.

Although the move to digitalised factories and products is both necessary and possible with today's technology, more needs to be done to stimulate both sustainability and growth. As such, it can be argued that "digitalisation" is a major understatement for the following reasons:

- **Technology is essential but will not achieve the transformation by itself**
- **Current computer models cannot be modified to meet future needs**
- **Organisational strategy will be fundamental and collaborative schemes will take centre stage**
- **As current business models are insufficient, change is inevitable**
- **Man and machine must learn from each other and improve their interaction**
- **Corporate ethics will play a key role in the new industrial value chain**

While technology is not the only key enabler, acquiring capabilities for managing, computing and exploiting vast amounts of data for different purposes is now crucial. This requires advanced computer knowledge, cutting-edge software solutions, new communication protocols and reliable standards.

Industry needs what experts often refer to as a Cybernetic Revolution. The word "cybernetics" (from Greek meaning "governance") is used in this context to realise the vision of creating a circular economy where inefficiencies and waste are minimised and eventually eliminated.

To facilitate this path, business models will be required that support the well-being of the planet's ecological system, as well as generating yields for stakeholders. The era of short-term gains is coming to an end. Companies will be more inclined to cooperate – in so called coopetition. Technical know-how, transparency and market-adapted products will all become part of the new enterprise model in the globalised society. And in this new world, ethics are likely to be regarded as the most valuable currency of all. So is industry geared up for this dramatic new business environment? Well, yes and no. Most industrial companies acknowledge that there are huge changes ahead and many have begun to address individual issues. But few have taken the bull by the horns to get themselves where they know they need to be. This is perfectly understandable. In the current economic maelstrom, there is little time to sit back, take stock and see the big picture. Business NOW and shareholder's demands take precedent. However, that doesn't mean the process of change can take a back seat.

For a number of years now, a few far-sighted IT companies have been quietly working in the background with these issues, helping companies to steer their ships in the right direction so that they will not only be able to meet the challenges ahead, but to benefit greatly from the discovery of new horizons.

TietoEVRY is one example. This Nordic company's innovative IT solutions are built with "the new world" in mind, taking into account that the way ahead is to invest in a series of small, well chosen steps that together and over time can deliver the desired result.

Rome, as the saying goes, was not built in a day and the same goes for global digitalisation.

In this respect, TietoEVRY emphasises that the most strategically pivotal decision any industrial company takes in this second decade of the new millennium, is simply to get on board and join the journey.

Brave new world

From the dawn of civilisation it would take a thousand years for human knowledge to double. Then, as transport systems improved and innovations such as Gutenberg's printing press emerged in the mid-15th century, the rate increased dramatically. But it was the computer revolution that would catapult human knowledge to exponential heights.

By 2015, the rate at which human knowledge has doubled is astonishing – less than one year. Thanks to the internet, all of the world's information has been made readily available and the challenge now lies with organisation and classification of relevant data.

Information has always been available in one form or another and knowing precisely what to capture is merely the first step. While this journey has only just begun, important trends reveal the direction in which we are headed – the drivers and enablers of a new industrial paradigm.

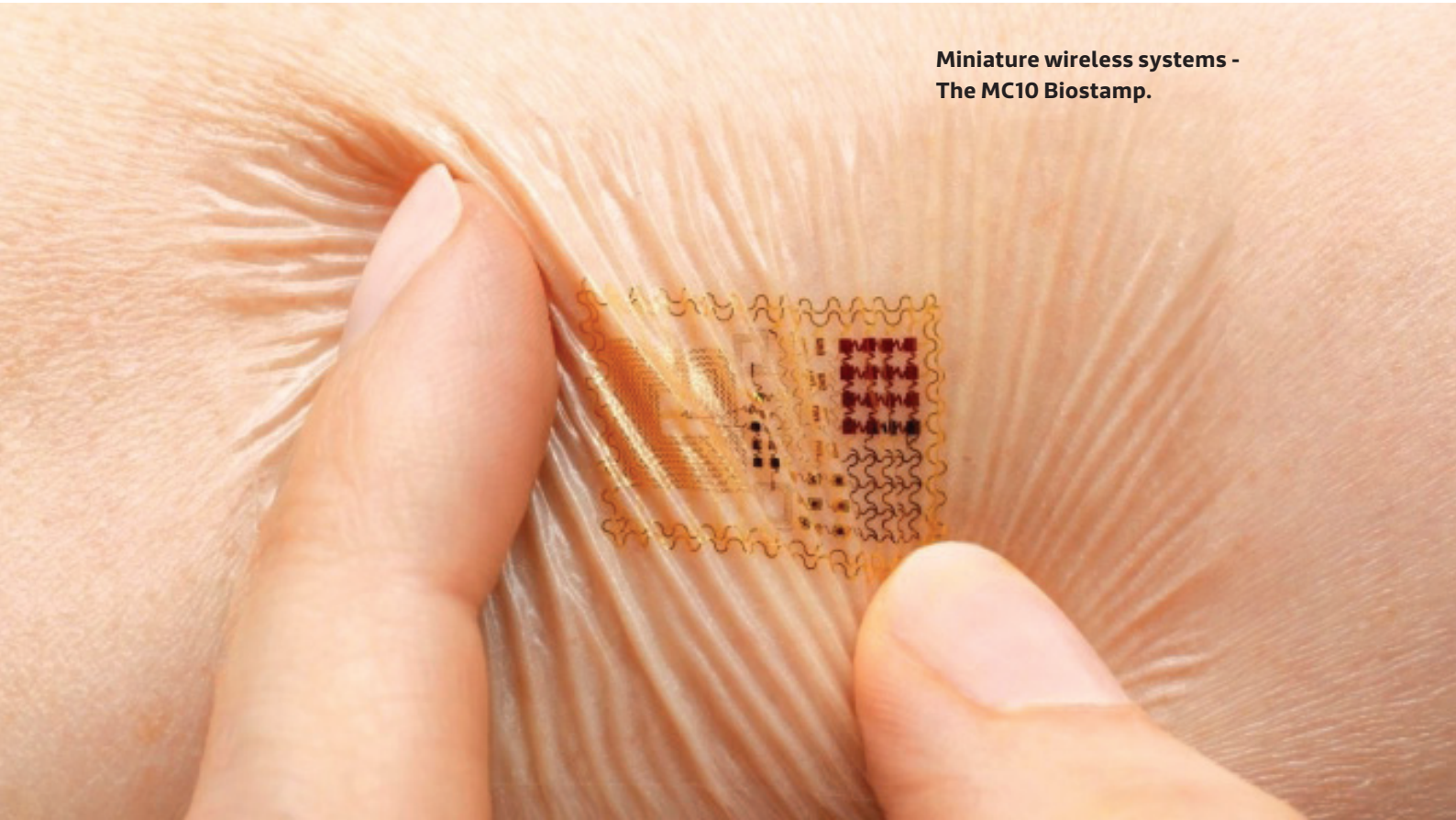
Personalisation takes off

Initially driven by the medical sector where patients are now benefiting greatly from personalised care, the personalisation trend is about to influence all areas of industry and consumer manufacturing. In fact, most companies have increasingly high ambitions when it comes to personalising their offering.

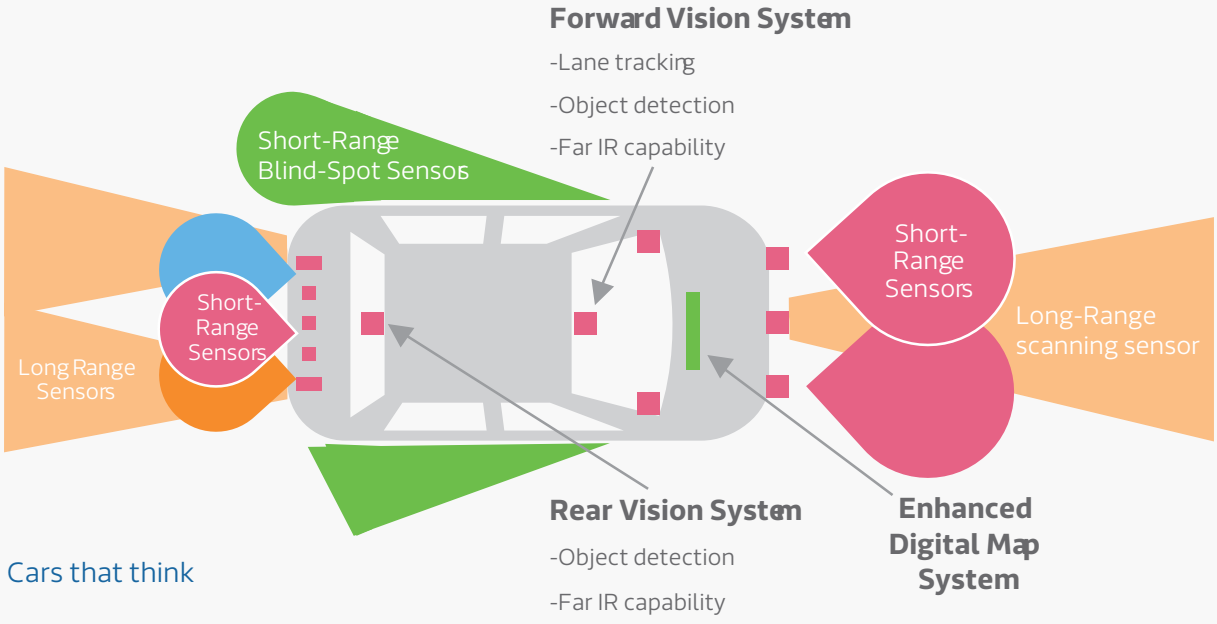
Within a short space of time, it is expected that all consumer goods such as digital cameras and laptop computers will have a design tailored to each customer's needs, going well beyond just software and settings. But it doesn't end there. Airbus has even expressed its vision of personalising all aircraft – making each one different but with maintained efficiency.

A key factor in this development in manufacturing is the arrival of new materials that are "resorbable", which implies materials that facilitate ingrowth and regeneration. For example, tailored implants can be created today using materials that are absorbed by the human tissue, that also feature microsystems connected via wireless networks.

So what is required to manufacture these products? The answer is two-fold:



Miniature wireless systems - The MC10 Biostamp.



1. **Production systems that have the capacity to learn and adapt**

2. **A vast interconnectivity of devices**

This adaptability or "evolvability" of materials means that they can be re-used in a range of similar production scenarios. The new production modules will be both intelligent and self-sufficient in the sense they will communicate with each other and self-optimise.

The shift toward personalisation is sending a strong signal to all manufacturers that current production systems need to be restructured. Single-generation and expensive implementations are no longer viable. Furthermore, the entire approach toward machine control is shifting extremely fast. This underlines an urgent need to pursue rentable, modular and self-maintaining processes that support change.

Rise of the sharing economy

Throughout the history of civilisation, the economic system in place has been centred on ownership. However, many of the products and services that are sold today will in the near future be shared on a mass-scale. The development of driverless cars, which have undergone many successful trials, is an interesting case in point.

When we combine the idea of driverless cars with already existing services such as UBER, the future arguably becomes predictable – people want access to vehicles but not necessarily the hassle of owning a car. A simple tap on a smartphone display, or even using single voice command, a flotilla of vehicles is readily available.

Extend this thought to the growing use of drones for delivering mail, packages or groceries and we can see that consumer behaviour is actually changing at the core. Driverless cars and delivery drones are just two examples of a global trend that will have a large impact on industry. Advanced sensor systems are required to enable communication and autonomous decision-making and the interconnectivity required places higher demands than ever on control systems.

Regardless of industry sector, collecting relevant data and maximising its potential will be vital for business success. As technology evolves and we increase our environmental awareness, sharing everything from cars to bicycles, segways, umbrellas and even our homes is becoming a part of everyday life – not a passing phenomenon, but a state of normality. In business relations, behaviour is also fundamentally changing as risk-sharing is a strategic approach adopted by more and more companies. For example, when the first SMART car was developed, Daimler commissioned the painting process from Eisenmann which had its target set on entering a conventional deal. Daimler then offered to pay Eisenmann a percentage share of each vehicle sold in order to share the investment risk, and so the deal was sealed.

The are many similar examples of how the sharing economy has infiltrated business practices and is leading to the emergence of new business models. The idea of "coopetition", or cooperative competition, is now picking up momentum.

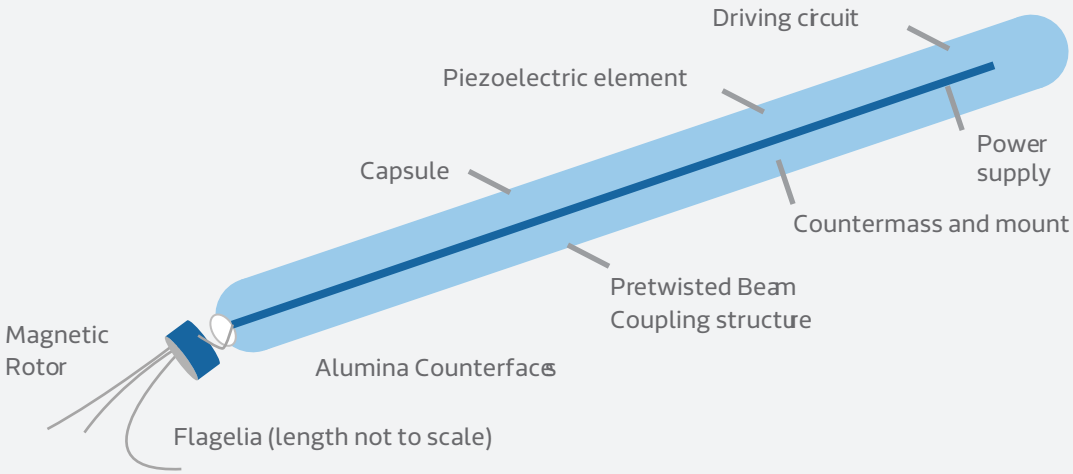
Sharing schemes for bicycles.

New face of manufacturing

Developing products that are capable of solving tasks autonomously is a trend that is likely to last well into the next decade. Embedded control is a principal building block of future manufacturing, and the potential of these devices has no limit.

Many industries, ranging from medical to automotive and paper pulp, will develop products that have on-board computers dedicated to specific tasks. There will be surgical tape that monitors the recovery of patients, parts and components that transmit data on wear and tear and packaging that monitors best-before dates.

In the future, trees deep in forests will be monitored and tracked to individual wood products – such is the detailed level at which data can be used to great advantage. Having said that, these multi-material, multi-process and multi-disciplinary production processes place enormous demands on efficiency.



Injectable robots.

Intelligent products: a new dimension

While these “intelligent” products will no doubt be revolutionary, companies need to be aware of the pitfalls in order to make production a reality. This includes the need to adapt to regulation and policies and a good case in point is Sysmelec, a Swiss company specialising in micro-assembly.

Although Sysmelec was perfectly capable of creating microsystems more than a decade ago, getting to the point of starting up production was a bumpy road. When the company embarked on a project to assemble a micro-medical device, similar to a micro-chip but with medication delivery through on-board control, expectations were high as the new device contained radioactive material that could be injected within the blood stream, find cancerous areas and target tumours with pinpoint accuracy.

The problem? Sysmelec had to guarantee a 100% fault-free production, partly due to the nature of the product but mainly due to regulations for the manufacturing of medical devices.

Groundbreaking materials

Sound-absorbers, or so-called bioisolators, carbon fibre, graphene, shape-memory alloys, and the list goes on. The potential that new

materials will have is only limited by our own creativity and ability to adopt flexible production processes. Interestingly enough, steel manufacturers are making considerable strides within this important segment but many others are destined to follow.

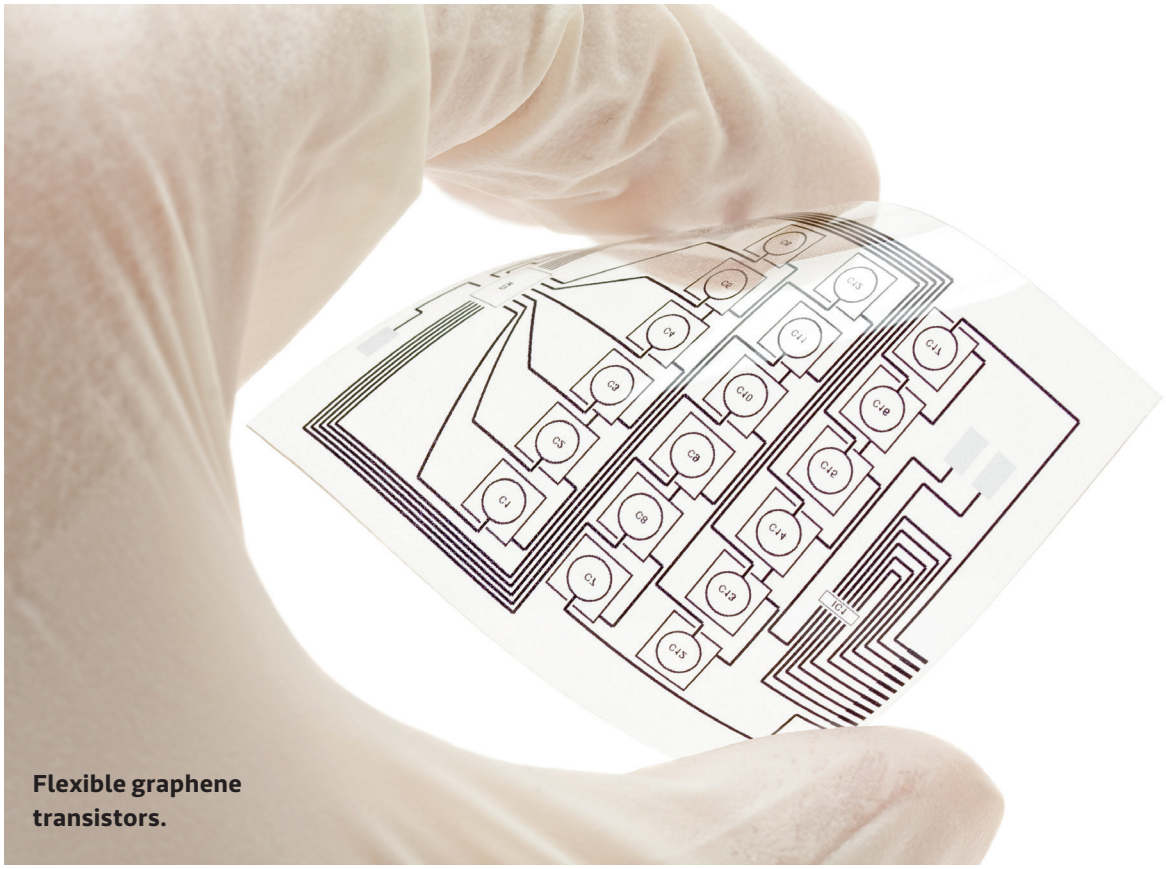
Bio-refineries are already supplying the forest industry with new, advanced biofuels, carbon fibres are increasingly used in vehicles, viscose is replacing cotton, the next generation of laptop computers are expected to use pliable graphene. As materials undergo a revolution in their own right, these examples underline the need for a re-structured approach toward production that is optimised for new schemes.

Furthermore, if the arrival of new materials is not planned for carefully, there is an environmental downside that threatens to cripple the progress, as multi-element materials are far more difficult for nature to degrade.

Although the Himalayas takes us thousands of miles from most large factory floors, this part of the world is a useful example. Up until the 1960s, the materials that were left behind in the Himalayan mountain rage by rock climbers did not pose a threat to the environment as wool, cotton, iron and steel would erode and disappear over time.

Today the story is quite different and, sadly, the Himalayas resemble an enormous garbage dump, now filled with materials that do not easily return to nature. These include polyesters, polycarbonates, composites and carbon fibres. In fact, most packaging has a negative impact on the environment and a simple beer can will very often consist of more than five elements in addition to aluminium.

Having pointed out areas of concern, materials that can be chemically separated are notably on the rise. Moreover, recyclable steel is expected to lay the foundation for sustainable production, as it is one of the few materials that can be used over and over. As new markets open up, close collaboration between steelmakers and producers of natural materials can potentially create a powerful industry segment.



Flexible graphene transistors.

The prosumer society

In the society now taking shape, manufacturers must prepare for a whole new production scenario. Business relations will not simply be about appealing to consumers but, increasingly so, “prosumers”: people who sell services, energy or products. In the home energy market, a growing portion of households are now producing their own electricity and feeding surplus energy back into the grid at a certain price.

These new patterns, from sharing schemes to “prosumers” taking an active part in the economy, are dependent on two areas of technology, or two key enablers: connectivity and sensoring. In order to provide accurate information at the right time, a vast amount

of sensors will need to be coordinated and synchronised.

In addition, algorithms that optimise all of these new transactions must also be developed. But above all, an ever increasing need to filter and structure mountains of data needs to be managed – a reality that is likely to render most inadequate computer infrastructures obsolete, and some within just a year or two.

The Internet of Things

Connected machines will revolutionise the factory floor and be the catalyst of a new era of smart manufacturing. With a constant

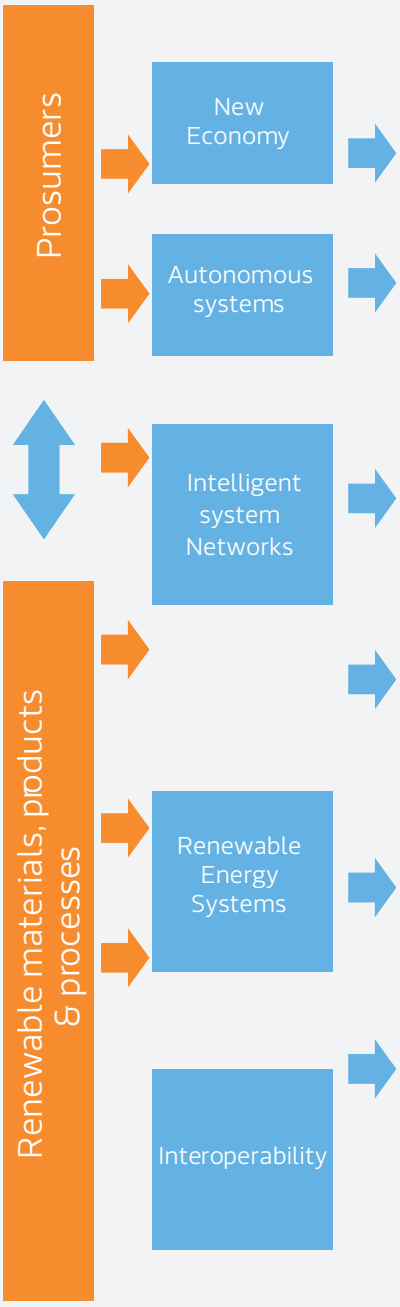
information exchange, production equipment will adjust itself automatically and increase uptime while improving energy efficiency and safety. It is widely agreed that The Internet of Things (IoT) will improve material flows and productivity by more than 30 per cent.

As proactive decision-making is brought into manufacturing, thanks to inter-connected machines and devices, asset management, maintenance and logistics are expected to make a quantum leap – resulting in lowered costs, minimised waste and increased time-to-market. Sensors will monitor the quality of parts and send reports to owners and manufacturers in an automatic feed which enables preventive actions to be taken.

But that’s not all. Real-time insights will enable customers to make on-demand orders for

all kinds of products, even with customised features. In this new production scenario where flexibility is king, business models will focus on providing a total service, not just products, and thereby create greater customer value. As such, the opportunities will be endless.

The prosumer society will evolve in a manufacturing model based on renewable energy, raw materials and multidisciplinary engineering.



Social/natural models for complex contol of dynamic world engineering

Innovative behavioral/social models for engineering systems
Artificial intelligence, cybemetics
The energy prosumer's role in a dynamic complex control ecosystem
Bio-mimicry, Design by nature
Self-balancing (resources) processes

Engineering design solutions for adoptable, complex and dynamic systems

Smart cities
Smart grids
Modular, evolvable production systems
Composite materials
composite embedded products
Flexible, responsive, secure and cost-effective energy systems

Dynamically modifiable CYBER PHYSICAL systems

Self learning self diagnostics for dynamic systems
Autonomous system components
smart products
Adaptable factories
Cyber security

Interoperability of "world sets" components & system

Multi-level CLOUDs
Architectures, protocols
Interfacing
Standards
Advanced data mgmt. and exploitation
Monitoring & supervision

Sustainability

The ecological dimension
Innovative business models
Circular economy dynamics
The disruptive element
Holistic management

Energy efficiency

Balancing energy use (Living-industry-transport)
Energy-efficient machines
Energy-efficient industrial processes
Energy storage
Green IT

Rethinking the business model

In the current global drive for increased efficiency, there are two major, interdependent mechanisms that are equally important to consider in manufacturing: **sustainability and increased competitiveness.** In the emerging prosumer society, sharing, leasing and renting products, services and production equipment will be far more common than the buy-use- discard cycle of today. As more eco-friendly methods and practices are adopted around the world, the reasons for producing will also change.

Looking forward, studies show that companies will need to collaborate more than ever in order to maximise the use of materials and resources. New technologies and the drive for sustainability will create a new economic paradigm. And it is therefore paramount that manufacturers develop analytical methods that are capable of formalising the key economic factors that call for radical change.

Most business models incorporate mathematical and quantifiable tools in decision-making as well as the strategic subdivision of tasks vs. yields. Cost issues are of primary concern. A greater understanding of cost factors must be spread to a wider audience within and without each organisation – where cross-border collaboration is the key to success.

Collaborative approaches are on the rise all around us. In the future, a paper mill which is situated next to a baby food plant, to give an example, may well use excess nutrients from the baby food production for its own biological water treatment processes. Other plants may provide heating and warm water for the local swimming pool and recreation centre, or indeed for housing in the local community.

The short message is: business models need to be modified and adapted to a new reality. Coupled with this, manufacturers need to recognise the need for a complete overhaul of computer systems and introduce flexible software tools.

The approach of upgrading legacy systems has played out its usefulness. Old mainframe computers, regardless of the applications built on top, are simply too outdated and incapable of supporting today's product development.

And they can't meet demands for speed and flexibility. Moreover, the functionality achieved by adding applications to old systems is limited and the IT projects required are both time-consuming and costly, on a level that is increasingly hard to motivate.

Scalable and mobile operations

New customer demands are steering manufacturers away from conventional high volume products towards scope-oriented products, which implies a range of product variants in medium to high volumes. This, in turn, requires flexible production capacity.

The shift from conventional products to a set of variants within the same production facility will affect all manufacturers, in process industries (converting raw materials) as well as in discrete manufacturing (duplicated products). This means that these companies will need to adopt the same solutions: cost-effective, fast production re-configurations. The move to scalable, cost-effective IT systems and new business approaches does not only make strategic sense, it is a matter of survival.

A highly likely consequence of this development is that the primary source of income for manufacturers will also change as they become far more dependent on a range of subsuppliers in different industry segments. In terms of operations at larger companies, having one main production site may well be a thing of the past.

Creating many small, market-oriented production sites that take advantage of local opportunities, including resource management and waste recycling, will be an important step. However, this creates a need for scalable production and equipment that can be moved cost-effectively from one location to another.

Mobile tumble drying barley, canola, oats, wheat, peas and rye and is plugged into the existing plant. The dryer has its© oTiwetno CPoLrpCorwatihoinch also controls the elevators and cool pockets in the barn. Picture: Farm Mac.

If these conditions and capabilities are given, the likely scenario in the near future can be summed up by a practical observation presented in the report "Enabling the bio-economy: the future has begun", published by CEPI, the Confederation of European Paper Industries, which states:

"A single industrial site can host the operations of five different companies benefiting from a saw mill's by-products and residues: construction timber, pallets, wood chips for pulp, energy pellets, and energy production."

The production shift

In the production systems of the future, machine automation and Plug to Order (PTO) modules will be key components. PTO refers to new ways of managing production without having to purchase equipment which is used and then discarded.

Going forward, industrial machines will be leased or hired and will also reconfigure themselves autonomously. When the equipment has become fully outdated and irrelevant, only then will it return to the service provider.

This idea is a cornerstone of an ongoing shift from "dedicated production", where human labour and machines perform a single task, to "autonomous production" – using equipment that is self configurating, self organising, self learning and self diagnostic.

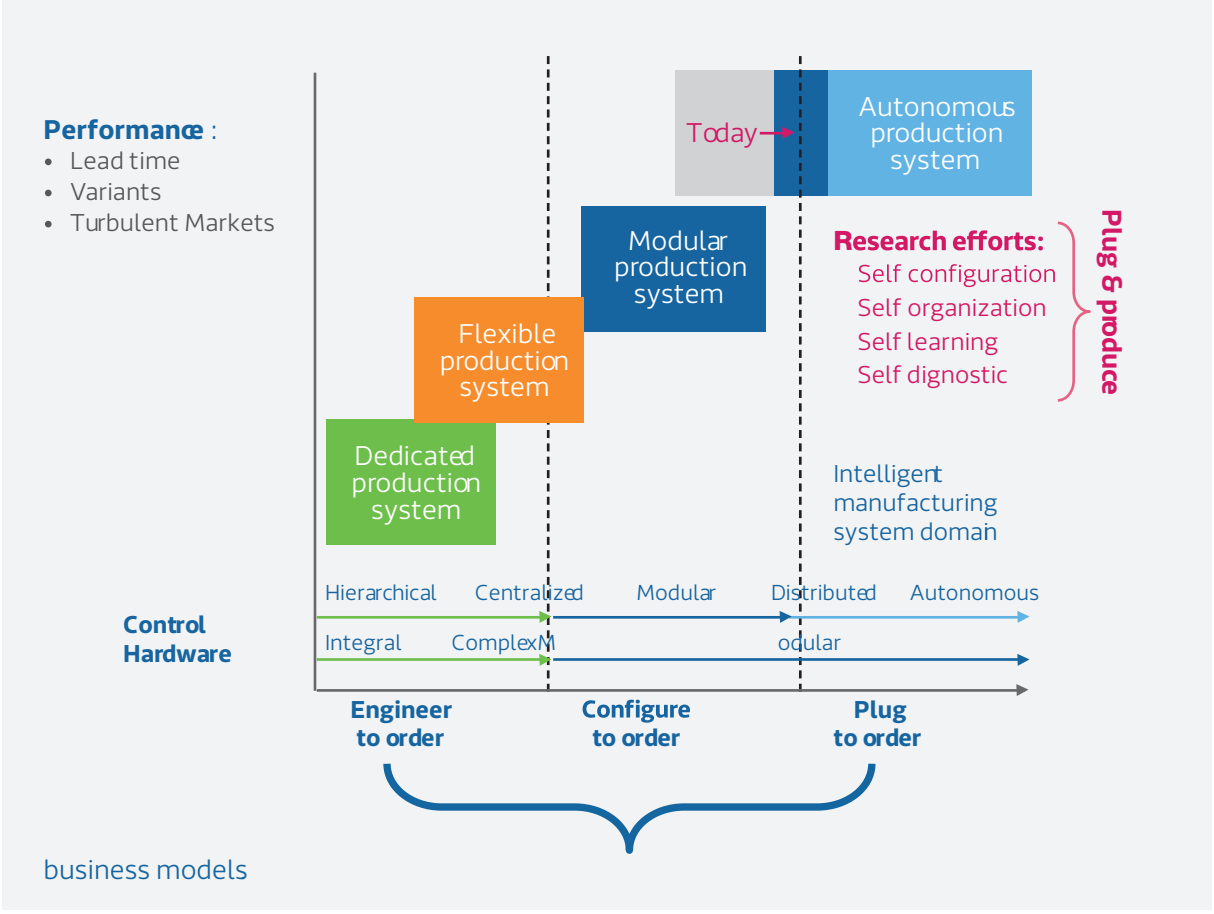
But regardless of technological developments, the creation of a production system requires intensive, in-depth analysis of the product in question, coupled with a step-by-step guide for how to integrate each production phase and create a continuous process. Getting from a dedicated production line, which is also often referred to as Engineer to Order (ETO), to an autonomous setup, requires a series of steps.

Each system can be viewed as a prototype built around a specific problem in the production of a given product. By adopting modular structures for hardware and control that are computer- aided, the foundation is laid for a shift from the traditional ETO system to a more efficient Configure to Order (CTO) system. CTO is an

approach based on fast, guided integration of predefined blocks of hardware and software. Customisation of the product is delayed until the last step of development.

Taking the approach a step further, by combining the modular approach with artificial intelligence, a production system can be achieved that solves problems and carries out tasks autonomously, resulting in Plug to Order production. A simple analogy in describing this development is how the personal computer has evolved over the past decade. The installation of driver software no longer requires human input – our devices are plug and play.

In the figure below, the path to automation has been plotted in a two dimensional chart. The vertical axis indicates performance levels while the horizontal axis distinguishes each concept, from the hierarchical ETO approach to an intermediary stage of modularisation, towards a final automated production system. The two lower horizontal axes represent the evolution of control and the parallel development of hardware.



From coopetition to innovation

Regardless of whether manufacturing companies are offering a product or service or both, they have a common mission: to enhance the lives of potential customers. The word “intelligence” is frequently used today in discussions about the latest innovations in robotics or computer engineering. The concept of the so-called “smart factory” of the future is taking hold and materialising.

While it is essential, science and technology is not the be all and end all factor. Management and business strategies are equally important and, here, the process of enlightenment needs to be speeded up. Organisational innovation must go hand-in-hand with technological innovation. Adjusting and optimising production capacities to meet local and global demands is an unavoidable necessity, but it can only happen given the right pre-conditions.

One of the main issues today is a lack of understanding for the production process itself. Expanding the knowledge base during the product lifecycle is a building block for future success as this will determine whether product designs, eco-sustainability, maintenance, supply chain management and the processes themselves can be optimised.

When Porsche was faced with the dilemma of not being able to ramp up the production of its 911 model fast enough in the mid-1990s, to meet a growing number of customer orders, process knowledge was identified as the main error factor. Most of the operators who had assembled the electrics harness system had retired, and the younger generation did not know how to fit these into the cars. It was a costly lesson: process knowledge had disappeared with the operators which required a complete re-design of the electrics.

The coopetition effect

The principle of “coopetition”, a concept that was launched in the 1990s*, is a method for bringing together companies with common interests to cooperate in order to attain a higher-value production. Recently, this method has proven to be very successful in helping to break new ground and to form solid working relationships that help companies to co-evolve in any given market sector. The coopetition effect is coming into full swing.

A shining example of coopetition at work was observed in Japan after the devastating tsunami. Despite the widespread destruction,

the majority of all larger companies in the area were up and running again within a week, delivering goods and services to tragedy- stricken inhabitants. Entire highway sections had been re-built and airlines were operating within days. All “coopetitors” came together to assist the end customers.

There are many other examples of the advantages of cross-border collaboration. In the next few years, the pulp and paper industry is expected to transition and become a fibre-producing industry. As more and more companies adopt a mono-material approach (100 per cent recyclable), this will create important opportunities in packaging, textiles, building materials, construction and retrieval and other adjacent industries. As such, the future scenario is that one industry’s waste product will become another industry’s raw material.

The next frontier: additive manufacturing

Minimising waste in the production cycle makes as much sense for business as it does for the environment. Adopting ecologically- geared processes will become a matter of competitiveness in the years ahead and a wide range of new approaches are now being tested and refined.

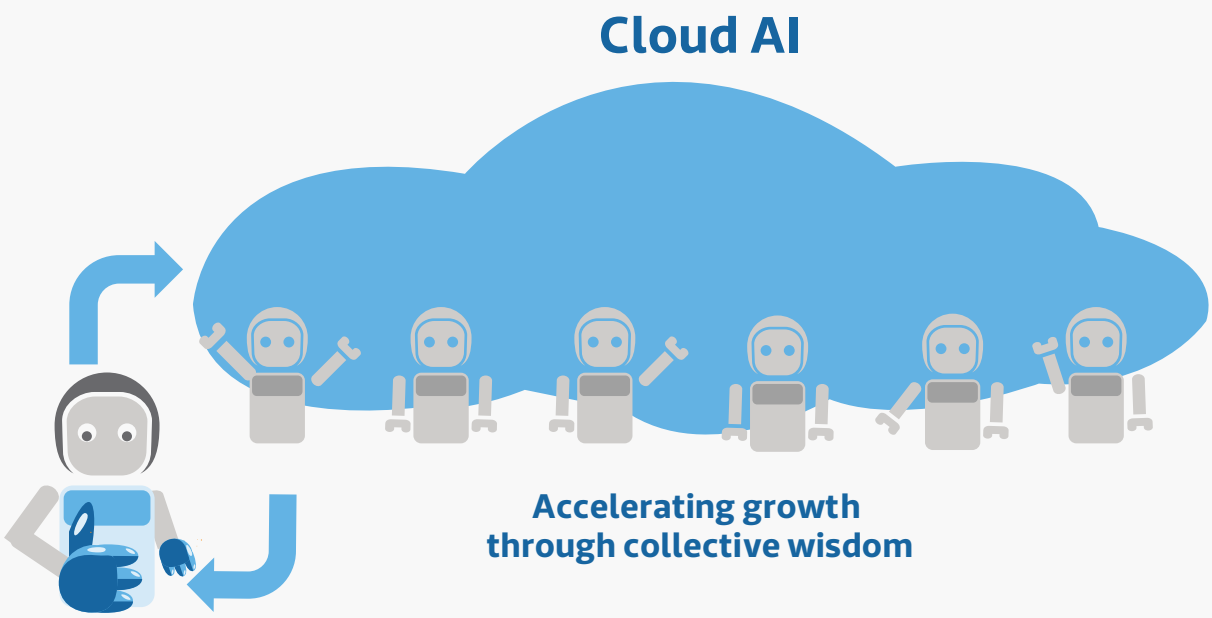
These include “additive manufacturing”, which involves 3D printing and water jet machining, a technique whereby a variety of materials can be cut using a high-pressure jet of water. Many more generative approaches are under development involving, for example, textile material created from biomass.

Extending the use of known materials is a growing focus area internationally. In the UK, the government has singled out a number of urgent research areas in order to foster new processes and has provided financing for large industrial technology centres. One example is the Manufacturing Technology Centre in Coventry, a 1200 sq m facility featuring a wide range of cutting-edge machinery.

Here, research is carried out on everything from robotics and 3D printing to intelligent automation and advanced metrology. Using real life cases in collaboration with companies such as Airbus, Rolls Royce and Jaguar, the centre is an important learning ground for the next generation of engineers and technicians who will fill the current skills gap in manufacturing.

The key driver behind these new manufacturing processes is both ecological and economical:

Manufacturing Technology Centre in Coventry, United Kingdom



components will be built and processes maintained by growing material layer-by-layer, rather than removing material which becomes waste.

Cloud manufacturing

With the rapid evolution of information technology, ways of thinking and conducting business in manufacturing have changed fundamentally. In order to cope with rising volumes of data and fast-changing customer demands, decision makers need to have constant access to the very latest data and reports from factory floors and other key sources. If applications and communications tools are lacking in any way, business will be affected.

Consequently, more and more companies are recognising the clear advantages of adopting a cloud-based platform as an integrated information portal, accessible at any time, from any location. A recent development in cloud computing is the growing popularity of the

pay-as-you-go model, not unlike many of the

streaming services in the entertainment industry that consumers have become accustomed

to including Netflix and Spotify. For small and medium-sized companies, the pay-as-you-go principle has opened up a new horizon thanks to cost predictability. But even large companies have begun to transition from old systems to cloud platforms with flexible payment models, thereby abandoning their resource-heavy systems, infrastructures and licenses.

By adopting these cloud-based platforms, small and medium-sized companies (SMEs) can minimise risk and exposure by sharing costs for features such as “Simulation as a Service”, ”Test as a Service” or “Optimization as a Service” in the cloud. Other advantages include:

- **Consistency in planning, control, and decision making**
- **A heterogeneous computer environment**
- **Mobile services**
- **Cloud-based manufacturing networks/ communities**

The metrology equation

In addition to changing patterns shaping our new society, where cars are shared and paper is used as a building material, increased quality will become a main requirement. Products will need to have a considerably longer lifespan and materials will need to be totally recyclable.

For this reason, manufacturers need to become greater experts than they are today. Knowledge about products, their longevity and the materials used will need to improve. Furthermore, materials will have to have certain characteristics which, in turn, affects measurement procedures, or metrology, for capturing product shape on a macro, micro and nano-level.

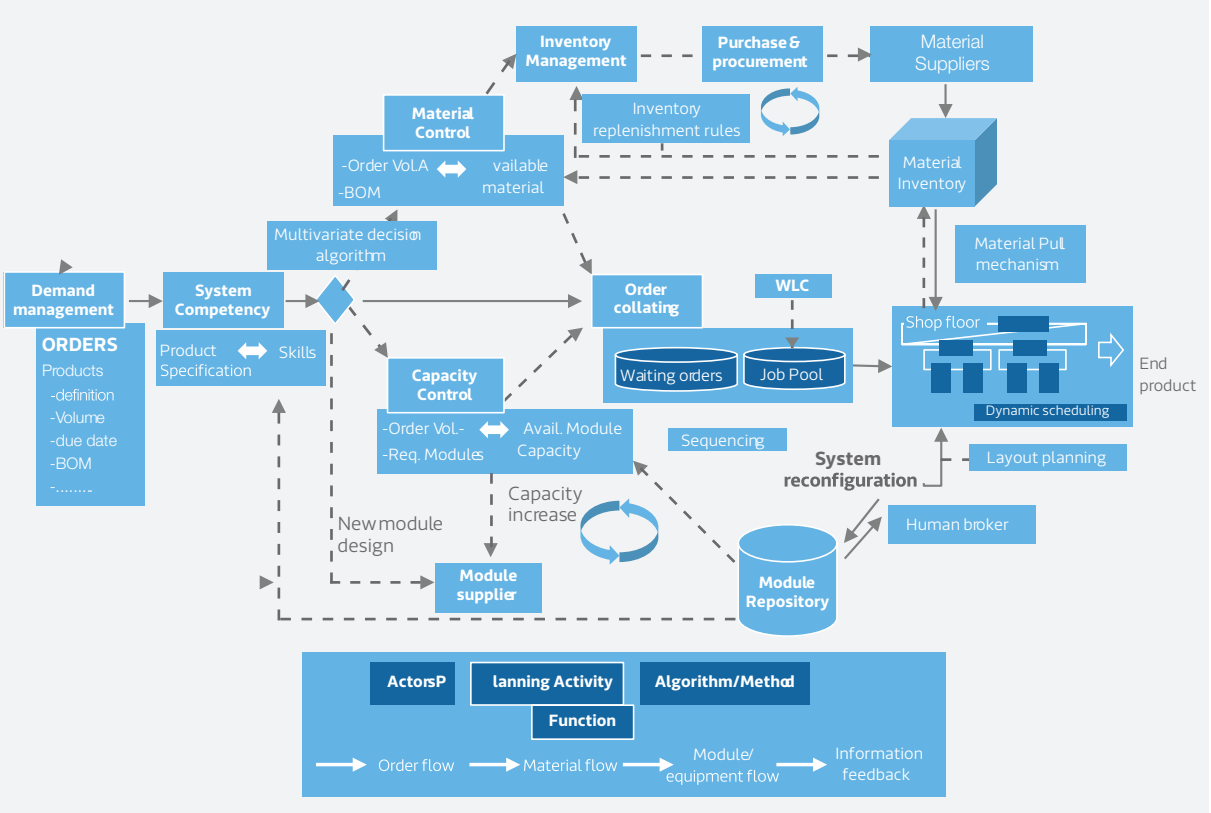
The most promising research in production metrology is the development of in-line metrology methods and tools that are combined with strategic measurement planning. The latter is a key-factor in order to reduce costs in the assembly process due to poor quality, which may result savings as high as 40 per cent on the total production cost. The in-line metrology process needs to be automated and be made as cost effective as possible.

Using metrology to its fullest potential is a vital step for closing the loop in the production chain and should ideally go hand-in-hand with the development of new production methods. By delivering instant feedback from the entire production line, high speed metrology prevents errors from occurring in the various processes, which unlocks the possibility of achieving 100 per cent yield and zero downtime.

In the near future, metrology will also provide sensor data that captures all machine information and monitors the products from creation to re-cycling, to mention a couple of its important features.

Adaptive scheduling

“Just in Time” is a manufacturing principle that has been around for many years, but few companies can pride themselves on having realised the concept. A tool that could potentially change all this is the Demand Responsive Planning (DRP) system which provides a fast



Demand Responsive Planning architecture.

route to workload control by systemizings the flow of activities.

By introducing DRP, manufacturers can make changes to their production sequences instantly – which is real Just in Time, and apply adaptive planning in resources and materials. This will have a revolutionary impact and provides an easy to route to optimising the following:

- Remote monitoring and control
- Dynamic feature modelling (interpretation)
- Adaptive and distributed process planning
- Configuration-free machine and robot control
- Remote machining and remote assembly
- Energy modelling for machining and assembly
- Cost and manufacturability evaluations

In the new dynamic manufacturing environment, unpredictability becomes a major concern. Frequent changes of machining processes for prototypes, rush orders and other unpredicted events make the conditions even tougher. In addition, the fact that many machine tools can produce several parts simultaneously only ads to the complexity in terms of scheduling.

With these fluctuations in customer orders and unpredictable production requirements, a new reality has presented itself. Current software and hardware at many large corporations have come to end of their life and a complete overhaul of computer systems is needed to safeguard the flexible software tools that are needed for adequate customer response.

Bridging the gap

Imagine a production system that can be reconfigured and set up to produce a completely different product range within a matter of hours or even minutes, using machinery that is leased or rented instead of purchased.

This future scenario is only just around the corner. But some companies will adapt faster than others. It is an unmistakable fact that today's computer systems are out of date. Most of them are based on the Programmable Logic Controller (PLC) architecture which was developed in the 1960s, which cannot bride the gap when it comes to meeting current customer requirements.

Controls systems now have to present a variety of solutions to specific manufacturing challenges where adaptable configuration, flexible scheduling, remanufacturing of components and exploitation of data are all part of the equation. This modern architecture is an open system where new equipment can be easily and rapidly incorporated. This provides the following benefits, to mention a few:

- Shorter lead times for installation and setup
- Lower investment costs and minimised risk
- Simple reconfigurations of original layout
- A second-hand market for equipment

The principle of distributed control, meaning that each equipment unit controls itself, is adhered to more and more and companies are adopting advanced communication protocols to enable this technology. Like most innovation, however, it has been a gradual build-up which is illustrated by Ford's approach toward production ramp up.

When one of the largest specialists in systems integration in Europe was given the task of integrating the Ford Transit assembly line in Valencia, Spain, hundreds of robots and transfer gates had to be synchronised. This was needed in order to enable a number of variants of the vehicle in the assembly line. Due to the complexity of the task and the limitations of conventional PLC-based programs, Ford couldn't exploit the full versatility of the vehicle design.

To solve this problem, the integration specialist added an extra software layer on the PLC system that communicated with all assembly cells and thereby exploited the data produced at each "node". Using advanced software (multi- agent, distributed approach), this enabled Ford to assemble all the potential vehicle variants. The project resulted in one of the very first distributed control applications in industry and it was a huge success for Ford.

While other sectors have for a while been discarding old PLCs and mainframe computers from the 60s and 70s, adopting responsive and adaptable systems instead, the manufacturing industry has been lagging behind. Several energy companies, the military and the stock

market, which was one of the drivers, have made the transition and it is now time for manufacturers to heed the call or risk losing their position in the value chain.

Total connectivity

Creating the conditions for total connectivity – incorporating customer requirements, design, production and distribution – will be a key challenge over the next few years. A familiar problem for manufacturers is that product design departments are not integrated enough and knowledgeable about developments on the factory floor. This lack of communication, which is often due to poor documentation and data transfer protocol issues, needs to be addressed.

To make a modern production system work efficiently, all data related to a product needs to be collected and analysed at every step, and then channeled to the right user. A typical example of human error is when process details regarding specific materials, tools or components never actually reach the product designer. It is therefore imperative that information flows equally in both directions.

Several companies have given high priority to this issue including Sony. In the late 1980s, Sony was facing huge competition from Chinese companies that copied their products. In an unprecedented move, they decided to design a product that could only be assembled by robots (miniaturised). This led to the creation of the Sony Smart system which led to both HandyCams and Walkmans being built using automation cells, which became a gamechanger in personal electronics.

Robots are being used in production.

Potential obstacles to progress

Europe is predominantly driven by its industry, and any downturn in this sector influences its welfare society. Manufacturing is a major socioeconomic force and, as such, disregarding its needs would be catastrophic.

So what are the greatest obstacles to progress in the years ahead? To begin with, more companies need to come to terms with the current transitional period and begin the process of modernising not just their systems and business models but also their mindset and business outlook.

Understanding the importance of digitalisation and what it means for each company is the best way of getting onboard and making the journey a fundamental part of business strategy. Looking at the need for transformation from a larger perspective, it is clear that environmental, economic and social challenges need to be overcome in order to create an optimal business environment.

Natural resources

The availability of natural resources and environmental issues will continue to be a major concern. In the U.S, for example, the demand for oil continues to be far greater than domestic production which means that approximately 75 per cent of its oil is imported. Economic booms in China, Brazil and India have resulted in increased oil consumption. This has led to the conclusion that not only is oil bad for the environment but it will not be available for much longer.

The global carbon footprint from a U.S. perspective

By all accounts, oil will be phased out and replaced. It is a question of time and how to meet energy demands in the transitional period to renewable sources. Another obstacle is the safeguarding of the world's clean water supply. Water consumption has reached an alarming rate which is demonstrated by the fact that large rivers such as the Colorado River in the U.S. and the Yangtze River in China are now less than half full compared with their previous normal levels.

In addition to determining the standard of living for the world's population, the availability of water is crucial for industries. But without responsible water management and rapid innovation, severe changes to both climate, business and life expectancy will come into effect.

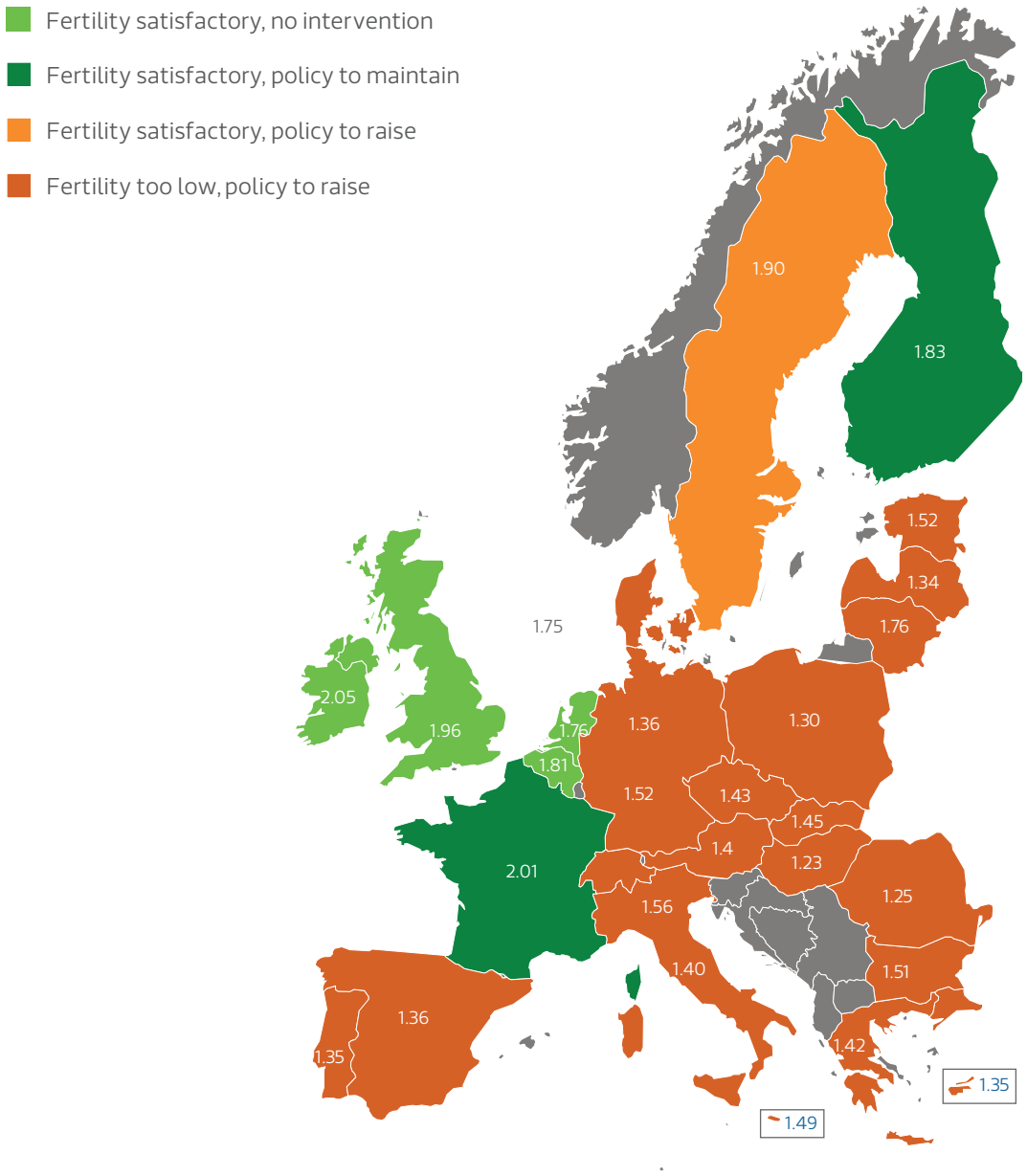
A number of concepts for a more sustainable approach have been presented over the years: Carbon Footprinting, Ecological Economics, The Natural Step, Industrial Ecology, Natural Capitalism, and the list goes on. Oil has been the single largest driver of our current standards of living. But the message now is clear: we have to change and move forward. Irrespective of the environment, Worldwatch points out that our resources are running out.

	Well Managed	A challenge	Urgent need of Attention
Water	• Local water pollution in certain OECD countries	• Surface water quality and wastewater management	• Water scarcity • Ground water quality • Agricultural water use & pollution
Air quality	• OECD countries SO2 & Nox emissions	• PM & ground-level ozone • road transport emissions	• Urban air quality
Dependence on oil	• Average on OECD countries	• Urgent need to modify usage patterns	• Policy/regulatory needs to curb usage
Biodiversity	• Forested areas in OECD countries	• Forest management • Area protection	• Ecosystem quality • Species loss • invasive species • tropical forests • coral reefs
Wash & Chemicals	• Waste management • CFC emissions in OECD countries	• Devoloping countries CFC emissions • Local waste management	• Hazardous waste transportation • chemicals in the environment
Climate change		• Declining GHG emission per unit of GDP	• Global GHG emissions • climate charge in progress

The OECD Environmental Outlook to 2030

Demography

Already a powerful political issue, demography has become a gamechanger if not a major driver of change. The rapid decline in labor forces and resulting narrowing of the skill base is an alarming issue and, to a large extent, a result of the outsourcing trend of the early 2000's. The steady birth decline in Europe will inevitably lead to a lack of available workforces. Basically, Europe is in danger of becoming a minority continent with decreasing demographic power. At the same time, it has the most rapidly growing group of retired people, which results in a troubling equation: decreasing workforces, decreasing tax revenues and increasing support costs. New services and products will be required, but where they will be developed and manufactured is very uncertain.



Fertility rates as of 2008

New regulations

The drive towards sustainability is not just about appealing to the conscience and good will of corporate leaders, and plain business sense, but is a case of adhering to regulations that have become stricter than ever.

The EU is constantly monitoring the ecological impact of new and old technologies, and is observing how these are influencing economy, society, globalisation and trade agreements. The good news here is that the EU has mechanisms to stipulate and enforce standardisation which

is beneficial to industry. However, it is also true that most European companies are compelled to abide by regulations while competitors in many emerging markets do not have that responsibility. This is an unbalanced approach which has a negative impact on all sectors of industry.

In the long-term perspective, these regulations will bring about new services, a reduced environmental impact and improved control of potential negative effects of new technology.

If politicians resort to the short-term solutions, they may cause the fall of many European companies: what is needed is long-term support for small and medium sized companies (SMEs).

Management culture

In the early 1900's, the majority of all manufacturing companies were formed and managed by engineers. This has dramatically changed since the 1980's when a business- focused community of economists and analysts came to power.

According to a large panel of experts, this development is undermining the long-term technological sustainability of companies. While history is full of countless examples of successful businesses that have had a

low adoption rate for new technologies, this approach will be difficult to maintain going forward. In short, being an outsider comes with large risk and it is increasingly clear that companies that have adopted an action plan for digitalisation are far more successful in formulating a long-term strategy.

Being inferior when it comes to technology also has a major bearing on the ability to capitalise on innovation. The exception to this conclusion is South East Asia where many companies have made sure to keep engineers in top-level management. Having said that, there is an argument to be made for taking a balanced

approach that incorporates professionals from a variety of backgrounds.

Ethics are an important aspect of management culture and refer to the rules, principles and codes of conduct that exist within a commercial context. They also assist in highlighting the direct link between decisions taken at corporate level and how the wider society is impacted by these decisions. Three main ethical topics are often raised:

- Ethics of internal reward schemes
- Demands on ethics posed by globalisation
- The sociological impact

Understanding the interdependence of ethics and successful business is a trademark of past success in European history. Globalisation is causing some people to fear the arrival of a "new global order" that disturbs the status quo.

Regardless, it is a fact that European industry, and not least Scandinavian companies, must become adaptable to whatever scenario that may arise. This depends almost exclusively on the control and IT systems that are adopted – and on the choice of whether or not to have the ability to take advantage of data and sensoring technology, and to reap the rewards.

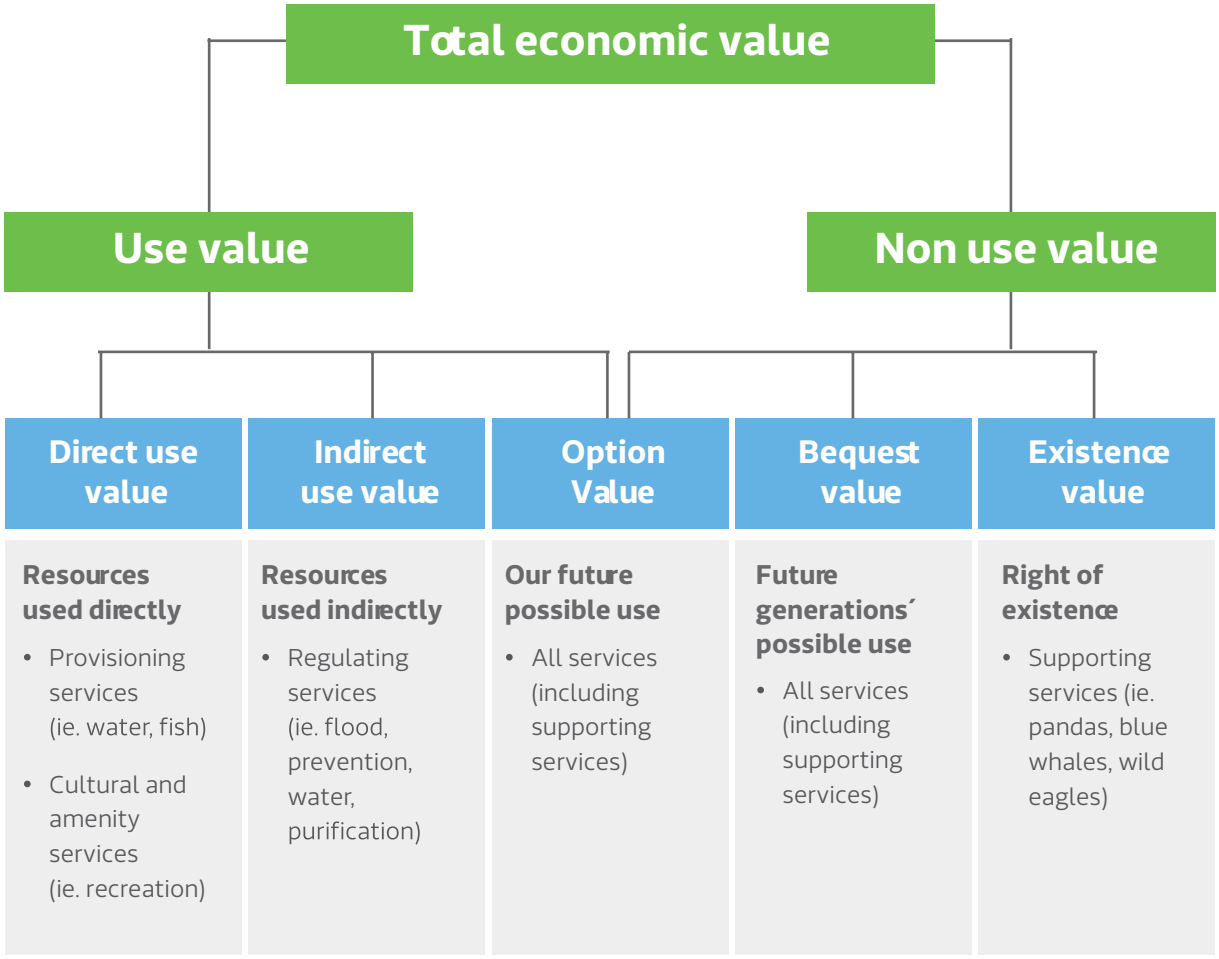
Toward a circular economy

The linear approach to consumption that has dominated the past century – make and dispose – is not sustainable in the long term. Change is possible here and now. Awareness is increasing and manufacturers have every opportunity to re-think their business models and contribute to increasing efficiency, predictability and prosperity.

By contrast to the old linear system established by human beings a long time ago, the biological system follows a cyclical model which continues to work. Why is the cyclical model destined to attract a mass-following in the years ahead? Simply because the pros far outweigh the cons. In fact, evidence is pointing to the notion that most companies will be more successful by adopting cyclical processes.

When following this route and new way of thinking, the re-designed materials, products, components and packaging of the future will not only help to create different products after usage, but also build more capital and value.

Although many manufactured goods including refrigerators and washing machines do not bio-degrade, metals, alloys, plastics and resins can all be recycled and become useful in a new context. What is more, the technological means now exist to create and distribute these products, and keep the cycle turning in a closed loop using renewable energy.

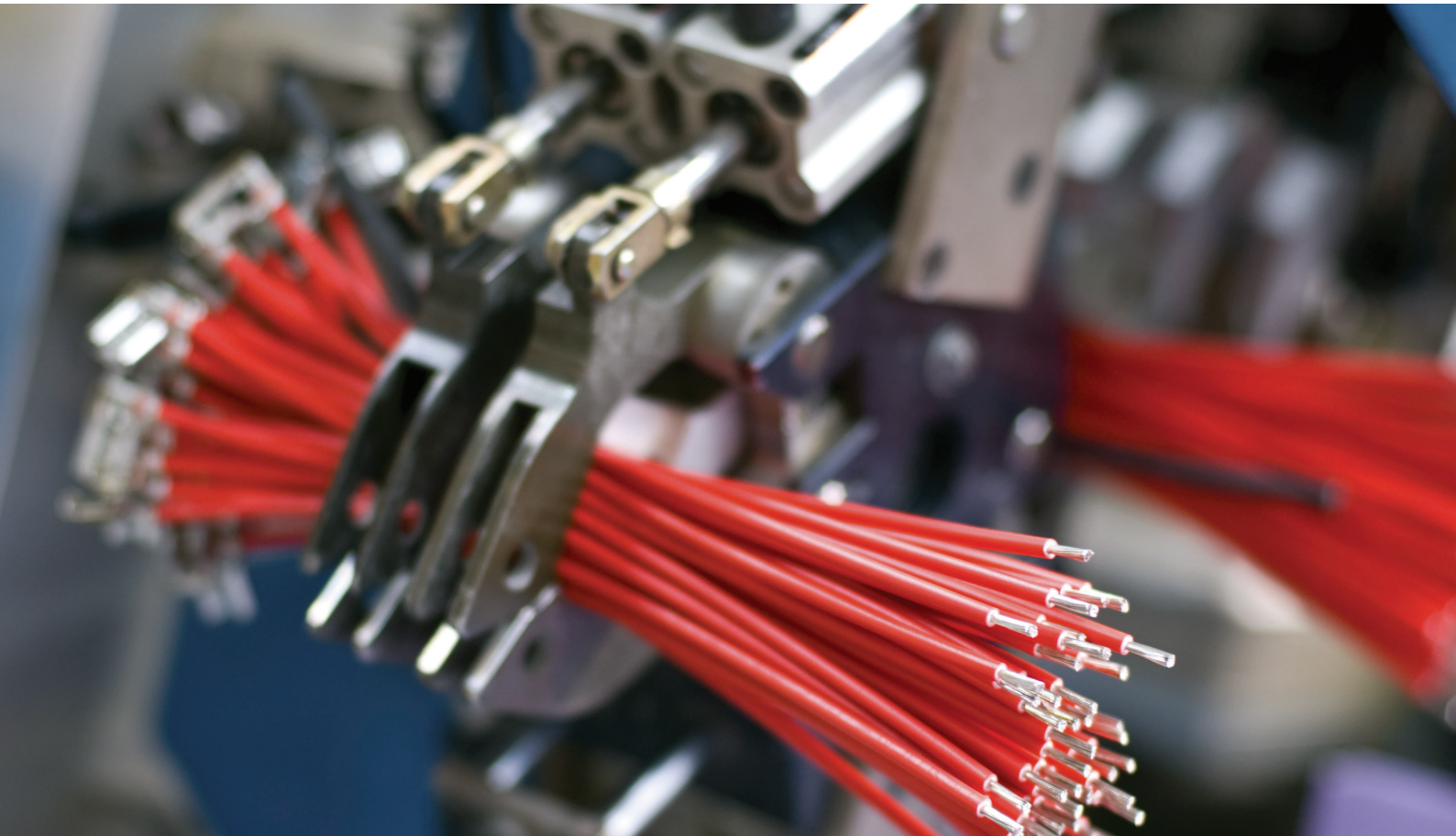


Eliminating waste is the principal aim of the new economic cycle

Connectivity and adaptable systems that bring together machines, analytics and people in new ways will play a crucial role in the development. Using Industrial Internet solutions, software will open up barriers and help to achieve the following:

- Re-usable machines and industrial equipment
- Intelligent machines that can adapt to new product ranges
- Proactive maintenance and support via the Cloud
- Enhanced interaction between customers and producers
- The integrated factory

Perhaps of even greater importance than the arrival of the Internet itself, the new approach to computer software is the engine that is making the technological cogwheel turn at a faster pace. Although computer systems used to be event-driven, the focus is now on distributed solutions that follow behaviours (attributes). This enables self-contained and re-usable modules to be created for control, supervision and service.



Birth of the digital factory

Over the past two decades, technological advancements have made it possible to create an environment where distributed manufacturing, or decentralised operations, can be applied with relative ease.

Using cloud computing, the cyber workspace is opened up to daily collaboration from any location. Manufacturing machinery can be controlled and monitored remotely and rescue operations can be launched at a moment's notice. Today's cloud technologies provide people and machines at every level of the factory operations with vast data resources.

How did this all begin? A key milestone on the path to digitalisation and Big Data exploitation was the arrival of so called "cyber-physical systems" (CPS), a term that was launched in the U.S. in 2006. This was when a growing body of experts began to recognise the rising importance of improving interaction between interconnected computing systems and the physical world.

From this point and onwards, embedded computers and networks began to monitor and control physical processes on a large scale with a feedback loop. This meant that new capabilities could be added to physical systems in an automated process.

Although a large number of manufacturers are well-versed when it comes to incorporating the latest technologies in production processes, they often lag behind compared with other industry sectors when it comes to analysing data in useful ways with maximised efficiency.

Digitalisation: a quantum leap

Today, CPS systems range from small devices, for example a pacemaker, to huge networks such as national power grids. The increased connectivity and capabilities of computers, which has largely been driven by the consumer market, has meant that man and technology have together made a quantum leap.

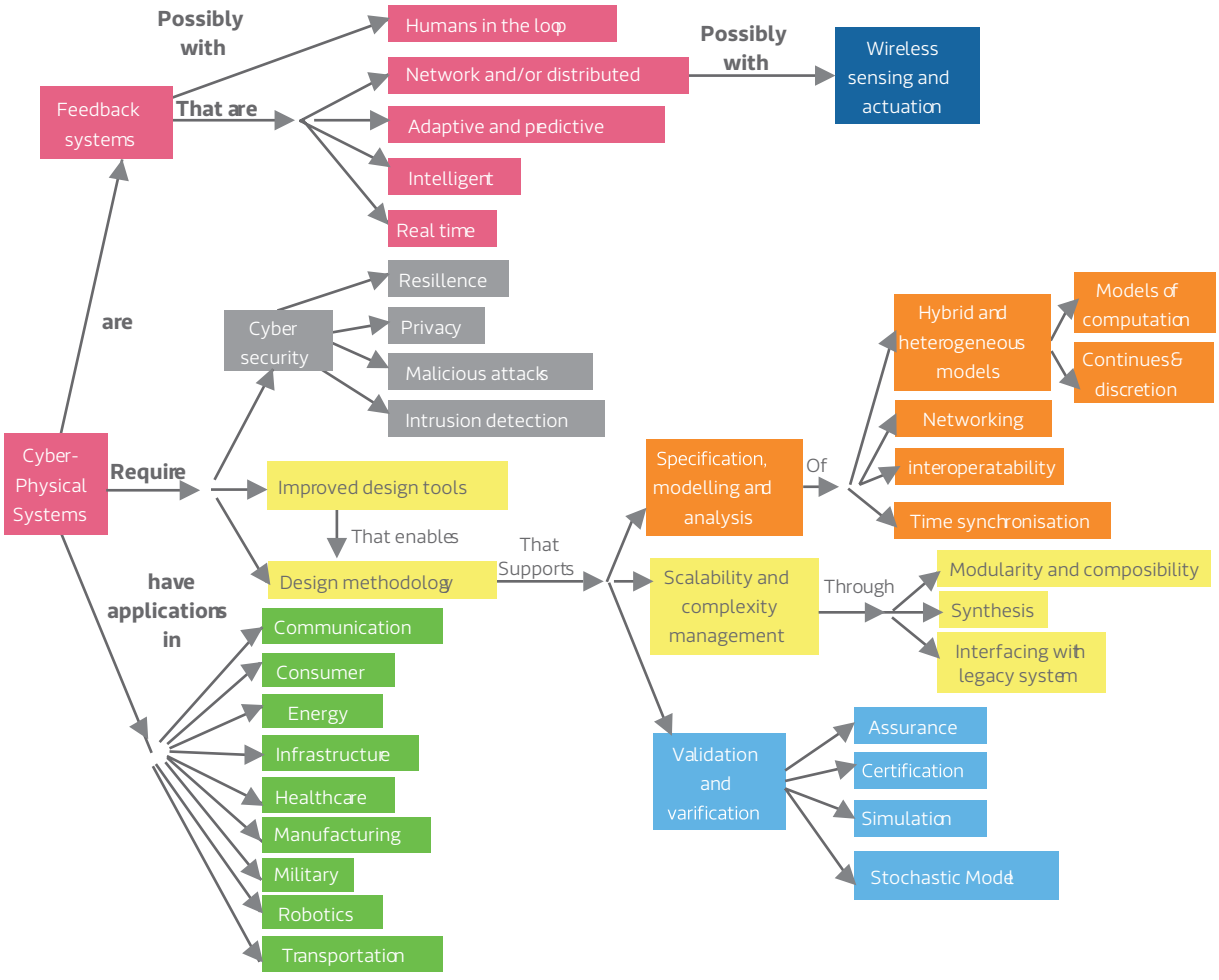
In just over a decade, a connected society has begun to take shape and new software has emerged that enables manufacturers to boost every aspect of their operations. The

Industrial Internet, the Internet of Things (IoT), Cloud, Big Data, Smart Data, Internet 4.0 – all of these concepts incorporate the same notion: that doing business, providing services or churning out products is now a different world altogether. Thanks to early development of CPS followed by sensoring technology and advanced communication protocols, growth has been facilitated and with long term sustainability in mind.

Integration is the key word for manufacturers as this will enable all levels of production to exchange information, which can only be facilitated by CPS. Typical processes where data flows continuously includes parts development, assembly, packaging, quality control and transport.

Digitalisation is unlocking new manufacturing technologies and giving rise to a vast exchange of data. The IT revolution has reached the factory floors and it is up to corporate management whether to embrace it or not. What is the pay-off, you might ask? Being able to handle both mass-production and customised orders in one and the same production facility is just one of many advantages. Reducing energy consumption by up to 50 per cent is yet another.

Using robotics, sensors, motion detection, camera images, accelerometers, thermometers, vibration meters and other tools, factories can also be controlled from any location. And tablets and smartphones, which are expected to have more than 2.6 billion users by 2017, are playing an increasingly important role in making industrial processes accessible at all times.



A concept map of CPS.

Fourth industrial revolution

From the steam engine and the first assembly line to electronics and robotics, we are now entering a fourth era of revolutionary manufacturing. Today, it is completely focused on the Industrial Internet and the evolution of the fully connected "smart factory" or "digital factory" where production has multiplied efficiency and is adaptable to changing customer requirements.

Global industries are becoming more service oriented in their structure and new business models are emerging that are geared towards meeting the needs of an "on-demand economy". Technology is the key enabler as it is now possible to monitor customer behaviour, design personalised products, introduce standardised models and simulate the production process so that investments are not jeopardised in real life assembly lines.

Innovations in connectivity, big data, analytics and machine learning are creating a new industrial paradigm with endless opportunities. A simple example is the preventive maintenance concept which, by applying data analytics and modern software, is well on its way to eliminate machine downtime due to wear and tear. This is resulting in huge cost savings and improved competitiveness.

Automation systems are also helping to ensure increased safety and productivity. The role of human labour has been thrown into question as intelligent machines take over many repetitive tasks. The social challenge is perhaps the largest unsolved dilemma. However, today's indications are that new jobs will be available in fields that require human intuition and the ability to draw conclusions. Reforming the educational system and training programmes to match these future positions will be crucial.

Bringing it all together

In the digital factory of the near future, of which there are several working examples in continental Europe, control systems will be embedded within machines or in separate hardware and connected to a large number of sensors via Device Integration Points (DIP) using a variety of communication protocols.

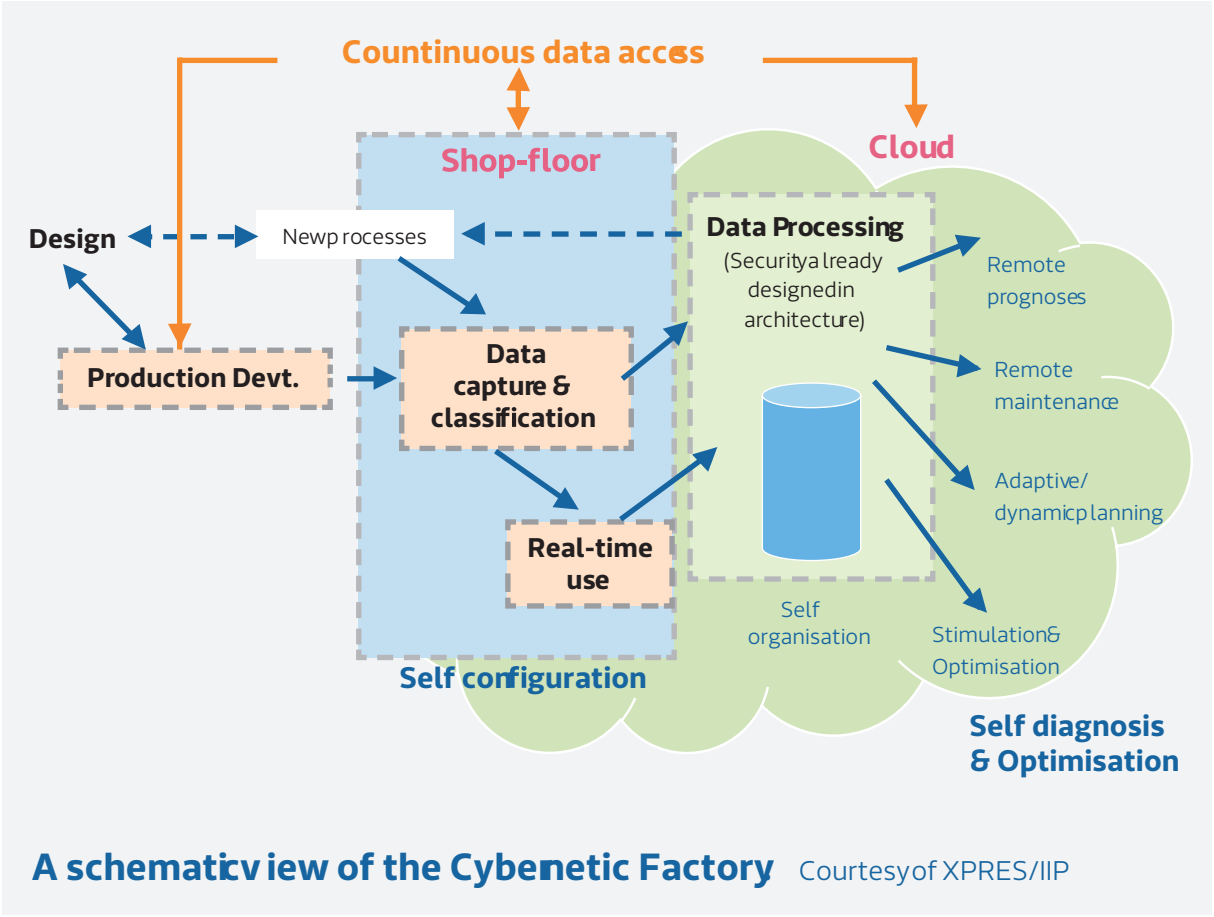
Connecting physical objects, devices, machines, vehicles and other items – everything from coffee machines to fuel depots, drill rigs and industrial cranes – in order to collect and analyse relevant data is the basic premise behind the Internet of Things (IoT). More and more manufacturers will need to offer these possibilities, not just to optimise production, but also to meet customer demands for real-time information and fast deliveries.

In its ongoing research, the Swedish Royal Institute of Technology (KTH) has developed a blueprint for the "cybernetic factory". It demonstrates how computer modules will be self-configured in factory floor operations and, for the future, this will involve a virtually non- existent setup time for equipment. As data is delivered to operators, decisions can be taken instantly, remote control means that changes can be made in real-time and production sequences can be automatically updated.

Cloud functionality will also play an instrumental role in the next few years. Using interface standards such as ROS Industrial, remote operations, maintenance and diagnostics, updated order scheme and the real-time optimisation of running processes are all unlocked. Platforms can be connected to mobile apps that enable on-site personnel to receive instructions and communicate with supervisors who may be located hundreds of miles away.

Cloud technologies not only enhance the industry community by integrating IT solutions, but also bridge the gap between customers and companies.

In a world where physical products are combined with software and sold as holistic solutions, the complexity of manufacturing is also destined to increase. Both manufactures and customers face the challenge of updating their knowledge about different versions of software and machinery, and how these solutions can help them reach new levels of efficiency in their operations.



A schematicv iew of the Cybernetic Factory Courtesyof XPRES/IIP

The age of transformation

Smart factories, coopetition, prosumers and the circular economy. Industry is moving in a direction that will require radical change to become an integral part of business strategy over the next few years.

As we have learned in this report, there are multiple drivers behind the new industrial paradigm – which is just around the corner. Sustainability, adaptable products and deliveries, increased speed to market and total transparency, these are just a few of the ingredients that are shaping a new path to competitiveness.

The manufacturing industry is moving in a clear direction. And the sooner that manufacturers get onboard with the transition to flexible systems, new materials and adaptable delivery models, the greater their chances are of staying relevant to their customers in Scandinavia and beyond. This will require new organisational leadership.

"This report provides an accurate reflection of the challenges and opportunities facing manufacturers today," says Per Håkansson, Customer Executive, TietoEVRY. "In terms of digitalisation, companies in process and discrete manufacturing need to act quickly to catch up with other business sectors such as telecom and retail. While this can be done in a relatively short timespan, the goals and visions must be clearly defined."

Tomorrow's society will be represented by tomorrow's consumers living in a world where natural resources and raw materials are not unlimited but increasingly scarce.

Globalisation will continue and markets will become multicultural. The drive toward sustainability will also mean that one company's waste becomes another company's product.

Håkansson continues:

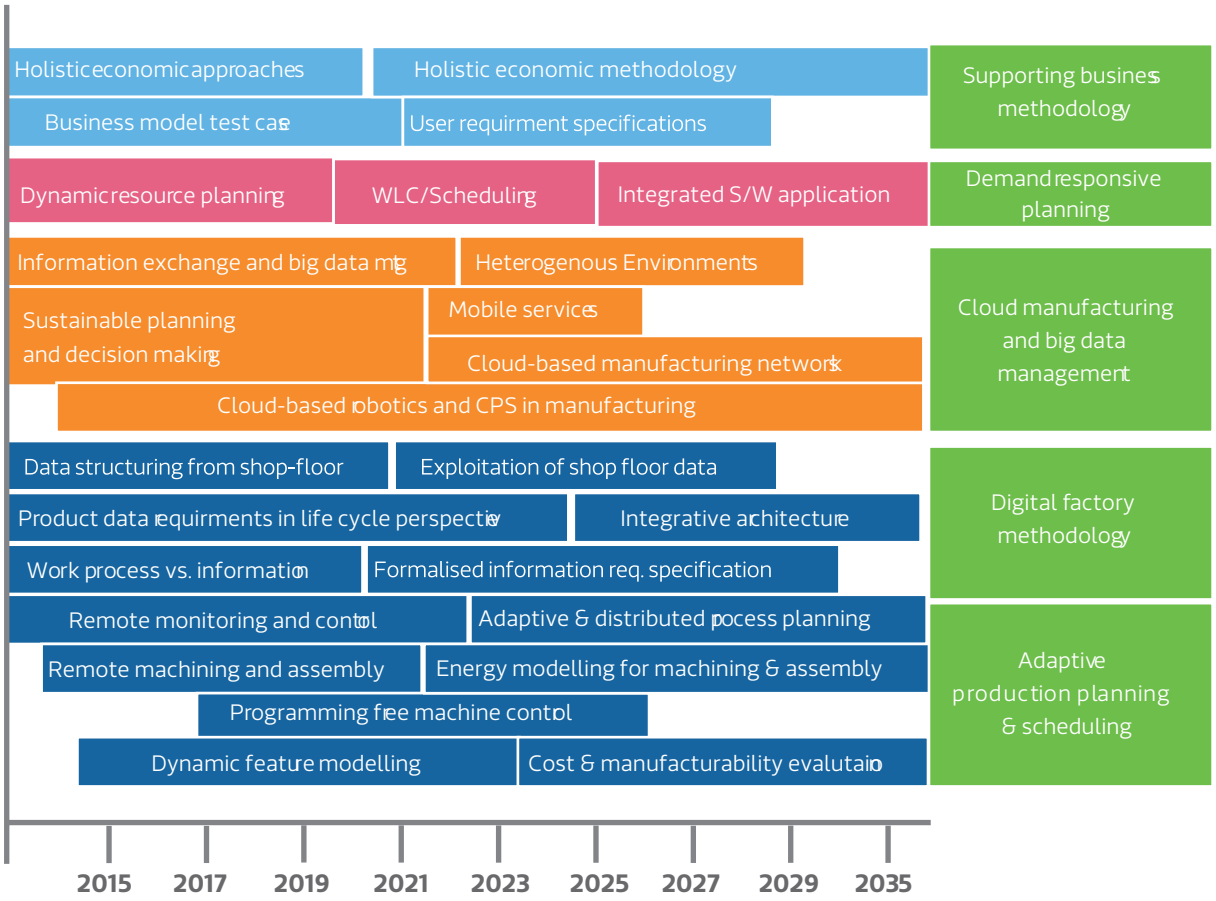
"I believe the most important step is to recognise the need for a new technological foundation in manufacturing. Mainframe systems that run COBOL or similar technology are outdated and simply incapable of meeting these challenges. These systems are also highly vulnerable to hackers and cyber-threats."

In gearing up for the change, a new mindset will need to be adopted. Products, including manufacturing machinery, will most likely be rented, leased and shared and every phase of the production line will involve elements of customisation. A new playing field is taking shape and, according to Håkansson, the efficiency gains offered by modernised ITsystems cannot be overemphasised.

"As more and more companies recognise that replacing legacy systems is not just worthwhile but crucial for survival, manufacturing will enter a new dimension. By implementing modern and scalable systems, manufacturers will gain time-to-market, cost predictability, flexible delivery models, new collaboration tools and the strength to innovate."

He concludes the report's findings:

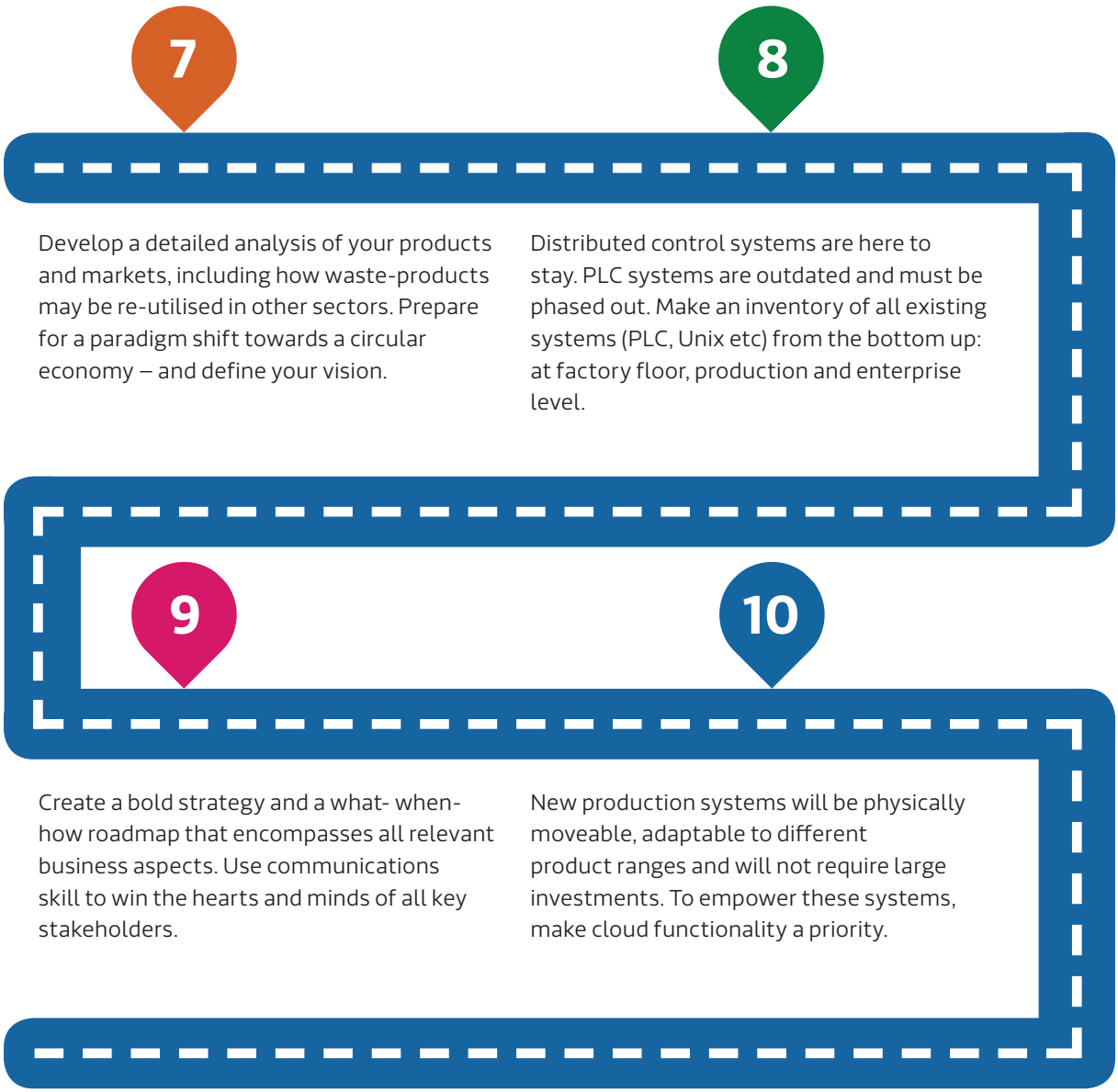
"Digitalisation has to be tackled in one way or another. We are in complete agreement with KTH that now is the time to re-evaluate current IT systems and reconsider our methods of risk analysis. Companies that focus on the advantages of modernisation stand a far better chance of surviving the storm, but also of building a prosperous future."



The requirements of future manufacturing

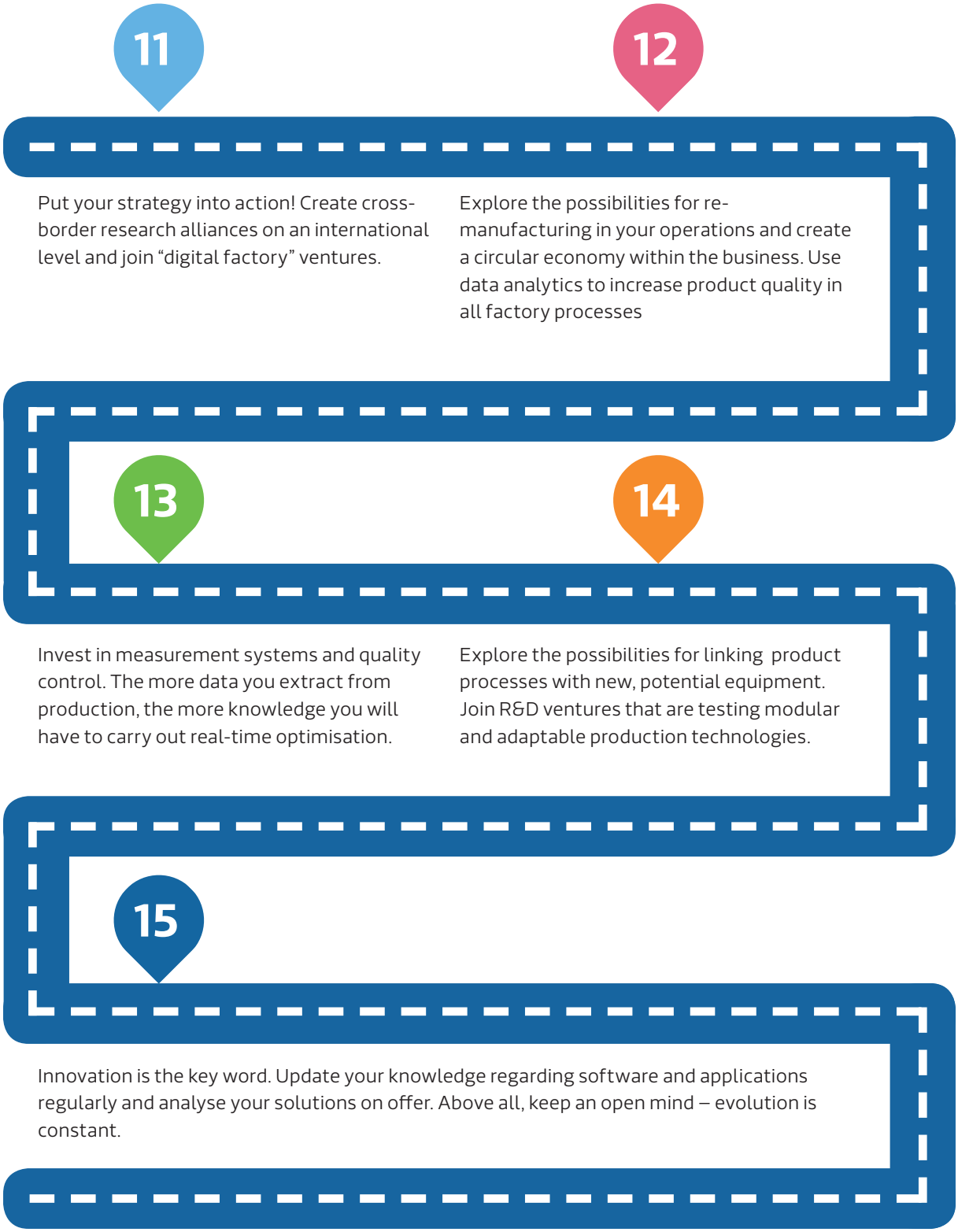
How to get onboard

0-5 year targets


7
8
Develop a detailed analysis of your products and markets, including how waste-products may be re-utilised in other sectors. Prepare for a paradigm shift towards a circular economy – and define your vision.
Distributed control systems are here to stay. PLC systems are outdated and must be phased out. Make an inventory of all existing systems (PLC, Unix etc) from the bottom up: at factory floor, production and enterprise level.
9
10
Create a bold strategy and a what- when- how roadmap that encompasses all relevant business aspects. Use communications skill to win the hearts and minds of all key stakeholders.
New production systems will be physically moveable, adaptable to different product ranges and will not require large investments. To empower these systems, make cloud functionality a priority.

How to get onboard

5-10 year targets



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