UNIT 1

Advanced manufacturing

Companies' mindset and current trends

Sub-Unit 1.2. Current trends: process and product technologies

Co-funded by the Erasmus+ Programme
Project number: **2018-1-ES01-KA202-050289**
This project has been funded with support from the European Commission. This publication reflects the views only of the author.

Contents

Introduction

Industry 4.0, the fourth industrial revolution, is revolutionizing manufacturing by providing manufacturers with the opportunity to utilize advanced manufacturing capabilities and information technology (IT) throughout the product lifecycle. As a result, manufacturers are benefitting from increased visibility into operations, substantial cost savings, faster production times and the ability to provide excellent customer support.

The only way manufacturers can stay ahead of competitors and win market share in today's quickly morphing environment is to embrace change. Those who wish to thrive and not just survive are leveraging the latest in growth-inducing Industry 4.0 technologies.

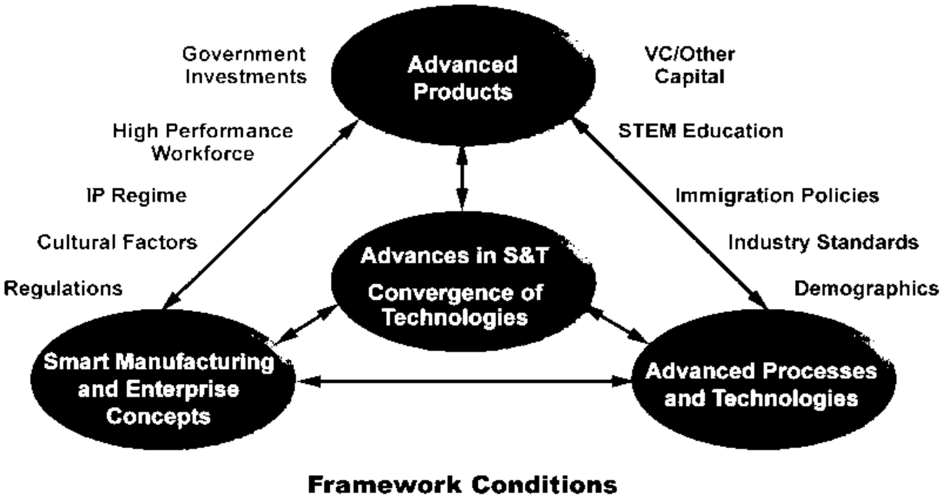

Image 1 – Advanced manufacturing network

1.1 Sub-unit: Process technologies

The worldwide market for automation products and solutions is around £188 billion growing to £500 billion by 2020, around 8% of total ICT expenditures (Pereira 2009). Factory automation is the largest sector of this market at 38%. The European automation market is around £62 billion. Over two-thirds of this market is composed of engineering services (i.e., application design, simulation and modelling, integration, installation, and maintenance), growing at around 10% annually. The potential market for engineering tools, thru-life services and control/service infrastructure is estimated to be over £120 billion globally, and applicable in diverse domains, making it resilient to economic down-turns. This market is predicted to double in 5 years and robust growth is predicted even in the current economic climate.

Although modularity in automation systems hardware is now evident, there is a lack of effective design and lifecycle tools and compatible control system architectures to support the engineering of such systems. This is evident in an inability to retain knowledge about such systems and capture lessons learned. There remains relatively poor integration with business systems. Shop floor systems remain predominantly vendor-specific. These factors limit agility and make the cost of change higher than it should be (Vera et. al. 2009) and that was the main part of Industry 3.0. What is automation?

Automation is the use of control systems and software to independently operate and monitor a mechanised system of industrial processes. In using mechatronics and computers to produce goods, automation may be divided into six categories:

• **Numerical control**, which involves the automation of machine tools through programmed commands. Most numerical control is undertaken via computers, applying computer numerical control (CNC), which manufacture specific products according to input programs.

• **Adaptive control**, which creates a control method with adaptable parameters for changing their response according to the desired model.

• **Material handling**, which involves the movement, storage, control and protection of materials throughout the manufacturing system.

• **Robotics**, which refers to automated machines that may replace the role of people in manufacturing processes.

• **Assembly**, which involves the mechanical act of combining components in manufacturing systems.

• **Flexible fixturing**, which enables machines to hold a variety of fixtures.

Fabrication is a process that involves the manufacturing of an item from materials rather than ready-made components or parts. Types of fabrication include: metal fabrication, which involves the cutting, bending and assembling of metal; and semi-conductor device fabrication, which involves the creation of everyday electrical and electronic devices.

Precision engineering, which refers to engineer's ability to work at considerably finer tolerances than previously achieved by series manufacturing. The outputs of precision engineering are items that differ in terms of size but are similar in terms of the relative accuracy with which they are produced Thus, precision engineering is a powerful technology, without which many high-tech products of a nano-, micro- or macro nature would not be realised.

Flexibility is the continuous re-use of existing infrastructures and processes for handling an array of manufacturing possibilities, thereby saving on the time and cost of implementing alternatives. According to Mandelbaum, flexibility can be categorised into two types:

- Action flexibility, whereby infrastructures and processes act to meet new circumstances.
- State flexibility, whereby infrastructures and processes continue to operate effectively despite changes in the new environment.

Nature of uncertainty	Flexibility type	Ability of a process to...
Demand for the kinds of products offered	Mix	"produce a number of different products at the same time"
Length of product life cycles	Changeover	"deal with additions to and subtractions from the mix over time"
Appropriate product characteristics	Modification	"make functional changes in the product"
Machine downtime	Rerouting	"[change] the operating sequence through which the parts flow"
Amount of aggregate product demand	Volume	"[easily make] changes in the aggregate amount of production"
Meeting raw material standards	Material	"handle uncontrollable variations in compositions and dimensions of parts"
Timing of arrival of inputs	Sequencing	"reorganise the order in which different kinds of parts are [processed]"

Source: Schmenner & Tatikonda, and Gerwin

Image 2 – The domain of manufacturing flexibility

The proces automation is not enough to be competitive in the global marketplace. Companies provide the concept of **felexible automation and advanced manufacturing** (Image 2). Digital integration of business processes, manufacturing processes and supply chains allows factories with high paid workers in advanced countries to compete with lower skilled, lower paid workers in developing economies. Computer controlled tools allow manufacturing products to be high precision and high quality and potentially low volume driving towards mass customization of products. Furthermore it allows manufacturing at scales not possible with human controlled tools. Nano-scale engineering and bioengineering are now producing viable products. Products, dependent on advances in artificial intelligence, such as autonomous robots, vacuum cleaners, grass mowers, drones, submarines and cars are already entering the marketplace.

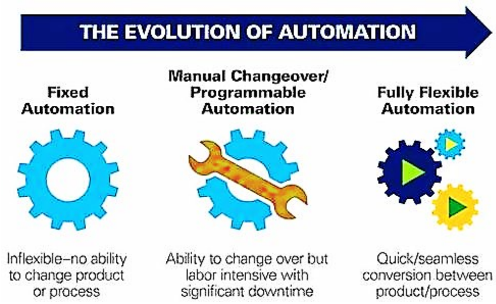

Image 3 – Evolution of automation

Image 4 – Advanced manufacturing

The 10 manufacturing trends are:

- **IOT (INTERNET OF THINGS)**

  Manufacturers are increasingly leveraging the Internet of Things (IoT), which entails the interconnection of unique devices within an existing Internet infrastructure, to achieve a variety of goals including cost reduction, increased efficiency, improved safety, meeting compliance requirements, and product innovation. IoT's existence is primarily due to three factors: **widely available Internet access, smaller sensors, and cloud computing.**

- **PREDICTIVE MAINTENANCE**

  Predictive maintenance programs predictive **monitor equipment** using any number of performance metrics. By automating the data collection process through the use of IoT technology, manufacturers can develop a better understanding of how systems work and when they will fail. The ability to predict when maintenance should be performed saves manufacturers valuable time, money, and resources. Typically, monitoring tests can be conducted while equipment is in operation, which means there is no loss of production due to equipment shutdown.

- **SHIFTING FOCUS FROM B2B TO B2B2C**

  Many manufacturers who traditionally had a B2B business model are shifting to a B2B2C (business-to-business-to-consumer) model due to the many benefits selling directly to consumers provides including:

  Increased Profit: You get the full manufacturer's suggested retail price (MSRP) rather than wholesale prices for your products.

  Faster Time to Market: You can prototype, test, and get products to market quickly instead of contending with the lengthy traditional retail sales cycle that requires locked-down product development far ahead of order and delivery. This agility gives you a competitive edge.

  Brand Control: You own your brand. It won't be diluted or misrepresented by third parties.

  Price Control: You can reinforce your MSRP.

  Better Customer Data: Selling direct to customers allows you to collect data about them that ultimately results in better products, stronger relationships, and increased sales.

- **LEVERAGING SUPPLY CHAIN FOR COMPETITIVE ADVANTAGE**

  Today's supply chain technology solutions address manufacturing needs in a variety of areas, including:

  - Manufacturing Optimization
  - Logistics Optimization
  - Sales and Operations Planning
  - Product Lifecycle Management
  - Business Intelligence
  - Network and Inventory Optimization
  - RFID
  - Procurement

- **ERP SYSTEMS ARE CONTINUING TO STREAMLINE PROCESSES**

  ERP systems offer two key benefits:

  - They streamline processes by automating all business operations and providing accurate, real-time information.
  - By providing accurate, real-time information, administrative and operational costs are reduced. The end result is that manufacturers can proactively manage operations, prevent disruptions and delays, break up information roadblocks and help users make quicker decisions.

- **GREATER VISIBILITY INTO BIG DATA IS HELPING MANUFACTURERS ACHIEVE MORE**

  IoT is transforming almost every surface into a sensor for data collection and providing real-time insights for manufacturers. This ability to collect data from so many sources combined with increasingly powerful cloud computing is finally making big data usable. Manufacturers can slice and dice data in ways that provide them with a comprehensive understanding of their business. This enables them to improve production, optimize operations, and address issues before problems arise.

- **VR AND AR ARE CONTINUING TO FORGE WINNING PARTNERSHIPS BETWEEN MAN AND MACHINE**

  Assistive technologies, such as augmented reality (AR) and virtual reality (VR), will continue to create mutually beneficial partnerships between man and machine that positively impact manufacturers.

- **3D PRINTING IS MAKING PRODUCTION FASTER AND CHEAPER**

  Manufacturers will benefit from faster, less expensive production as a result of 3D printing. It makes rapid prototyping, which is a highly cost-effective way for product designers to test and troubleshoot their products, possible. In addition, it enables manufacturers to produce items on demand instead of having to manufacture and warehouse them.

- **CONTINUED RESHORING IS LEADING TO AN INCREASE IN MADE PRODUCTS**

  Reshoring – bringing operations back to state shores – is becoming increasingly common among manufacturers. There are multiple factors contributing to reshoring. Firstly, the economies in many go-to offshoring countries are doing well, which has led to an increase in wages for their residents. Secondly, in countries where labor remains inexpensive, the infrastructures typically can't support complex manufacturing operations. In addition, transportation costs are rising.

- **FINDING TECH-SAVVY EMPLOYEES WILL BE CHALLENGING**

  As manufacturers increasingly rely on technology, their need to hire tech-savvy employees is increasing. The challenge is that there are not enough skilled employees to fill the number of open jobs. To fill the void, manufacturers are having to do two things:

  - Train existing workers to perform skilled tasks.
  - Find ways to make their business appealing to computer coders, app developers, data scientists, 3-D printing specialists, and other highly trained professionals.

Advanced manufacturing providing **smart products** which are specializations of hybrid products with physical realizations of product categories and digital product descriptions that provide the following characteristics:

- Situated: recognition and processing of situational and community contexts
- Personalized: tailoring to buyer's and consumer's needs and affects
- Adaptive: change according to buyer's and consumer's responses and tasks
- Pro-active: attempt to anticipate buyer's and consumer's plans and intentions
- Business aware: considering business and legal constraints
- Location aware: considering functional performing and restricted location choice
- Network capable: ability to communicate and bundle (product bundling) with another product (business) or product sets

The vision of smart products poses questions relevant to various research areas, including marketing, product engineering, computer science, artificial intelligence, economics, communication science, media economics, cognitive science, consumer psychology, innovation management and many more.

Examples of good practices in companies

- 4 June 2019 – The Laboratory for Handling, Assembly and Pneumatics at the Faculty of Mechanical Engineering (University of Ljubljana) opened the Smart Factory demo centre, which is the only and one of a kind centre in Slovenia. It was made in parallel to the GOSTOP programme, the largest S4 Smart Specialisation Programme dealing with smart factories in Slovenia. The idea of a demo centre is in line with the fundamental idea of S4 smart specialisation, namely to demonstrate the innovative use and introduction of 4.0 Industry technologies and the smart factory concept in real industrial environment. https://www.kolektor.com/en/about-us/media/news/opening-of-the-first-demo-smart-factory-in-slovenia-2019-06-06

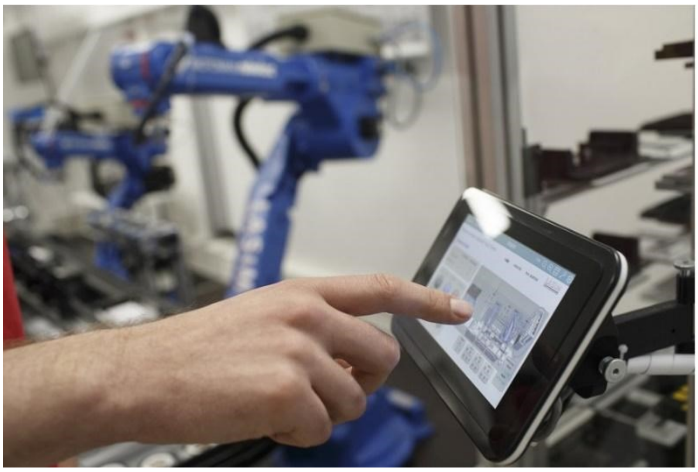

Image 4 – Smart factory demo centre

- Company Gorenje – Providing Industry 4.0

  https://www.gorenjegroup.com/si/za-medije/novice/2018/02/7957-Industrija-4-0-in-pametne-tovarne-Smo-ze-tam

- Industry 4.0 good examples

  https://www.diginnobsr.eu/industry-4-0-best-practice

1.2 Sub-unit: Product technologies

Modern digital markets are characterized by a high complexity, which makes it harder for companies to keep their competitive position for a longer period of time. Potential customers might choose from a wide range of products and services of globally acting providers, whereby requirements in terms of quality, price and availability are increasing (cf. Becker et al., 2004 p.393) (cf. Grundig, 2018 p.13). Companies of all sizes are challenged by increasing market requirements along the life cycle of their products and services. According to various scientific publications, Industry 4.0 includes the capability of solving the majority of known, existing difficulties in relevant areas and might add sustainable value to current businesses.

With these SMeART- guidelines, the Smart Engineering related concepts, processes and technologies that are required for a successful implementation of Industry 4.0 within SMEs, are presented on two linked levels: on one hand on the above life cycle level. On the other hand, necessary concepts, processes, and technologies are provided by the subsequently introduced SMeART Coaching and Collaboration Model.

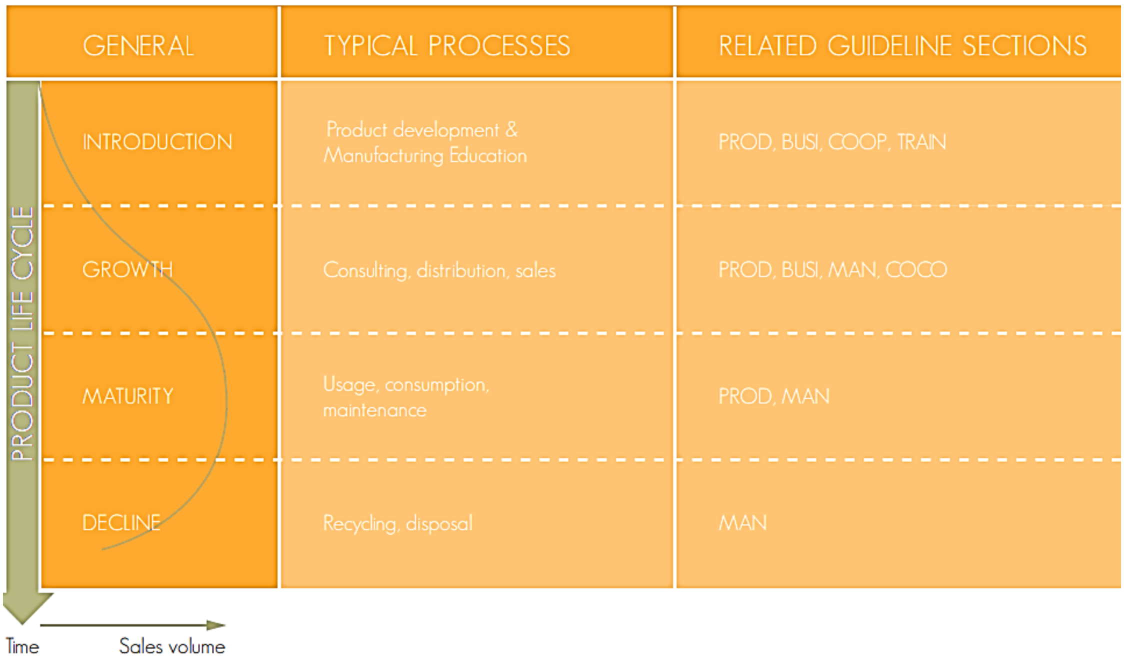

Image 5 – The SMeART-product life cycle: Relation between a general product life cycle, typical processes, and related sections of these guidelines

Co-funded by the Erasmus+ Programme of the European Union

Project number: 2018-1-ES01-KA202-050289

The SMeART Coaching and Collaboration Model supports the general process of supporting SMEs on their way to become digital. At the same time, the model provides a clear structure of the tools and measures that are provided by the SMeART project. The SMeART Coaching and Collaboration Model is based on the SMeART strategic framework. In addition, the instruments of the SMeART toolbox that are provided with the model relate to different stages of various coaching and consulting processes.

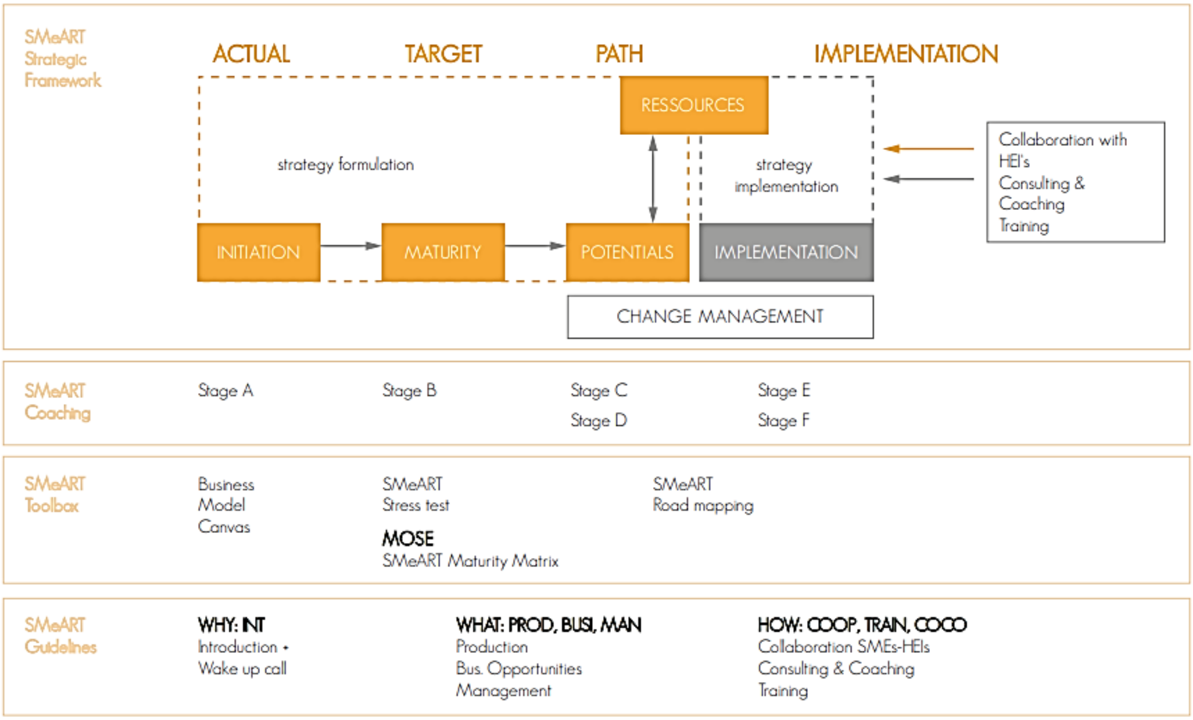

Image 6 - The SMeART Coaching and collaboration Model

1.2.2 Challenges along the product life cycle

The starting point of each product novelty is an idea, emerging from the needs, problems or trends and developments in a specific market or customer segment (cf. Grote et al., 2014 p.1). Due to the wide variety of different companies offering similar products, nowadays understanding and meeting customer demands by a flexible adaptation of requirements, products and processes is seen as one of the key elements for economic success (cf. Becker et al., 2004 p.393). Therefore, the first great challenge for manufacturing companies is to recognize or better anticipate the wishes of their customers and react upon these demands in a short period of time

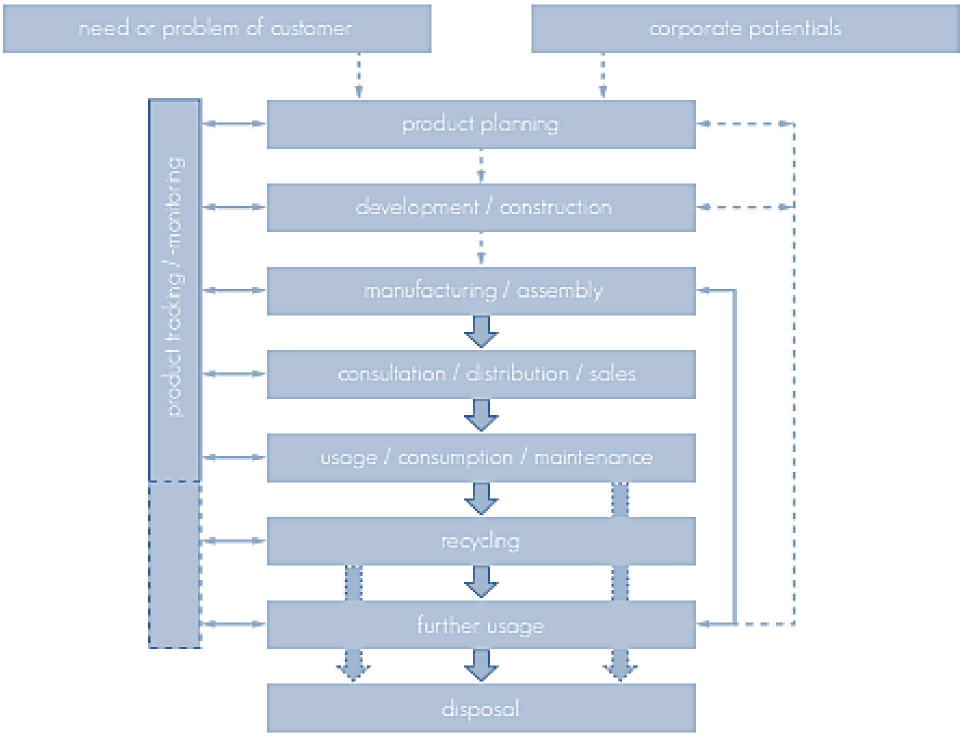

Image 6 - Lifecycle of products

Overall, smart companies are facing numerous challenges across the life cycleof a product or service: Requirements in terms of time, price, quality, sustainability, and service have risen in the last years. In addition, fluctuations in demand and the preference for individualized products necessitate a high flexibility and responsiveness of processes along the entire supply chain that cannot be realized with current production systems. These shortcomings and difficulties of production systems are the point where Industry 4.0 comes into play. In scientific literature, the introduction of I4.0 is not discussed as a possibility to handle all these challenges, it is rather seen as a mandatory requirement for manufacturing companies in order to ensure their economic survival (cf. Roth, 2016a p.13 f.) Based upon its various features, Industry 4.0 opens up completely new opportunities for companies of all sizes and all industries. Looking back at the life cycle of products, the first challenge for companies was the fast, efficient development of products, that can satisfy the wants and needs of targeted customers. Firstly, I4.0 enables product innovations, that can offer greater value to customers. In this context, the buzzword Internet-of-things is often used to describe web-enabled objects with identification and sensors. Besides product innovations, companies can profit from time and cost savings during development processes. For example, augmented reality technologies be a great opportunity to increase efficiency during this stage. It enables the virtual design of prototypes and the virtual change of product features, such as colours or materials and virtual introduction of functionalities without additional material- and manufacturing costs. In addition, all provided changes can be documented automatically and transparent (cf. Borgmeier, Grohmann, & Gross, 2017c p.127 f.)

1.2.3 Applications of Industry 4.0 along the product life cycle

Although various authors emphasize the potential of I4.0 to enhance processes along the entire product life cycle, many publications only focus on specific sub-sectors such as logistics (cf. Bousonville 2017) or manufacturing processes (cf. Spath et al. 2013). Therefore, this section aims to compile possible applications of I4.0 along the entire product life cycle from various publications. Due to the variety of arising technologies and their wide-ranging capabilities, the following compilation does not attempt to cover all possible applications. Much more, it aims to provide a concise overview to interested readers and encourage further research. The starting point of each successful product innovation is an idea. The idea might emerge from the requirements or problems of a specific market or customer segment (cf. Grote et al. 2014, p.1). Researchers and managers report, that Big Data currently is “a strong driver of innovation and a significant source of value creation” (Tan et al. 2015, p.223). Big Data can be used to derive insights concerning current and future trends and can help companies to gain a better “understanding of their products, customers, and markets which is crucial to innovation” (Tan et al. 2015, p.224). Various Big data solutions already exist on the market, which can automatically analyze data such as transactions and interactions of customers, user-generated content or social media data and thus support companies in generating ideas for innovations (cf. Markl et al. 2013, p.11). So far, transforming those ideas to a working product requires various time-consuming and cost-intensive activities, such as feasibility tests, design studies, the fabrication and testing of different prototypes (cf. Cooper und Centre 1980, p.27 ff.).

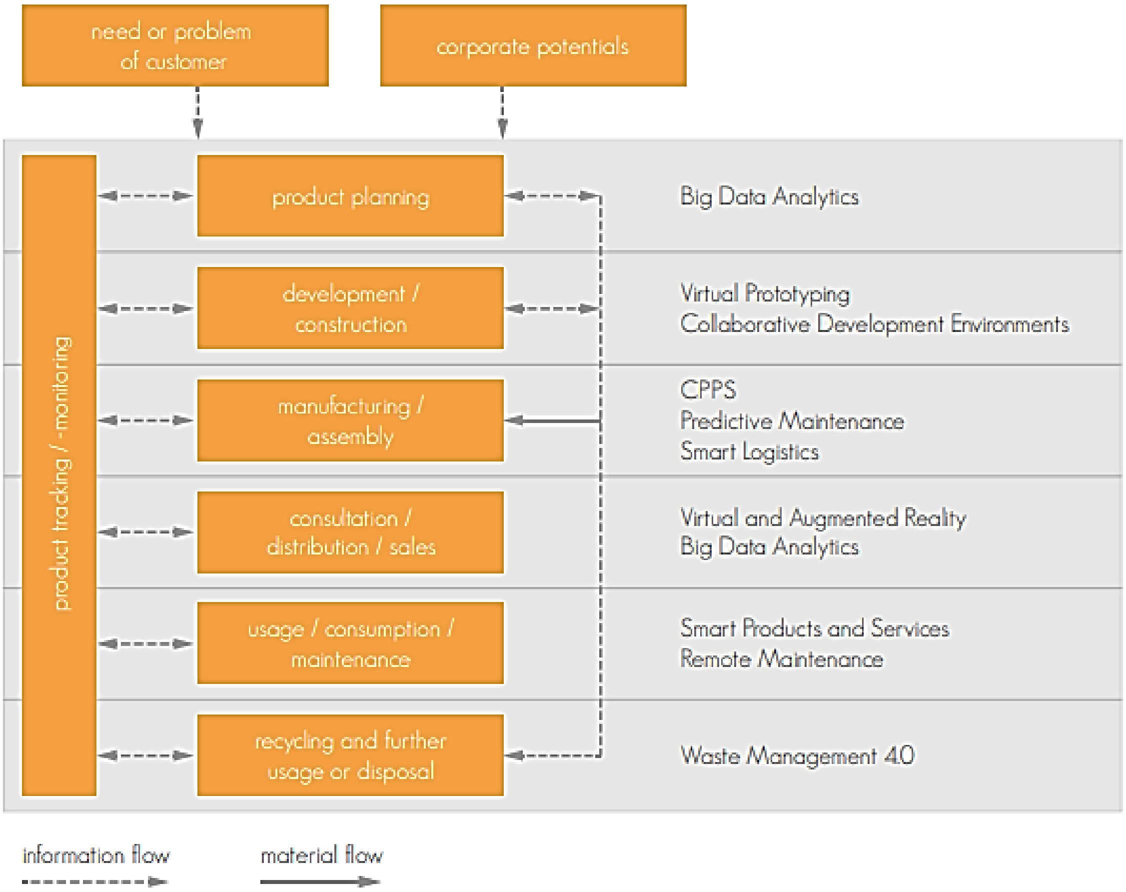

Image 7 - Product life cycle with flows

Data glasses can display relevant information such as current process data, technical documentations, maintenance rules or repair instructions and thus improve the efficiency and quality of processes through the targeted support of employees. In case of a system failure, the visual field of the user of the data glasses can be transmitted directly to the helpdesk of the manufacturer of the affected equipment, who then can offer optimal support and increase the rapidity of the maintenance process (cf. Bauernhansl et al. 2014, p.488). Smart exoskeletons such as Robo-Mates can be worn by employees when performing physically strenuous activities. Integrated sensors register physical stress and the exoskeleton redistributes heavy loads from the shoulder area to the entire body. As a result, even demanding tasks can be executed more efficiently, the physical stress decreases and the health of employees will be promoted in long term (cf. Fraunhofer IAO 2015). The combination of various I4.0-technologies enables innovative solutions with the capability of enhancing the entire production. Table 3 shows a compilation of a few successful I4.0-applications, which resulted in higher revenues and higher quality of products.

1.2.4 Examples for smart products

“Smart Industry digitizes and integrates processes across the entire organization, from product development and purchasing, through manufacturing, logistics and service. All data about sales, operations processes, process efficiency and quality management, as well as operations planning are available real-time, supported by ICT-systems and software (f.i. augmented reality) and optimized in an integrated network. By integrating new methods of data collection and analysis, companies can generate data on product use and refine products to meet the increasing needs of end-customers” (PWC, 2016a).

Making products smart(er) can be achieved by:

• Adding digital features to existing products (such as cameras and sensors and communication devices to make them connected)

• Combining digital products and (databases) services, offering customers total solutions • Using data analytics to create products-as-a-service and creating an online platform for customer access to content as well as data-based services

• Integrating external data and products and services from other companies in own portfolio and platform in order to unburden customers. This will mean cooperation with other suppliers and/or value chain integration, building a customer-centric ecosystem.

In the industry, many improvement methods that provide flow and change are applied (Lean Production, Six Sigma, TOC, QRM, TPM, Agile, First time Right, Value Stream mapping etc.). QRM and Lean, for example, are methods for reducing faults in office and production processes. At QRM, the main goal is to deliver quality with high delivery reliability, despite a large variation in orders. While with Lean, the emphasis is more on reducing or eliminating waste on the production floor. Due to both, there will be fewer faults and lower costs through efficiency

In order to design, produce and deliver tailor-made products in a faster way, it is essential to switch from an ETO (Engineering-to-Order) to a CTO (Configure-to-Order) process. While 45 ETO forces you to engineer every single order ‘from scratch’, CTO compiles each order from existing building blocks. By varying in standardized building blocks such as hardware, software, electronics, but also operational building blocks such as production systems and resources, customers will get tailored solutions through a standardized route. The advantages are better products, fewer errors, shorter time to market, more time for innovation and less costs (Cadac Group-Create, manage & Information, 2017).

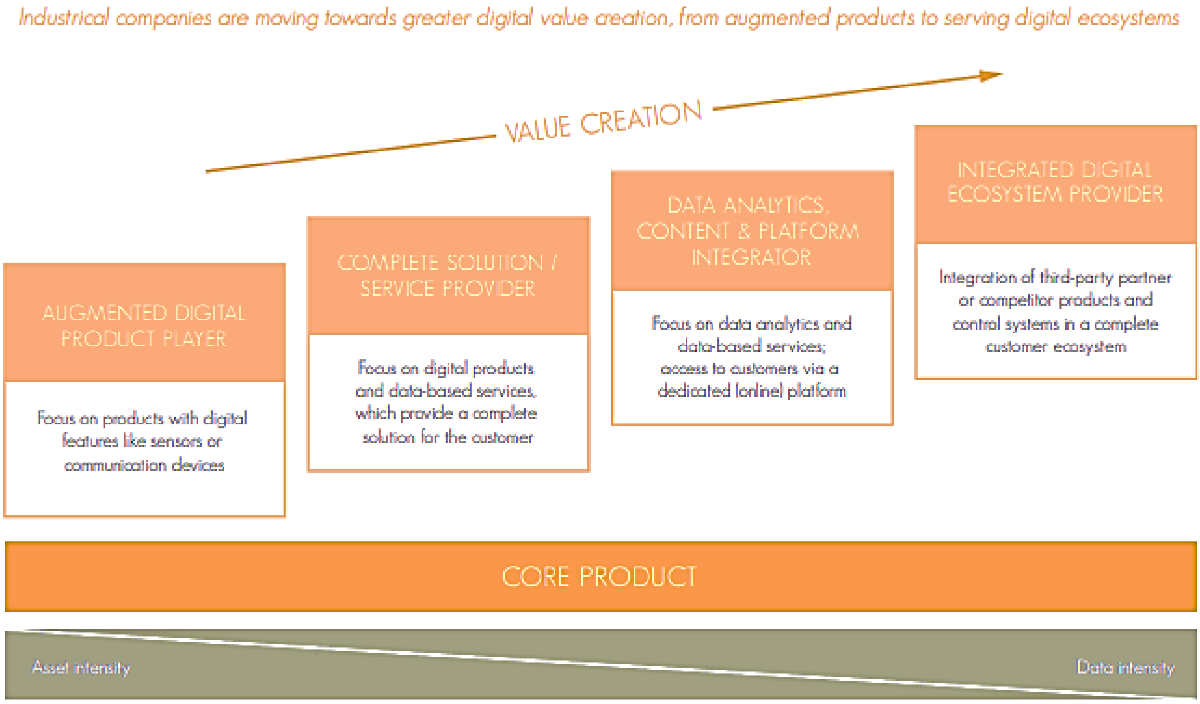

Image 8 - Digital Value Propositions

According to our survey, the use of Computer Aided Design (CAD) is quite common. Automated product configurators are far less used [link Q43&Q65]. Automated quality checks of products are hardly implemented by SMEs (link Q49&Q71]. In addition to the mentioned CAD, smart companies use a whole range of Computer-aided technologies (CAx) for design, analysis and manufacturing of products like Computer-aided manufacturing (CAM) and Computer-aided engineering (CAE).

References

Websites

Irishmedtechskillnet.ie. (2019). [online] Available at: https://www.irishmedtechskillnet.ie/Sectors/IMDA/IMDA.nsf/vPages/Key_themes~Manufacturing~manufacturing-4.0-and-additive-manufacturing-reports/$file/02-amt-new-manufacturing-engineering_en.pdf [Accessed 22 Sep. 2019].

Boggess, M. and Boggess, M. (2019). *10 Trends that Will Dominate Manufacturing Trends in 2019*. [online] Hitachi Solutions. Available at: https://us.hitachi-solutions.com/blog/top-manufacturing-trends/ [Accessed 18 Sep. 2019].

Wilsoncenter.org. (2019). [online] Available at: https://www.wilsoncenter.org/sites/default/files/Emerging_Global_Trends_in_Advanced_Manufacturing.pdf [Accessed 18 Sep. 2019].

Als2018.com. (2019). [online] Available at: https://www.als2018.com/pdf/ALS2018%20ppt_5.6%20Thriving%20in%20Industry%204.0%20–%20The%20Festo%20Way.pdf [Accessed 22 Sep. 2019].

SMeART University-Business Cooperation Model and Guidelines. (2020) Aviable at:

http://www.smeart.eu/en/results/handbook-smeart/SMeART_Handbook_2019__web_EN.pdf

Videos

Industry 4.0 global trends:

https://www.youtube.com/watch?v=VhqMyZMws3Q

What is smart manufacturing?

https://www.youtube.com/watch?v=EV1Ygw6_rCs