Chapter 5

Maximising Economic Benefits and Firm Competitiveness

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October 2018

This chapter should be cited as

Blunck, Erskin, H. Werthmann and V. Ambumozhi (2018), 'Maximising Economic Benefits and Firm Competitiveness', in Anbumozhi, Venkatachalam and F. Kimura (eds.), *Industry 4.0: Empowering ASEAN for the Circular Economy*, Jakarta: ERIA, pp.127-160.

Chapter 5

Maximising Economic Benefits and Firm Competitiveness

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1. Introduction

The world economy is on the cusp of the fourth industrial revolution. Driven by the internet, the real and the virtual worlds merge together to form the internet of things (IoT). This development is of utmost importance, especially for the manufacturing industry. Production comes together with the latest information and communications technology, and the digitalisation of economy and society changes the way things are produced in a permanent way (BMBF, 2016; GTAI, 2014).

The notion 'Industry 4.0' (derived from the German term 'Industrie 4.0') was mentioned for the first time in public at the Hannover trade fair in Germany in 2011 (Kagermann et al., 2016). The initiative that followed, set by the Federal Ministry of Education and Research, Germany (Bundesministerium für Bildung und Forschung, BMBF), was intended to encourage the German manufacturing industry to prepare for the future of production (BMBF, 2016). Since 2012, BMBF has been promoting various projects worth more than €120 million in the context of Industry 4.0, with industry, researchers, and policymakers working closely together (BMBF, 2015).

The digital transformation of the industry is accelerated by exponentially growing technologies like intelligent robots, autonomous drones, sensors, and three-dimensional (3D)-printing. Due to this technology-driven change, whole firms and their industrial processes need to adapt so as not to be left behind by their competitors. An early adaption to this new environment will increase their competitiveness in the future. This adaption goes beyond the automation of production, which has already been taking place since the early 1970s. Through the proper application of recent information and communications technology, the boundaries between the real and virtual worlds increasingly disappear and cyber-physical systems (CPS) emerge. In the future, there will be online networks of communicating machines, linking information technology (IT) with mechanical and electronic components (Deloitte, 2015). Out of that, interlinked and self-operating production systems or even totally re-engineered value chains can arise (GTAI, 2014).

The concept of Industry 4.0 is also widely known across Europe and the United States (US). In Germany, for example, there is an initiative called the pan-European partnership for the 'factories of the future', which aims to help European manufacturing companies adapt to the global competitive pressures by developing necessary key technologies. A budget of €1.15 billion has been allocated for it from 2014 to 2020 (European Commission, 2013). In the US, the Industrial Internet Consortium aims to accelerate the growth of the industrial internet by bringing organisations and technologies together to prepare for the upcoming revolution (Industrial Internet Consortium, 2016). Between these organisations, there is close cooperation to ensure global standards. For example, the American Industrial Internet Consortium is working closely together with the German 'Plattform Industrie 4.0' to create an international framework to ensure consistent rules and norms (Giersberg, 2016).

According to the vision of Industry 4.0, the future of production could look like the following. There will be communications via software and networks over the whole vertical value chain (product development, production, and services). Smart machines will exchange information and instructions in real time with smart products as well as with individuals across the whole value chain and the overall product life cycle (PLC). Through sensors and control elements, machines will be able to link plants, fleets, networks, and human beings. The machines will continually share information about current stock levels, problems, faults, and changes in orders or demand levels. Furthermore, processes and deadlines are coordinated to raise efficiency and throughput times are optimised. Consequently, we experience an increase in quality throughout the whole PLC. In total, this will create a production system with autonomous control and optimisation (Siemens 2014b; Deloitte, 2015).

Companies that are aware of this development in the manufacturing landscape and invest in all the technologies coming along will be able to profit from the enormous potential of optimisation in logistics and production, and could be part of totally new business models (Kagermann, Lukas, and Wahlster, 2016). But Industry 4.0 not only changes how things are produced but also have strong influence on the operative and strategic performance management through greater flexibility and decentralisation (Sauter, Bode, and Kittelberger, 2015).

Through digital transformation, there is an expected additional potential of value creation in Europe of about €250 billion per year (Roland Berger Strategy Consultants, 2015). Based on this enormous potential, there is consensus within (at least) the German industry that Industry 4.0-related topics have to be on the management agenda of each company and have to be considered with respect to strategic planning over the coming years (Roland Berger Strategy Consultants, 2015; Koch et al., 2014).

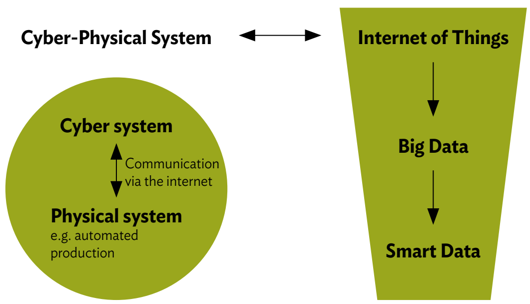
Beyond all competitive advantages through, for example, improvement of efficiency and flexibility, which come along with the implementation of Industry 4.0, efficient uses of resources should also be considered. Production processes within Industry 4.0 should be seen as holistic balanced circuits, which guide and shape the new industrial production (Arbeitskreis Industrie 4.0, 2013). Environmental pollution and shrinking resources have incrementally increased pressure on industrial businesses. These circumstances force manufacturing industries to cope with the pressure of environmental regulations set by governments, the challenges in resource price volatility because resources get scarce, and risks in resource supply. Therefore, a rethinking of the conventional linear economy (take, make, dispose) takes place, and the concept of a circular economy emerges. A circular economy could be the solution to harmonise ambitions for economic growth and environmental protection, where it is understood as a realisation of a closed-loop material flow in the whole economic system (Lieder and Rashid, 2015). Here, the development towards Industry 4.0 provides immense opportunities for the realisation of sustainable, eco-friendly, and resource-saving manufacturing (Stock and Seliger, 2016). For example, IoT and wireless technologies can be used to monitor emissions to supervise air quality, the collection of recyclable materials, and the reuse of packaging resources and electronic parts. The disposal of electronic parts, for example, could be advanced by using radio-frequency identification technology to identify electronic subcomponents of personal computers, mobile phones, and other consumer electronics products to increase the reuse of these scarce resources and reduce waste. Furthermore, radio-frequency identification technology enables a greater visibility into the supply chain, which makes it possible for companies to, for example, efficiently track and manage inventories, consequently reducing unnecessary transportation requirements and fuel usage (Sundmaeker et al., 2010).

The main purpose of this chapter is to explain the potential effects of Industry 4.0 on creating economic value and increasing competitiveness of corporations. In addition to the analysis of the benefits of Industry 4.0, the opportunities to create a circular economy through Industry 4.0 will be studied. For a proper discussion of the topic, some definitions of key terms will be introduced before addressing the main theme of economic benefits and competitiveness, and its consequences for Industry 4.0. This analysis will be followed by a description of new Industry 4.0-related business opportunities and business models, and their impacts on a circular economy. Since even the Industry 4.0-pioneer countries are still in the early stages of Industry 4.0 imagination, creation, and implementation, some key challenges and obstacles on the visionary concepts are discussed. An approach to the transfer to the specific situation of the various Association of Southeast Asian Nations (ASEAN) countries is briefly proposed at the last part of the chapter.

2. Definitions

Industry 4.0 is still based on automation technology (e.g. robots), but these technologies are now connected via sensors and other control elements that link the real and the virtual worlds forming CPS. These CPSs are then able to cross-link all productive entities to each other through the internet. This communication of physical objects without any human interaction is known as IoT. The huge amount of data that arise out of that interaction (big data) could be stored in clouds and should then be converted into smart data to filter the information really needed and to evaluate the generated data in a proper way (see Figure 1). If we take all these technologies together, we will be able to form the smart, digital factories of the future.

Figure 1. Interplay of Components Used Within Industry 4.0



Notes: Cyber systems, together with physical systems, form the so-called cyber-physical systems, which can communicate via the internet. Through small embedded devices (e.g. radio-frequency chips) within physical systems, objects become 'intelligent'. The communication of these smart objects without human interaction is known as the internet of things. The huge amounts of data recorded within these processes are called big data, which must be converted into smart data for proper use. All these concepts are the basis for the upcoming industrial revolution called 'Industry 4.0', where smart factories are producing smart products in a self-organised manner.

Source: Author´s own representation (Hedwig Werthmann).

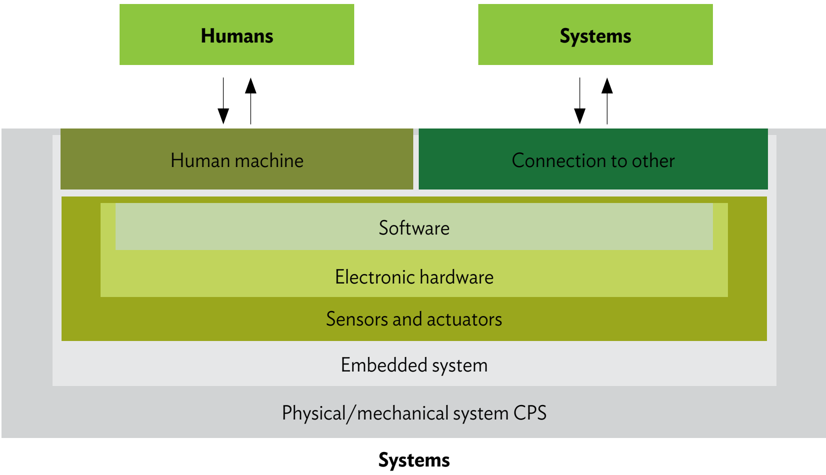
All these concepts, which are important to Industry 4.0, are explained in more detail in the following subsections.

2.1 Cyber-Physical Systems

A CPS describes the technological basis of information technology in combination with the physical world. This means that they connect information technology with mechanical and electronic elements. These systems of collaborating computational entities are therefore in a steady intensive connection with the surrounding physical world and its on-going processes (Monostori, 2014). Therefore, open, cross-linked systems arise, which can collect data in various situations in the physical world. In addition, they interpret data and make them available. Furthermore, these systems can react via actuator systems to processes within the physical world and can therefore influence the behaviour of equipment, things, and services (Geisberger and Broy, 2012). CPSs, which provide and use data at the same time, are intelligently linked with each other and are continuously interchanging data via virtual networks (like clouds), making data available via the internet. These CPSs can also be used within manufacturing systems, where the intelligent cross-linking is, for example, realised by embedded sensors, processors, software, and connectivity in products, coupled with a product cloud in which product data is stored and analysed. These data can be used to improve product functionality and performance (Stock and Seliger, 2016).

CPSs can also behave as human-to-machine interfaces, or it can support machines to interact with the products (see Figure 2). Therefore, a CPS enables development across all levels of production, from processes through machines up to production and logistic networks, where manufacturing systems can interact and operate in a self-organised and decentralised manner (Monostori, 2014; Brettel et al., 2014).

Figure 2. Interaction Between Humans and Machines in Cyber-physical Systems



CPS= cyber-physical system.

Notes: Cyber-physical systems consisting of physical/mechanical systems with embedded software using sensors and actuators to record, store, and evaluate data, can connect the real and virtual worlds. To ensure communication between users and, for example, production plants, there are man-machine interfaces, as well as interfaces between the systems itself (e.g. machine-to-machine interaction, product-machine interaction). The elements of CPS can control tasks in an autonomous manner and are able to interact with humans via interfaces.

Sources: Authors' representation based on Monostori, 2014; Brettel et al., 2014.

Recent developments have resulted in higher availability and affordability of sensors, data acquisition systems, and computer networks, and changed the competitive landscape of the current manufacturing industries. More factories are constrained to implement high-technology methodologies to stay competitive and up-to-date. Therefore, the ever growing use of sensors and networked machines has resulted in the continuous generation of high-volume data, which is known as big data (Lee, Bagheri, and Kao, 2015). But CPSs do not only have the potential to change the manufacturing landscape; it also has enormous potential to change every aspect of life. Ideas such as autonomous cars, intelligent buildings, smart electric grid, 3-D printing, and robotic surgery are just some selected practical examples that have already emerged (Monostori, 2014).

2.2 The Internet of Things

The notion 'internet of things' was mentioned for the first time by Kevin Aston in 1999 (Pande and Padwalkar, 2014). According to his definition, computers and, consequently, the internet are dependent on humans for information. Humans capture and create most information available in the internet. Therefore, information available is based on ideas, not on things. His vision was:

> If we had computers that knew everything there was to know about things – using data they gathered without any help from us – we would be able to track and count everything, and greatly reduce waste, loss, and cost. We would know when things needed replacing, repairing or recalling, and whether they were fresh or past their best (Ashton, 2009).

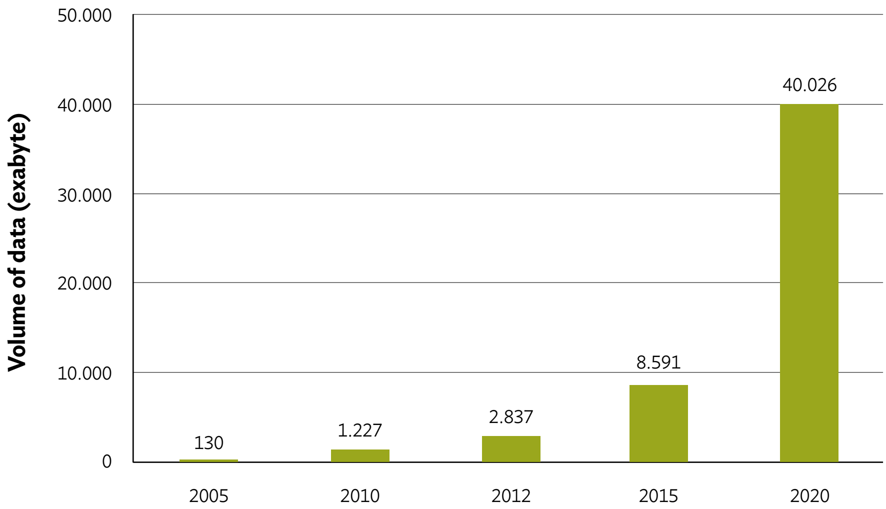
To reach that level, humans must empower computers to obtain information from surrounding things. This will be possible through embedded radio-frequency identification and sensor network technologies in our surrounding environment. Consequently, there will be an omnipresent interlink of persons, things, and machines at any time – enabled by IoT. The result will be enormous amounts of data, which have to be stored, processed, and presented in an efficient and easily interpretable form. Cloud computing can provide the virtual infrastructure for such utility computing, which integrates monitoring and storage devices as well as analytical tools (Gubbi et al., 2013). Companies and organisations have several ways to explain IoT. But it is commonly described as an 'ecosystem of technologies monitoring the status of physical objects, capturing meaningful data, and communicating that information through networks to software applications' (Thrasher, 2014). The recurring topics in all definitions of IoT include smart objects, machine-to-machine communication, and radio frequency technologies (Thrasher, 2014).

Through IoT, it is possible to connect everyday objects to remotely determine their state via information systems, which continuously collect up-to-date information on these physical objects and processes. It is like billions of objects will report and receive data without human interaction. IoT is exploding. Therefore, the total number of connectable things will be increasing from 7% of the total objects in 2013 to 15% by 2020 (EMC2, 2014). This enables many aspects of the real, physical world to be monitored in detail and at low cost. Using these technologies within 'the future of manufacturing' (Industry 4.0), would allow a better understanding of production processes as well as a more efficient control and management of these processes. As a consequence, the ability to react to events in the physical world in an automatic, fast, and informed way is gained, which will ease the optimisation of processes and the handling of complex situations (Friedemann and Floerkemeir, 2010).

2.3 From Big Data to Smart Data

The set of data worldwide is exploding. In 2005, there were 130 exabytes (10^{18} bytes) available (Webel, 2016). In 2012, it was already 2,837 exabytes and in 2020, experts expect it to increase to about 40,000 exabytes (Heuring, 2015; Statista.com, 2016; see Figure 3).

Figure 3. **Growth in Data Amount Until 2020**



Notes: Prediction is based on the volume of the yearly generated digital amount of data worldwide between 2005 and 2020 (numbers in exabytes).

Source: Authors' representation based on Statista.com, 2016.

Different sources give different figures on the increase in the volume of generated data over the coming years. But there is a clear consensus that the amount of data will increase dramatically across the following years.

Through Industry 4.0 applications, there is a change in the whole industrial value chain through increasing digitalisation and networking. The huge and continuously produced amount of data through the growing use of sensors, networked machines in CPS, and the development towards an industry with smart factories is called big data.

These sensor-generated, networked data from a wide variety of sources are therefore unstructured. To use these data to, for example, generate forecasts and enable companies to take fact-based decisions, it is important to consolidate and evaluate these data in an intelligent way (Sauter, Bode, and Kittelberger, 2015). Consequently, companies must face the challenge of developing smart predictive informatic tools to manage big data. Within this approach, it is important to think about information retrieval, representation, and the interpretation of data with special regard to security aspects, thereby achieving transparency and productivity (Monostori, 2014; Lee, Kao, and Yang, 2014). In the age of digitalisation and IoT, businesses are collecting more data than they know what to do with. To convert this bulk of data into useful information, it is necessary to reduce their complexity when structuring the information. Then these data have to be evaluated in a proper way to be used for knowledge advances and decision-making throughout the whole PLC (Stock and Seliger, 2016). If this challenge succeeds, then smart factories producing smart products with the aid of CPSs, collecting smart data at each step of production will be enabled to self-organise each required manufacturing step throughout the whole production process or even the whole value chain.

2.4 The Smart Factory

How the smart factory of the future will look like, no one knows exactly. But a probable scenario would be that machines and products will organise the production, supply chains will arrange themselves, and orders will convert to information needed for production to start the manufacturing process. This means the originating product itself will guide the process of production, supervise the environment through its embedded sensors, and react to disturbances with counteractions. This may become a reality when using the technologies described in the previous subsections above. There are some existing advanced factories that are deemed to be part of the most modern production sites in the world. We are in the midst of the fourth industrial revolution. Hence, these plants show the direction of where to go in the future.

Examples of these sites are the Siemens' electronics plant in Amberg, Germany, which produces Simatic programmable logic controls (Siemens, 2014a), and Festo`s technology plant in Scharnhausen, Germany (Festo AG and Co. KG, 2015), which is a pioneer in putting into practice Industry 4.0. Within Festo's technology plant, employees cooperate in safe interaction with flexible robots, energy systems track all energy flows in real-time, and new working tools detect and rectify machine faults directly on-site.

Within the electronics plant of Siemens, products and machines are already communicating with each other. IT processes are optimised with a minimal error rate and products regulate their production on their own. The result is impressive. By using a constant production area and only slight changes in numbers of employees, the production site has octuplicated its production volume. This means man and machine are eight times more productive compared to 20 years ago. In addition, the defect rate could be kept to a minimum. Production quality is at 99.99885%, and a series of test stations detect the few defects that occur (Siemens, 2014a).

As we can see from these examples, smart factories will make the growing complexity of manufacturing processes manageable and ensure that production can be attractive, sustainable, and profitable at the same time.

In evaluating the readiness of European countries to Industry 4.0, Roland Berger identified Germany, Finland, Sweden, Ireland, and Austria as frontrunners; and, Belgium, the Netherlands, Denmark, the United Kingdom, and France as 'potentialists' with high Industry 4.0 readiness but rather small manufacturing share (Roland Berger Strategy Consultants, 2014).

In comparison to corporations in the US, German industry is seen to be strong in the systems level of sensors, actuators, and data collection. Until recently, there were concerns that Germany has deficits in data security and data analysis. However, German industry has strengthened its position through the creation of an Industrial Data Space, which is a joint industry effort, coordinated by the German research network Fraunhofer-Society as a neutral entity. China is also interested to follow the Industrial Data Space (Marx and Neugebauer, 2016).

Asian countries have been inspired by Germany with its Industry 4.0 initiative. Following that Industry 4.0 effort, the powerful industry association Keidanren in Japan has created a new initiative called Super Smart Society, also called Society 5.0 (Welter, 2016).

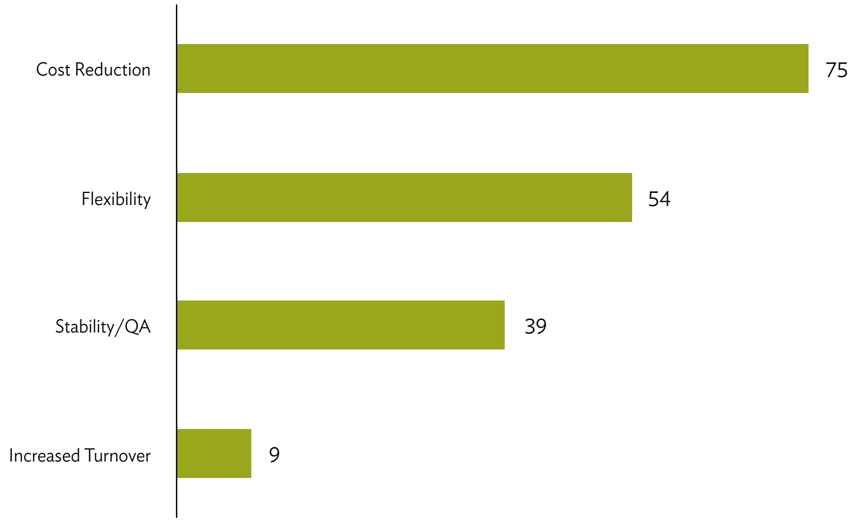
3. Economic Benefits and Improved Competitiveness Within Industry 4.0

In this chapter, economic benefits, which can be achieved when using Industry 4.0 technologies, will be explained. Researchers and strategy consulting firms indicate various value drivers. When looking at these value drivers and trying to optimise and work with them, there is high potential to accomplish economic improvement within business and manufacturing processes. Furthermore, there will be a demonstration of three dimensions to work with, according to which companies can gain competitive advantage by implementing what was learned when looking at these value drivers.

3.1 Economic Benefits

The users of Industry 4.0 technologies expect four major economic benefits in the future compared to companies not taking part in the upcoming industrial revolution (see Figure 4). The main driving force to apply Industry 4.0 is seen within the possibility of reducing costs, which can be realised through an increase in the degree of automation and efficiency. The cost-reducing goal is followed by an increase in flexibility, which allows companies to react quickly to changes in orders and capacities, and respond to increasingly individualised customer demands. Furthermore, intelligent maintenance concepts (e.g. predictive maintenance) are expected to increase stability and improve quality. As a fourth economic benefit, an increase in turnover is expected through incremental efficiency in business as well as manufacturing processes and by entering new markets (Sauter, Bode, and Kittelberger, 2015).

Figure 4. Potential Benefits of Industry 4.0 Applications



QA = quality assurance

Note: The number of multiple answers possible is 112.

Source: Authors' representation based on Sauter, Bode, and Kittelberger, 2015.

According to McKinsey`s Digital Compass, there are eight value drivers, creating value for companies and customers. Using these value drivers, it is possible to describe in more depth economic benefits for companies applying Industry 4.0 concepts. These value drivers will explain how they impact the performance of companies concerning Industry 4.0, having in mind the objective to maximise value (McKinsey, 2015).

In a world of perfect information, it is possible to manufacture more efficiently, to use fewer resources while getting the same results as before. and production becomes more flexible. Consequently, smaller production batches are possible. Such efficiency improvements can also be used for the implementation of a circular economy, even though this might only be the starting point for more radical circular economy innovations in the coming years.

When using all information provided by Industry 4.0 technologies, companies can harness this at each step of value creation across the entire PLC. In the following subsections, concrete value drivers are described across the whole value chain/PLC, where Industry 4.0 technologies can be used to optimise business processes to become more efficient and productive. Besides the efficiency perspective, potentials for reaching a circular economy are indicated.

3.2 Using Resources and Optimising Processes

The possibilities to improve processes and the consumption of materials when using the concepts of Industry 4.0 are versatile. It is possible to decrease material costs by less defective goods and optimise processes (in speed or yield) via the use of CPS, which allows the observation of processes in real time. Through these technologies, it will be possible to react to events in the physical world in an automatic and fast way. Therefore, the improvement in manufacturing processes, including the optimisation of material consumption, will drive value and will make it possible to increase productivity by 3%-5% (McKinsey, 2015; see Figure 5).

The cross-linking of value-creation networks in Industry 4.0 provides new opportunities for implementing closed-loop PLCs and the so-called industrial symbiosis in a circular economy. Efficient coordination of the product, material, energy, and water flows throughout the PLC as well as between different factories can be realised. PLCs with closed loops help keep products in life cycles of multiple use phases with remanufacturing or reuse in between (Stock and Seliger, 2016). Industrial symbiosis is described as the (cross-company) cooperation of different factories for realising a competitive advantage by trading and exchanging products, materials, energy, water (Chertow, 2007), and smart data on a local level (Stock and Seliger, 2016).

3.3 Utilisation of Assets

The optimal use of a company's machinery park is supported by Industry 4.0-based technologies, which enable, for example, predictive maintenance. Through the permanent monitoring of machinery conditions, it becomes possible to reduce machine downtimes or changeover times by an early detection of possible problems and continuous maintenance. The avoidance and early correction of defects can therefore save costs and drive production throughput, which consequently drives value (McKinsey, 2015). Based on analyses, the use of predictive maintenance decreases total machine downtime by 30%–50% and increases machine life by 20%–40% (see Figure 5).

In a circular economy, manufacturing equipment in factories is often a capital good with a long use phase of up to 20 or more years. Retrofitting enables an easy and cost-efficient way of upgrading existing manufacturing equipment with sensor and actuator systems as well as related control logics to overcome the heterogeneity of equipment in factories (Spath et al., 2013). Retrofitting can thus be used as an approach for realising a CPS throughout a value-creation module, such as a factory, with already existing manufacturing equipment. This extends the use phase or facilitates the application in a new use phase of the manufacturing equipment and can essentially contribute to the economic and environmental dimensions of sustainability. It is particularly suitable for small- and medium-sized enterprises, being a low-cost alternative to the new procurement of manufacturing equipment (Stock and Seliger, 2016).

The same applies to the finished product to be developed. The approach for the sustainable design of products in Industry 4.0 focuses on the realisation of closed-loop life cycles for products by enabling the reuse and remanufacturing of the specific product or by applying cradle-to-cradle principles, also called circular economy. Different approaches also focus on designing for the well-being of the consumer. These concepts can be supported by the application of identification systems, e.g. recovering the core for remanufacturing, or applying new additional services to the product for achieving a higher level of well-being for the customer (Stock and Seliger, 2016).

3.4 Labour Productivity

An increase in the productivity of labour can significantly drive value. The improvement of labour productivity can be realised by using the new technologies of Industry 4.0, which make it possible, for example, to reduce waiting times between different production steps in manufacturing or to accelerate the research and development (R&D) process (e.g. through 3D printing). Furthermore, the burden or complexity of tasks can increase the speed of manual production steps executed by workers (McKinsey, 2015). Examples of such assistance within production processes are Etalex, a Canadian manufacturer of warehouse furniture, and the German company Festo, where human–robot collaborations work in close proximity to each other (Universal Robots, 2016; Festo AG & Co. KG, 2015). Through this technology, Etalex was able to increase sales by about 40% with the same number of employees (see Figure 5).

Humans will still be the organisers of value creation in Industry 4.0 (VDI/VDE and GMA, 2014). To cope with the social challenge in Industry 4.0 in a sustainable way, the training efficiency of workers can be improved by combining new information and communications technology, increasing the intrinsic motivation and fostering creativity by establishing new CPS-based approaches of work organisation and design, and increasing the extrinsic motivation by implementing individual incentive systems for the worker, e.g. by taking into account the smart data within the PLC for providing individual feedback mechanisms (Stock and Seliger, 2016).

3.5 Management of Inventories

Proper management of inventories is very important, because too much inventory leads to huge capital costs. By applying Industry 4.0 levers, drivers of excess inventories can be targeted by addressing problems like unreliable demand planning and overproduction (McKinsey, 2015). Through intelligent technologies like systems which automatically reorder, if necessary, costs for inventory holding can be reduced by 20%–50% (see Figure 5).

Regarding the circular economy, the benefits of such a reduction in inventory are reductions in energy needs for the proper storage of the inventory as well as less waste created by materials turning old or outdated due to technical progress.

3.6 Quality Improvement

Industry 4.0 facilitates the improvement of product and process qualities by using real-time problem solving, advanced process control, or real-time error corrections to decrease unstable manufacturing processes, rework, and extra costs (McKinsey, 2015). By using these approaches, cost saving related to suboptimal quality of about 10%–20% could be achieved (see Figure 5). As described in section 2.4 on the smart factor, Siemens was able to decrease the defect rate to a minimum, and a production quality of 99.99885% could be reached through the use of advanced technologies emerging with the fourth industrial revolution (Siemens, 2014a).

A sustainable-oriented decentralised organisation for a circular economy in a smart factory focuses on the efficient allocation of products, materials, energy, and water by taking into account the dynamic constraints of CPS, e.g. the smart logistics, smart grid, self-sufficient supply, or customer (Stock and Seliger, 2016). Such a concept towards a holistic resource efficiency in the sense of a circular economy is being described as one of the essential advantages of Industry 4.0 (Kagermann, Lukas, and Wahlster, 2015).

3.7 Match of Supply and Demand

To prevent waste by unnecessary inventory and storage costs, a perfect understanding of customer demand in terms of quantity and product features leads to a much better predictability through new possibilities like crowd forecasting based on advanced analytics (McKinsey, 2015). The use of such technologies to optimise the match of supply and actual demand can increase the accuracy of demand forecasting to more than 85% (see Figure 5).

Accurate demand forecasts lead to reductions in waste and, therefore, to a smoothly operating circular economy. In developed countries, this topic already caught the attention of the public as food is being dumped by retailers while at the same time people in other parts of the world do not have sufficient food supply.

3.8 Reducing Time to Market

Being the first supplier of a new product in the market can create value in terms of increased revenues and less competition. New technologies emerging with Industry 4.0, which enable faster and cheaper R&D processes, for example, concurrent engineering or rapid prototyping by using 3D-printing, can significantly reduce the time to market (McKinsey, 2015). Typically, the use of such technologies within R&D processes can reduce the time to market by 30%–50% (see Figure 5). Local Motors is already using this approach to drive value. It produces cars almost completely through 3D printing. They were able to reduce the development cycle from about 7 years to only 1 year, consequently reducing their R&D costs massively (Local Motors, 2015, Werner, 2015).

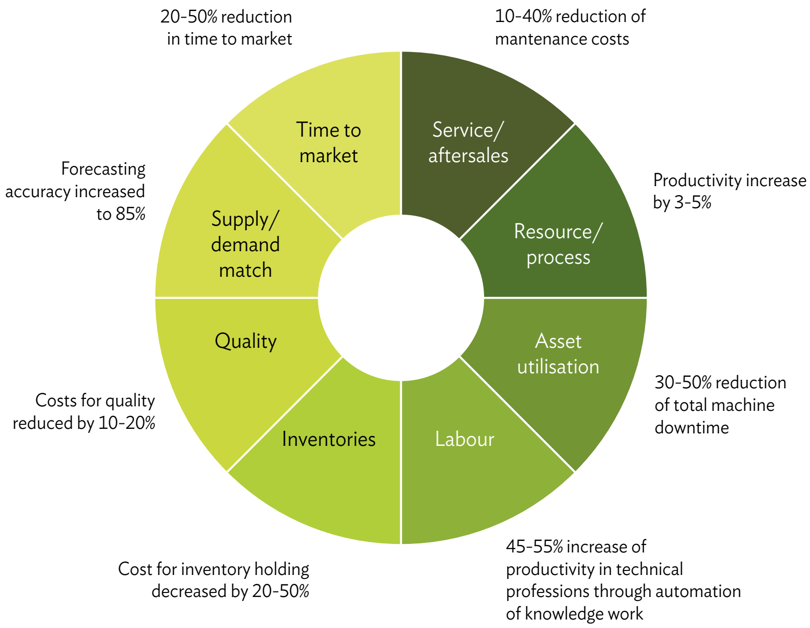
Reducing time to market also means faster learning if a product or process turns out to be less suitable for the circular economy. This means that the continuous improvement cycles are accelerated through the latest technology and practices to implement a circular economy.

3.9 Service and Aftersales

The sustainable design of processes addresses the holistic resource efficiency approach of Industry 4.0 by designing appropriate manufacturing process chains or by using new technologies (Stock and Seliger, 2016).

Innovative services lead to new possibilities of repairing products and to the chance to keep them operational longer. Manufacturing of products can be more cost effective when machines get a longer operational time, supported by maintenance services and repairs, e.g. through remote maintenance. In this case, it is possible to carry out error diagnosis and even repair without the necessity of a technician visiting the site (McKinsey, 2015). Average maintenance costs could be reduced by about 10%–40% through remote and predictive maintenance (see Figure 5).

Figure 5. Indicative Quantification of the Eight Value Drivers



Source: Authors' own representation based on McKinsey, 2015.

All eight value drivers are showing high improvement potentials within already existing production systems enabled by Industry 4.0. Which one of these value drivers will have the highest room for improvement is strongly dependent on the firm itself as well as the industry the company is operating in. To activate these value drivers and really exploit the potential they offer, it is necessary to prepare the company along three dimensions to get ready to take part in the fourth industrial revolution.

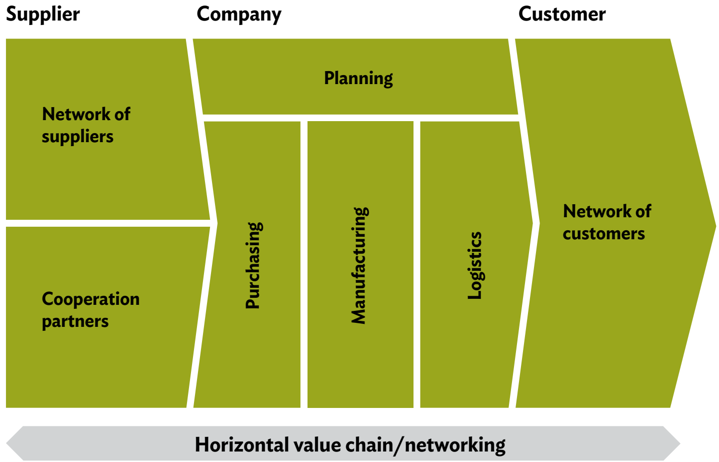
3.10 Improving Competitiveness Within Industry 4.0

The paradigm of Industry 4.0 is basically outlined by three dimensions: the horizontal integration across the entire value creation network; the end-to-end engineering across the whole PLC; and the vertical integration and networked manufacturing systems (Stock and Seliger, 2016; Acatech, 2013; Deloitte, 2015). To deliver the goals of Industry 4.0 and gain improved competitiveness, the features of the three dimensions described in the following subsections should be implemented.

3.11 Horizontal Integration

Horizontal integration characterises the cross-company and company-internal smart networking and digitalisation throughout the value chain of a PLC and between value chains of neighbouring PLCs (Stock and Seliger, 2016). The digitalisation of the horizontal value chain integrates and optimises the flow of information and goods from the customer over the whole corporation to the point of the supplier and vice versa (see Figure 6). Within this approach, all company-internal areas (e.g. purchasing, production, and logistics) will be connected and regulated together with all external partners as part of value creation (Koch et al., 2014).

Figure 6. Horizontal Value Chain



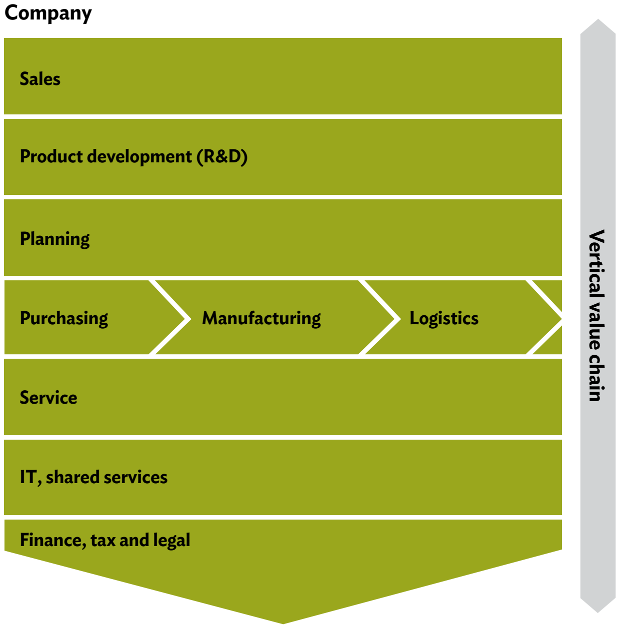
Note: Horizontal integration across value creation networks/supply networks.
Source: Authors' own representation based on Koch et al., 2014.

As the complexity of products and processes increase with Industry 4.0, concepts such as collaborative manufacturing and collaborative development environments are becoming important, especially for companies with limited resources like small and medium-sized enterprises. Within these collaborative networks, risks and resources can be shared and, consequently, the range of market opportunities can be expanded. Therefore, it is easier to adapt to volatile markets within such cross-company networks. But to reach an increased productivity within these inter-company value chains and networks, companies and their employees must communicate with various departments across company boundaries very efficiently. The prerequisite for the global optimisation of the production processes within or across company boundaries is the availability of product data throughout the entire network. To maintain global competitive advantage, companies will have to focus on their core competencies while outsourcing other activities within the network (Brettel et al., 2014).

3.12 Vertical Integration

Vertical integration specifies the intelligent cross-linking and digitalisation within the different hierarchical levels of a value chain. This will enable digital order processes and customer-specific product development, where an automated transfer of data into an integrated planning and manufacturing system can be assured. Furthermore, the associated value chain activities such as marketing and sales or technology development are integrated (Koch et al., 2014; Stock and Seliger, 2016; see Figure 7).

Figure 7. Vertical Value Chain



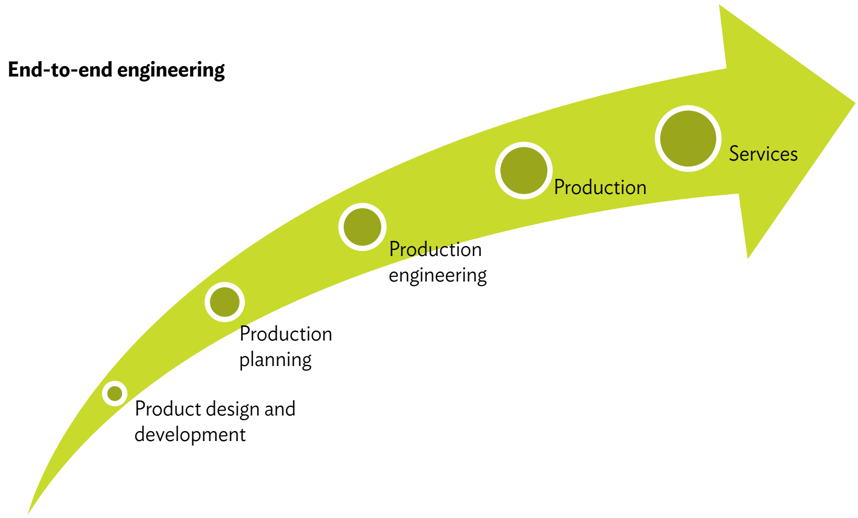
IT = information technology, R&D = research and development.
Note: vertical integration and connected production systems.
Source: Authors' own representation based on Koch et al., 2014.

With vertical integration, it becomes possible to have flexible and reconfigurable production structures, which can be adapted to each specific customer order or even to changing market requirements. These features are key enablers for manufacturers to stay competitive within highly volatile markets and it will allow them to reach fast and fault-free production (Stock and Seliger, 2016).
As better availability and integrated use of all relevant data through the cross-linking of all products, entities, and companies that are part of the value creation process are the base for Industry 4.0, the digitalisation of value chains is a premise to all companies to sustain their competitive ability. According to a study conducted by Strategy& and PricewaterhouseCoopers, where they interviewed 235 German companies, the digitalisation of value chains will increase tremendously within the following 5 years (Koch et al., 2014).

3.13 End-to-End Engineering

End-to-end engineering describes the intelligent cross-linking and digitalisation throughout the whole PLC, from the procurement of raw materials to the use of the product till its end of life (Stock and Seliger, 2016). This integrated engineering along the whole value chain promises high optimisation potential. Under this type of engineering, all entities that are part of the engineering process will be provided with real-time information. The advantage is that it encompasses both the manufacturing process and the manufactured product (see Figure 8).

Figure 8. End-to-End Engineering



Note: Digital patency of the engineering across the whole value chain
Source: Authors' own representation based on Acatech, 2013.

4. New Business Opportunities and Business Models

In Chapter 3, the value drivers of Industry 4.0 were described with a rather narrow focus on economic benefits through improved efficiency and cost reductions, and other improvements related to the existing business model. There are ways of creating new markets by reinventing the way things are done. They can be seen beyond pure competitiveness, as new market opportunities (Blue Oceans) can be discovered beyond traditional markets with high levels of competition (Red Oceans). Existing business models will change and new disruptive digital business models enabling, for example, mass customisation will emerge. Similar to the concept of re-engineering, business models and concepts can be imagined in a radically different way, based on the new possibilities of Industry 4.0.

In Industry 4.0, new evolving business models are highly driven by smart data for offering new services. This development can be exploited for the creation of new sustainable business models. Sustainable business models significantly create positive impacts or reduce negative impacts for the environment or society (Bocken et al., 2014). They can even fundamentally contribute to solving an environmental or social problem (Schaltegger and Wagner, 2011). In addition, sustainable business models are necessarily characterised by competitiveness in the long run (Schaltegger and Wagner, 2011). In this context, selling the functionality and accessibility of products instead of only selling the tangible products will be a leading concept (Stock and Seliger, 2016).

This creative and disruptive process can be imagined at an early stage of development, even though there are already four new types of business models emerging. All four of them are leveraging disruptive technologies and providing opportunities for current and new players.

1. Platform models have in common products, services, and information that are exchanged on predefined communication streams. Further, there is the option for an interaction platform in the function of a marketplace, which means the technological conditions are provided to connect various parties and coordinate those transactions. Another category is called the technology platform or ecosystem. In this case, the company is facilitating the further development of other company's own technologies or products.
2. As-a-service-business model means that organisations are moving from selling equipment to a pay-by-usage model. In this case, machinery equipment is in the factory of the manufacturer, paid per use and not as a one-off payment, and not owned by that company. Another less radical shift in the role is related to a subscription-based model, which ensures recurring revenues for the provider of the service (continuous revenues instead of one-off payments, as well as pay-by-usage which can transform fixed costs into variable costs).
3. Intellectual property rights-based business models follow the idea of generating value from their proprietary data or intellectual property of the corporation. This could be through licensing fees or by providing add-on services to the core product (example, systems, application, and products consulting services in addition to software revenues).

4. Data-driven business models are new ways of gathering and using data that can be leveraged by using a data-driven business model. The two main approaches to such models are either direct or indirect. Google is an example of a direct monetisation of data, as the primary product creates the data that is further analysed and used for target advertising. The indirect use of the data refers to the insights from the data to identify and target specific customer needs and characteristics. Examples could be pricing micro-segmentation or use-specific machine maintenance plans (McKinsey, 2015).

In a circular economy, all four new categories of business models provide opportunities to generate growth in revenues and employment for people without the linear increase in physical materials consumed. Improvement in the usage of data, machinery equipment, software, and other resources can reduce the need for such limited resources and reduce the ecological footprint of production.

Furthermore, jobs eliminated by Industry 4.0 can be counter-balanced by new job opportunities in the new business models. This refers to the social dimension of sustainability.

Case example: A European example for Industry 4.0 implementation for the circular economy is Elanders Group, a printing and fulfilment company with headquarters in Sweden. It also has strong operations in Germany and other countries throughout the world. Elanders calls itself a specialist in information management and distribution. The company offers cost-efficient and innovative solutions that meet customers' needs for printed materials both locally and globally. Elanders has developed advanced, user-friendly and internet-based order platforms that streamline the process of order to delivery and enable customised just-in-time or sequenced deliveries (Elanders Group, 2016a). Furthermore, Elanders is one of the few companies in the graphics industry that can follow multinational customers over country borders and offer comprehensive solutions that include printed matters and other related services such as kitting and packing or just-in-time and sequence deliveries. Facilities in Brazil, China, Hungary, India, and Italy are good examples of how Elanders has followed its customers out into the world. Some of its core products are manuals and marketing materials, personalised prints, and print-on-demand. Small batch digital printing of user manuals for the permanently increasing product variety of the automotive industry is an example of improvements in efficiency, reduction of inventory levels, and reduction of waste through outdated or inadequately configured user manuals. Rather than producing a large-volume mass-printing product at price levels of a commodity, Elanders has changed to a business model that follows the just-in-time production needs of the automotive industry (Elanders Group, 2016b). Such business models could be also transferred to 3D printing, where the digital printing products will be substituted by 3D customised products.

5. Challenges and Obstacles When Implementing Technologies of Industry 4.0

There are some obstacles and challenges to the implementation of emerging technologies in the context of Industry 4.0, like the need for qualified personnel (e.g. specialists for data analysis), concerns about data security (cybersecurity), and the need for global uniform standards (Koch et al., 2014).

By using technologies like IoT, these wireless smart devices face threats from the proliferation and sharing of data. Therefore, deciding a common strategy and policy for the future is a priority for the European Union (EU). There is concern about the privacy of citizens through the use of, for instance, wireless medicards or passports with built-in chips, as well as concern about the misuse of sensitive or secret data, for example, production parameters from manufacturing companies (Sundmaeker et al., 2010). The saving and sharing of data through, for example, cloud systems, and the networking and integration of several different companies through value networks will comprise a lot of risks such as industrial espionage, attacks by hackers, and data theft, which could have a devastating impact on Industry 4.0. Therefore, companies need an appropriate cybersecurity strategy and a set of common standards such that partnerships can become a reality without bearing too much risk for its participants (Deloitte, 2015). Companies, the German government, and research institutes are aware of these threats. Consequently, there are collaborations where standardisation and security are under development. One example is the Industrial Data Space, which enables a reliable exchange of data with common rules for all firms. This initiative aims to create a secure data space and develops guidelines for the certification, standardisation, and utilisation of data (Industrial Data Space e.V., 2016).

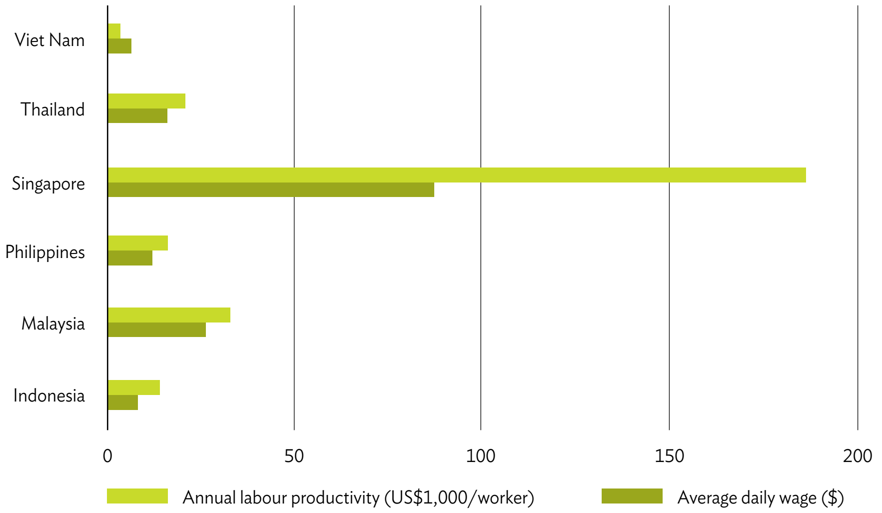
In addition to doubts about data security, the high investments and vague economic feasibility for new Industry 4.0 applications represent a challenge for many firms, especially small and medium-sized enterprises. Also, many German companies do not have prepared concrete implementation plans because they avoid the extensive and complex transformations that will come up with the forthcoming industrial revolution. Therefore, there is a need for more transparency and intersectoral exchange of experiences (Koch et al., 2014).

In line with Industry 4.0, there will also be a change in the required qualifications of employees (Koch et al., 2014). On the one hand, there will be less heavy and repetitive work in future manufacturing systems as this work will be transferred to the manufacturing system itself (e.g. robots). On the other hand, there will be more skilled work needed as production becomes increasingly autonomous and agile. That is why there is a higher need for creative working processes like strategic planning or R&D because there will be new skills required to introduce and implement all new and innovative business opportunities offered by Industry 4.0 (Deloitte, 2015). For these more complex tasks, good qualifications are needed, which can be implemented already into prospective education. One can think about a more interdisciplinary education system, where pupils already get familiarised with techniques and information technology needed for a digitalised professional life. In addition, workers whose tasks are now done by robots should be further trained to be able to carry out more complex tasks, take over more responsibilities, and act on their own initiatives (Acatech, 2013). A more recent study of Acatech claims that the strengths of Germany can be seen in the areas of sustainability, training and education, market access, and security. Also, a lot had been done recently on standardisation. However, according to the authors, the creation of digital business models and the spirit of pioneering those are missing in Germany. Access to capital and the experience to develop user-friendly products are further challenges for Germany (Acatech, RWTH Aachen, Universität Paderborn, 2016).

6. ASEAN and Industry 4.0

ASEAN encompasses 10 economies that are at vastly different stages of development, and is already a major manufacturing hub. It has a window of opportunity to capture a greater share of global manufacturing, especially for multinationals that are seeking a lower cost base. The availability of low-cost labour in Cambodia, Indonesia, Lao People's Democratic Republic, Myanmar, and Viet Nam can be a competitive advantage. The average cost of labour is about US$7/day in Viet Nam and US$9/day in Indonesia. However, the advantage of low labour costs in these countries is undermined by weak output per worker (see Figure 9).

Figure 9. ASEAN's Labour Cost and Productivity



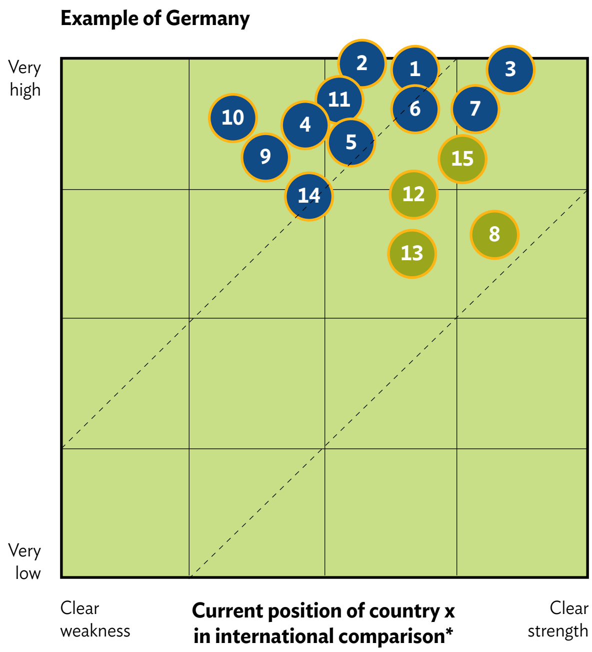
Source: Authors' own representation based on APO, 2015.

To stay competitive and accessible in an increasingly connected and collaborative global supply chain, and to move towards a digital society and the related economic benefits, ASEAN countries need to identify their specific vision regarding Industry 4.0. Key questions to be addressed are: How can they be a competitive player? Should less-developed countries do something in between or step-by-step? What are country-specific drivers towards Industry 4.0?

Considering that both highly industrialised countries (e.g. Singapore) and much less industrialised countries (e.g. Cambodia and Myanmar) are ASEAN member countries, the current initial situation of ASEAN countries for Industry 4.0 is quite diverse. The policy community also has concern about the relatively high share of the agricultural sector and the lower share of the manufacturing sector (Kathiravale, 2016). Therefore, a careful analysis of the status quo for each country would need to be done. In addition, a vision of a desirable future state should be created and key areas of action to focus on must be identified. Based on the results, new business models for the value creation from waste materials can be designed by managing waste holistically and increasing coordination of waste management via a waste management platform (Kathiravale, 2016). State-of-the-art Industry 4.0 technology can be used for an efficient and effective monitoring and management of waste processes rather than implementing processes with a high degree of bureaucratic overhead.

A good methodological basis for analysis is provided by the recent study of Acatech, which is based on interviews with experts in 13 countries (Acatech, RWTH Aachen, Universität Paderborn, 2016). A total of 15 areas of focus for successful implementation of a desired future state were identified. This study suggests that four out of those 15 areas are indicating that the country is on the right track. The other 11 are areas in which there is a need to focus action on in the very near future. Figure 10 illustrates the results for the example of Germany (Acatech, RWTH Aachen, Universität Paderborn, 2016).

Figure 10. Future Importance of Focus Theme



Focus themes

1. Security
2. Standards, migration, and interoperability
3. Sustainability
4. Usability
5. Field data collection and analysis
6. Material and information flow
7. Education and qualification
8. Societal acceptance of production
9. Pioneer spirit
10. Business models
11. Organisational culture and flexibility
12. Degree of internationalisation
13. Political support and restrictions
14. Access to capital
15. Access to markets of demand and supply

Note: Critical focus themes indicate needs for action. Items coloured green are not considered for focused action.
Source: Authors' own representation based on Acatech, RWTH Aachen, Universität Paderborn, 2016.

Depending on the degree of technological maturity of a country as well as on the comparative labour cost versus the cost and accessibility of capital, the optimal implementation of Industry 4.0 solutions can be quite different. While a high degree of automation might be most useful in high-labour-cost countries like Singapore, less automation might be more competitive and suitable in lower-labour-cost countries like Myanmar or Cambodia. Nevertheless, labour will need to be documented and monitored by sensors providing data to the smart data system. For this purpose, augmented reality devices like smart glasses (e.g. Google glasses) can compensate for deficits in the skill levels of employees, improve quality and efficiency of operations, and document manual processes to reach the target of seamlessly traced production processes for smart data analysis. Such tracking of manual processes can help production suppliers in ASEAN region fulfil the documentation needs for sustainability reports of global brands, as required, for example, in the textile and shoe industries (e.g. Nike, Adidas, and Hugo Boss).

In manufacturing, technologies like IoT could increase profit margins and reduce costs, potentially creating US$20 billion to US$45 billion of annual impact on ASEAN by 2030 (Woetzel et al., 2014). The use of IoT could improve demand for forecasting and production planning, leading to better customer service and higher profit margin. Most of the ASEAN participants in the recent workshop on Industry 4.0 conducted by the Economic Research Institute for ASEAN and East Asia mentioned that they are optimistic about Industry 4.0's ability to improve forecast accuracy that could increase revenue and resource efficiency. On the cost side, analysing detailed real time data on everything, from supplier's inventory and shipments in transit to downstream consumer demand, allows manufacturing companies to tighten inventory control and maximise production capacity. However, many manufacturing companies in ASEAN are still behind in applying the available IoT for their operations. Beyond awareness of opportunities, skill gaps appear to be an important barrier. Companies will need to recruit or groom three types of talents: workers with deep analytical skills to execute IoT, managers and analysts who know how to request and consume these analyses, and technology support personnel focused on implementation.

On the implementation of a business model for the circular economy, we can look at the example of Fuji Xerox Asia Pacific. Its project for a sustainable value chain shows how the company is transforming its operations in ASEAN from a printer manufacturer to a document services and communications solutions provider. By looking at the value chain in a holistic way, the corporation intends to reduce paper use and provide green monitoring and reporting for its customers. This is done by digital alternatives to paper like DokuWorks, by introducing scanning and workflow technologies, and by providing mobile solutions. To reach a greener, smarter, and more efficient workplace, the company is working with people, processes, and technology (Fuji Xerox Asia Pacific, 2016). One element of the circular economy helps to minimise the economic impact of resource scarcity. Considering history's most dramatic resource demand shock and emerging signs of resource scarcity, improving materials productivity is a crucial response at a company level and a self-preserving reflex at a market level.

Industry 4.0 will be having a similar groundbreaking impact on our lives and work, business models, and technologies like industrialisation, mass production, and automation. To become more competitive and an attractive economic region for business partners throughout the world, ASEAN member countries need to consider creating a similar initiative as the 'platform Industrie 4.0' in Germany. It would be helpful for ASEAN member countries to learn from other economies throughout the world and to identify suitable standards, adjust, and develop them together in a regionally suitable way. By working together, not each country would have to invest in this on its own. ASEAN could expand collaboration with other regions like the EU and the US that are cooperating together. This would also improve and speed up communication between policy, industry, science, and education to get recommended actions implemented in a timely manner and included into the extremely important education of future generations of employees, managers, and leaders at all levels. For developing economies like Indonesia, Thailand, the Philippines, and Malaysia (Ramanathan, 2016), the digital economy will enable them to connect to multinational firms' production networks. With less legacy infrastructure and fewer investments in maintaining older technologies, some of them can leapfrog towards more efficient technology rather than upgrade existing equipment.

Nevertheless, we must keep in mind that the introduction of such technology needs to be the end – not the beginning – of a well-considered chain of thoughts and actions. It means powerful IT systems need well-structured processes, which implement a corporate strategy and a successful business model. Strategies and business models have to target future potentials for success (Acatech, RWTH Aachen, Universität Paderborn, 2016).

Given ASEAN's unique context, several IoT technologies will be attractive for certain sectors but less relevant for the region. Many ASEAN member countries (with notable exception of Singapore) are starting from a relatively low base in terms of digital infrastructure, adoption, and innovation. The Readiness Index shows that only Singapore, Malaysia, and Brunei are amongst the world's top 50 countries for the quality of their digital environment and the extent of their technology usage. While it highlights the challenges ahead, it implies that the opportunity for technology-driven growth is larger for ASEAN than advanced economies.

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