Petrillo, Antonella (Ed.); Cioffi, Raffaele (Ed.); De Felice, Fabio (Ed.)

Book

Digital transformation in smart manufacturing

Reference: (2018). Digital transformation in smart manufacturing. Rijeka, Croatia : InTech.
doi:10.5772/intechopen.69336.

Chapter 1

Fourth Industrial Revolution: Current Practices, Challenges, and Opportunities

Antonella Petrillo, Fabio De Felice,
Raffaele Cioffi and Federico Zomparelli

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.72304

Abstract

The globalization and the competitiveness are forcing companies to rethink and to innovate their production processes following the so-called Industry 4.0 paradigm. It represents the integration of tools already used in the past (big data, cloud, robot, 3D printing, simulation, etc.) that are now connected into a global network by transmitting digital data. The implementation of this new paradigm represents a huge change for companies, which are faced with big investments. In order to benefit from the opportunities offered by the smart revolution, companies must have the prerequisites needed to withstand changes generated by "smart" system. In addition, new workers who face the world of work 4.0 must have new skills in automation, digitization, and information technology, without forgetting soft skills. This chapter aims to present the main good practices, challenges, and opportunities related to Industry 4.0 paradigm.

Keywords: Industry 4.0, innovation, opportunities, digitalization, economy

1. Introduction

In recent decades, producers and suppliers of goods and services have improved the quality of their organizations through the use of innovative technologies [1]. This is because the industry is undergoing transformation and evolution toward complete digitization and the intelligence of production processes to ensure high efficiency [2]. To achieve these goals, it is necessary to implement new technologies for the automation of industrial processes. These concepts are the pillars of the fourth industrial revolution called "Industry 4.0" [3]. The fourth industrial revolution was developed in Germany in 2013 but is spreading rapidly in Europe and the world as a whole [4]. This new work model focuses on the integrated man-machine approach through “sustainable” production.

The Industry 4.0 is based on the concept of smart factory, where the machines are integrated with men through cyber-physical systems (CPS). In other words, Industry 4.0 is a new level of organization that manages and controls the whole value chain of personalized products to satisfy customer needs [5]. Digitalization is the most important element in Industry 4.0 because it allows to connect man and technology [6].

Industry 4.0 covers three fundamental aspects:

1. *Digitization and increased integration of vertical and horizontal value chains*: development of custom products, customer’s digital orders, automatic data transfer, and integrated customer service systems.

2. *Digitization of product and service offerings*: complete descriptions of the product and its related services through intelligent networks.

3. *Introduction of innovative digital business models*: the high level of interaction between systems and technology opportunities develops new and integrated digital solutions. The basis of industrial Internet is the integrated and real-time availability and control of systems across the enterprise.

The effect is a radical transformation of traditional industries that are changing their “approach” to the work. It means the use of new production technology, new machinery, new materials, and new inputs. In this context, knowledge has become the crucial input. Furthermore, a complete integration between the cyber and physical dimensions is occurred.

Western civilization has passed through three stages of the industrial revolution, and the fourth revolution is in progress. An industrial revolution can be defined as a disruptive leap in the industrial process [7], a development that produces fundamental changes in the society and the economy [8].

Figure 1 describes the main phases that characterized industrial revolutions. The first industrial revolution was developed in the eighteenth century due to mechanical production obtained by water and steam, with the development of machine tools and an improvement of their efficiency. The second industrial revolution developed with the arrival of electricity and mass production, theorized by Smith and Taylor and implemented by Henry Ford in his Detroit factory for the production of the Model T. The third revolution was characterized by machine automation through the use of electronics and IT applied in the production processes [9].

The fourth industrial revolution integrates IT systems with physical systems to get a cyber-physical system that brings the real world in a virtual reality. There are also several opposing opinions. For example, *The Economist* [10] stated that the fourth industrial revolution is only an evolution of the third industrial revolution. Harald Krüger, Chief Production Officer at the BMW Group, instead, considers this development not as a fundamental revolution taking a huge digital leap forward. He explained that it is a constant development

http://dx.doi.org/10.5772/intechopen.72304

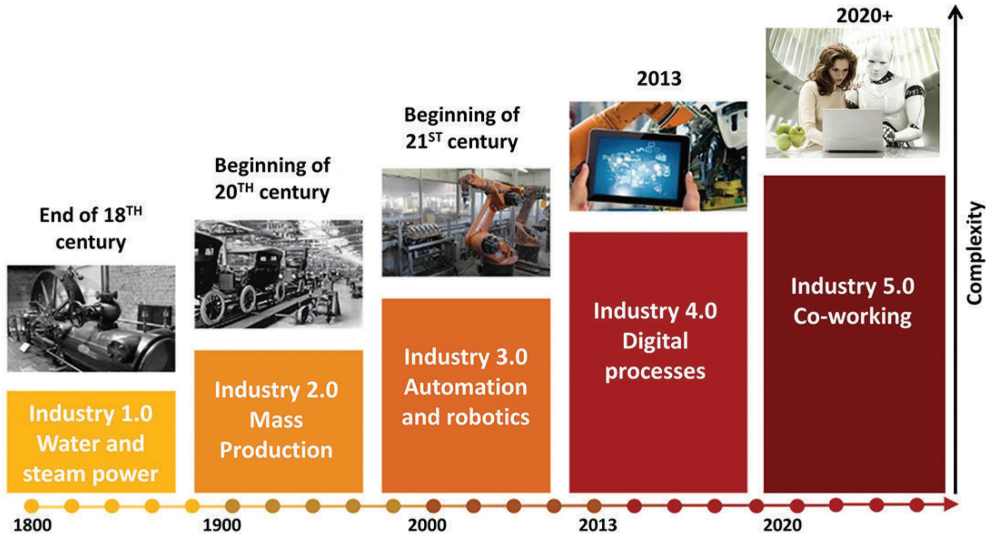

Figure 1. Industrial revolutions.

of technologies that will enable companies to achieve higher productivity, flexibility, as well as enhanced product and service qualities [11]. Roland Berger [12] also mentioned that there are slow and steady changes in some areas and described some evolutionary effects of this development. However, the majority of experts, including those in leading companies such as McKinsey & Company, Boston Consulting Group, Capgemini Consulting, Accenture, and General Electric have clearly pointed out the fundamental change of this development considering this transformation toward digital manufacturing as a new and considerable industrial revolution with tremendous effects on countries, economics, businesses, and human labor.

The current industrial revolution is characterized by the collaboration of intelligent machines, storage systems, and production systems into intelligent networks, merging the real and virtual worlds in cyber-physical systems (CPS) [13]. CPS are the integration of IT system with mechanical and electronic components connected to online networks that allow the communication between machines in a similar way to social networks [14]. These innovative technologies enable factories to become “smart,” resulting in productions of customized products on an industrial scale while providing many opportunities for improvements in operational flexibility and efficiency. Japan begins to talk about the fifth industrial revolution coming, which will be based on cooperation between man and machine.

The rest of the chapter is organized as follows: Section 2 presents state of the art on the “Industry 4.0”; Section 3 analyzes the main principles of digital technologies and industrial transformations. In Section 4 the main opportunities related to Industry 4.0 are analyzed. Then, Section 5 presents qualification and skills operator required for Industry 4.0. Finally, in Section 6 the main conclusions of the chapter are presented.

2. State of the art on "Industry 4.0"

A comprehensive overview of the state of the emerging industrial revolution is essential to understand the *phenomenon* around the world. To this purpose an investigation on Scopus database, the largest abstract and citation database of peer-reviewed literature, was carried out. The methodological approach used for literature review survey is shown in **Figure 2**.

Search string used in the literature survey was "Industry 4.0." The string was defined according to the standards of Scopus database. Articles, conference, and book chapters in which the string was found in *keywords* were analyzed. The analysis on Scopus pointed out that from 2012 (the year in which the first article was published) until October 2017 (the period of research), there is a constant, growing interest on this topic. Considering this time period, the Scopus database returns 886 results related to the topic "Industry 4.0." From 2015 onward scientific production has increased considerably, as shown in **Figure 3**.

The survey confirmed that most of the publications are German. It is worthy to note that German publications are quadruple compared to Chinese publications, and compared to Italian publications, the value is seven times more as shown in **Figure 4**.

The search was refined considering only articles. The research shows 274 published articles since 2012. Since 2015, there is a growing trend of publications on these issues. This strong interest is certainly due to the strong attractiveness of the issues of smart manufacturing both

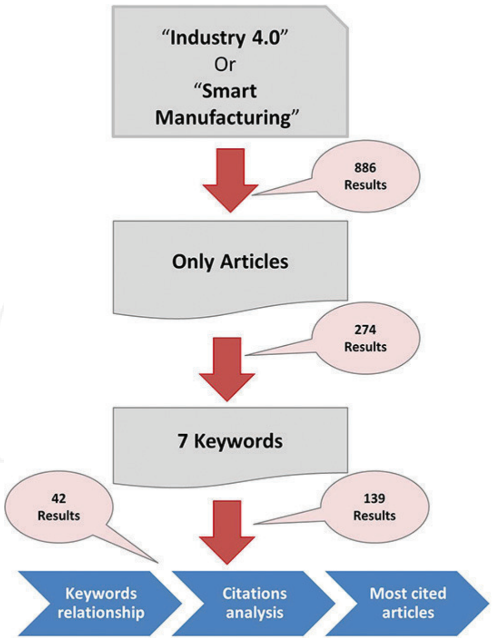

Figure 2. Literature review methodological approach.

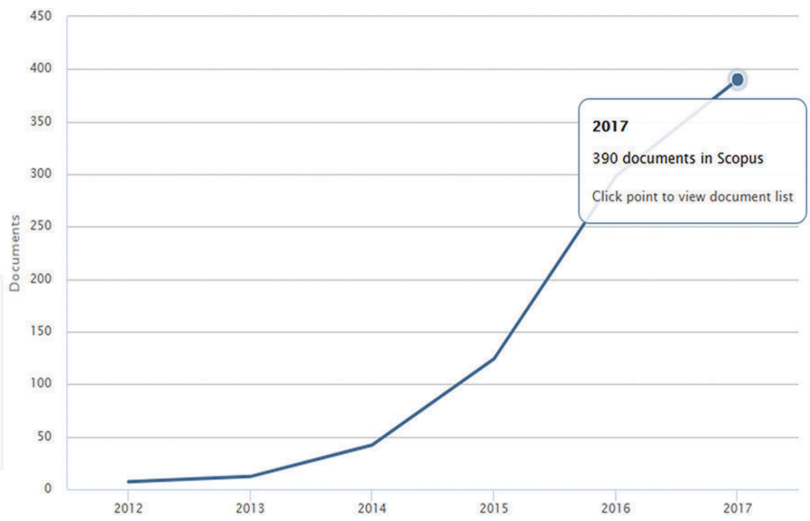

Figure 3. Documents by year.

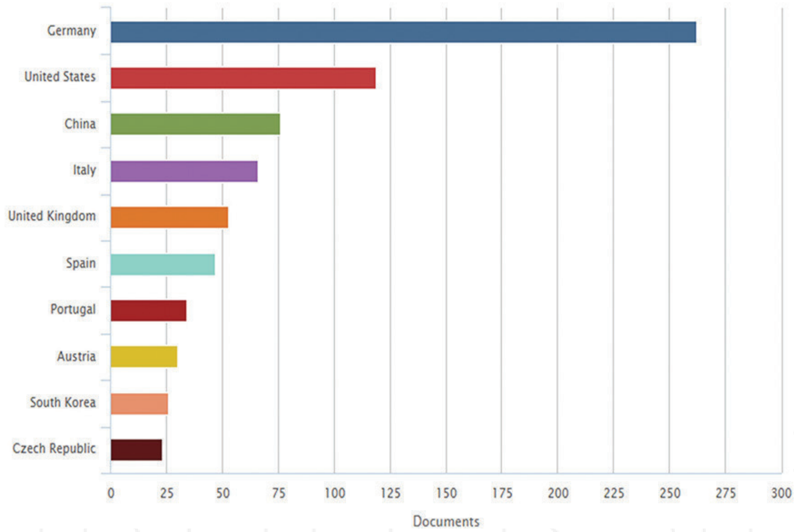

Figure 4. Documents by country.

from a research and business point of view. The analysis pointed out that 73% of the analyzed publications refers to engineering issues, 39.4% refers to communications issues, and 20.4% refers to business process management. Analyzing the 274 articles found, the search was more refined using seven specific keywords that characterize "Industry 4.0" as detailed below:

- *Cyber-physical systems*. There are 55 articles (20.07%) that contained the keyword (CPS) between the keywords. The first publication dates back to 2012, but since 2015, a "stable" research on this issue has started.
- *Big data or digitalization or digital*. There are 43 articles (15.69%) that contained the previously defined keywords. The first publication dates back to 2015, and in 2016–2017, there was a growing, extremely positive trend.
- *Internet of things (IoT) or wireless*. There are 50 articles (18.25%) that contained the previously defined keywords. The first publication dates back to 2016, while in 2017 there has been a downward trend of about 10 publications. This trend could turn out to grow, as several months remain missing at the end of 2017.
- *Automation or artificial intelligence or robotics*. There are 18 articles (6.57%) that contained the previously defined keywords. The interesting publications for the analysis are from 2015 to 2017 which show a positive trend.
- *Additive manufacturing or 3D printers*. There are six articles (2.19%) that contained the previously defined keywords. The first release dates back to 2014; there are other publications until 2017, but the number is very limited.
- *Cloud*. There were 10 articles (3.65%) that contained the previously defined keywords. The first release dates back to 2015. There are no such publications for 2017.
- *Simulation/augmented/virtual reality*. There were 10 articles (3.65%) that contained the previously defined keywords. The first publication dates back to 2012. But in the 2-year period 2016–2017, research began to produce more complete and complete documents.

Figure 5 describes the number of articles classified for each keyword.

In the rest of the papers, other keywords are cited. Furthermore, it is worthy to note the relationship between different keywords in the same article. The results are shown in **Table 1**. The most important relationships are developed between cyber-physical systems and big data systems.

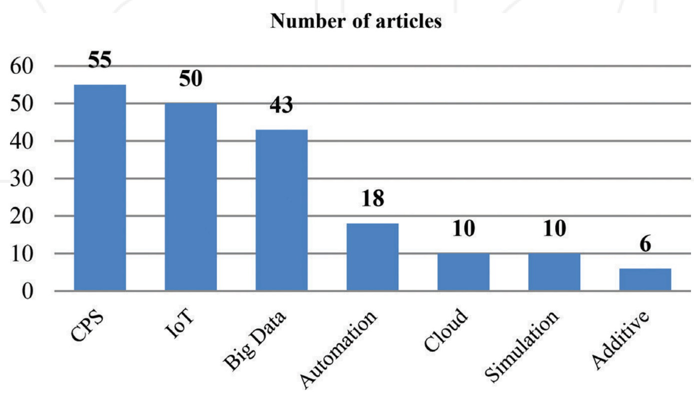

Figure 5. Number of articles classified for keywords.

	CPS	IoT	Big data	Automation	Cloud	Simulation	Additive
CPS		8	21	2	1	3	1
IoT			9	1	—	1	3
Big data				3	—	6	1
Automation					—	1	2
Cloud						—	—
Simulation							—
Additive							

Table 1. Relationship between keywords.

Authors	Title	Year	Citations
Lee, J.; Bagheri, B.; Kao, H.	A cyber-physical systems architecture for Industry 4.0-based manufacturing systems	2015	258
Davis, J.; Edgar, T.; Porter, J.; Bernaden, J.; Sarli, M.	Smart manufacturing, manufacturing intelligence, and demand-dynamic performance	2012	103
Posada, J.; Toro, C.; Barandiaran, I.; Döllner, J.; Vallarino, I.	Visual Computing as a Key Enabling Technology for Industrie 4.0 and Industrial Internet	2015	45
Kang, H.S.; Lee, J.Y.; Choi, S.; Kim, B.H.; Noh, S.D.	Smart manufacturing: past research, present findings, and future directions	2016	38
Yue, X.; Cai, H.; Yan, H.; Zou, C.; Zhou, K.	Cloud-assisted industrial cyber-physical systems: an insight	2015	19

Table 2. Most cited articles.

Table 2 shows the most cited analyzed articles. In detail, the most cited article is proposed by Lee et al. that present an integrated five-level system for the implementation of a cyber-physical system [1]. Then, Davis et al. present the smart manufacturing approach based on intelligent cyber-physical components for smart organization management [15]. In 2015, Posada et al. describe the positioning of visual computing within the smart manufacturing system to indicate specific future scenarios [16]. In 2016, Kang et al. develop a literature review analysis identifying and analyzing different articles related to smart manufacturing to create a clear view of existing technologies, practices in companies, and future trends [17]. Finally, Yue et al. analyze the development of industrialization and technology digitization by presenting a model supported by a cloud system for managing a sustainable industrial system [18].

3. Digital technologies and industrial transformations

The key objective of Industry 4.0 is to be faster and to drive manufacturing to be more efficient. The main technology used in the context of Industry 4.0 is **cyber-physical systems (CPS)** [19]. CPS are considered a Key Enabling Technology (KET) in the fourth industrial revolution.

CPS are a set of different enabling technologies, which generate a stand-alone, intercom, and intelligent system and, therefore, can facilitate integration between different and physically distant subjects. This system enables three sequential scenarios: *data generation and acquisition*, *computation and aggregation of previously acquired data*, and finally *decision support*. This definition includes the presence of interconnected objects which, by means of **sensors**, **actuators**, and a **network connection**, are able to generate data, thus reducing the distances between the various subjects involved. Therefore, a CPS can be defined as a system in which physical objects are required to be flanked by their representation in the digital world; are integrated with elements that are capable of computing, memorizing, and communicating; and are networked with each other [20]. The functionality of a CPS can be summarized in five levels, as defined below:

- **Level #1. Smart connection**: The ability to manage and acquire data made available in real time thanks to intelligent sensors and to transfer them with specific communication protocols
- **Level #2. Data-to-information conversion**: The ability to aggregate data and convert it to value-added information
- **Level #3. Digital twin**: The ability to represent real time in a digital reality
- **Level #4. Cognition**: The ability to identify different scenarios and support a proper decision-making process
- **Level #5. Configuration**: Provides feedback on physical reality from virtual reality and applies corrective actions to the previous level

Following the development of CPS, the fourth industrial revolution is characterized by the use of specific enabling technologies. The main nine technologies are described below and depicted in **Figure 6**.

Big data is certainly one of the most important technologies adopted in Industry 4.0. It is related to the large collection, processing, and analysis of structured and unstructured data with intelligent algorithms. It has recently become a topic widely debated in the business and university world, as it offers a number of new opportunities for businesses. Another important technology is **cloud computing** that allows to manage huge data volumes in open systems and ensure real-time communication for production system. Cloud computing allows access to information from anywhere in the world at any time, thus increasing flexibility [21]. In intelligent factory, data are transmitted digitally, so **cybersecurity** plays a key role in the new industrial revolution. IT security systems are important to enable the full potential of the other technologies. Industry 4.0 includes the use of **automated robots** managed directly by the intelligent factory and connected to the rest of the enterprise system. Processing is automatically handled by cyber-physical systems. Generally, automatic robots are used for ergonomically difficult or highly tiring jobs. The evolution of technological systems and the increasingly personalized demands of customers have led to the evolution of **additive manufacturing** techniques and 3D printing. Through this technique, it is possible to construct prototypes but also finished products in three sizes for the most different purposes. With prototypes it is possible to test the material while the finished products are used. In particular,

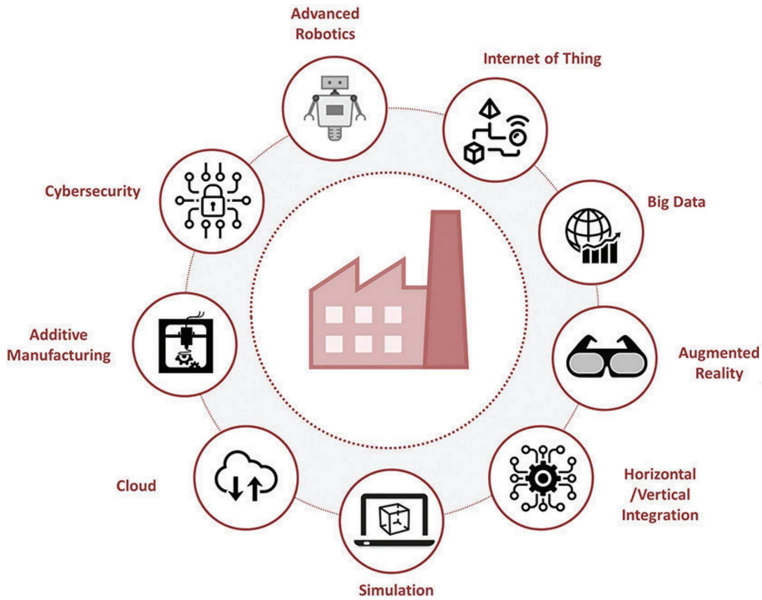

Figure 6. Enabling technologies for Industry 4.0.

3D printing for the production of finished products is used for highly personalized products, such as biophysical part or parts for cars of formula 1. New educational models 4.0 exploit increased reality technology, through **augmented reality**. Through virtual reality it is possible to educate operators, by teaching the right operations to do for maintenance or machine setup. The augmented reality system aims to replace old paper manuals that are difficult to understand. Through **horizontal and vertical integration** technology, it is possible to cross company data integration based on data transfer standards. In other words, computer and command processes are increasingly networked and integrated.

Finally, **simulation systems** and software are also very much used. Through these tools it is possible to simulate business systems and manufacturing processes by analyzing system input and output in real time and obtaining a detailed report about the process under study.

Industry 4.0 has developed a profound impact on society, factories, household, public sector, economies, etc. There are developing countries that are already preparing for and adopting strategies regarding Industry 4.0, such as China and India. A major challenge for developing countries is to reverse their strategy. In the past, they have pointed to low labor costs. With the advent of Industry 4.0, this is not possible because it is necessary to have highly specialized operators. Industry 4.0 offers opportunities, such as increased productivity, reduced waste, and promotion of the circular economy and more sustainable patterns of production and consumption [22].

Industry 4.0 requires different **prerequisites** for its application. Digital skills are definitely the most important factors. In addition, other important elements are automation and big data analysis that connect all stakeholders of a system and create a smart network that transmits real-time data. The correct implementation of a 4.0 system within a company depends on its ability to respond to change and innovation management.

The most important steps for supporting Industry 4.0 are:

- Step#1: Create awareness of the importance of innovation.
- Step#2: Educate the innovation management.
- Step#3: Identify potential improvements.

Another key prerequisite for implementing system 4.0 is related to the skills of operators (the last paragraph analyzes this topic in depth).

It is crucial to distinguish the expected **changes** with the implementation of the 4.0 systems. In this case it is considered the change of a developed country, developing country, business manufacturing, and research organization.

For **a developed country**, the implementation of 4.0 systems involves several challenges:

- The need for experimentation and learning, to give a way for companies to strengthen their business
- Data explosion, to send information more and more quickly and increase data volume
- Transformation of the workforce, integrating the system operators with new skills that enable it to manage work digitally with the help of cyber-physical systems

There are three major challenges for **developing countries**:

- Training of operators with specific skills in managing digital jobs.
- Scalability. There are few companies that have now implemented industry-leading 4.0 systems.
- The need for funding to start planning at the national or regional level for the implementation of systems 4.0.

The implementation of an Industry 4.0 system involves significant changes to **business manufacturing.** Firstly, it is necessary to attract strong investments, as the industrial Internet is expecting a great digitization and therefore a strong investment [23]. In addition to investments, it is important to promote strong leadership practices to promote the proposed changes. If the company is not open to change, it will fail. Another major obstacle to the digitization process is the inability to predict the return on investment, and this pushes many companies to invest.

According to Accenture and General Electric [24], a major change concerns big data analytics, since all operations will be managed by intelligent sensor systems, which will have to transmit huge volumes of data in a shorter time. The task of the operator will be to capture and analyze the data [25]. Companies should take advantage of the opportunities offered by CPS to generate added value from the collected data to meet customer needs.

Further challenge for companies will be the security of computer data. Standard will be needed to ensure communication between intelligent systems by avoiding any external intrusion. Companies face the challenge of ensuring that their operations are safe to avoid data leaks that could compromise their competitiveness and include the loss of confidential information on major customers.

Companies implement 4.0 systems that have been developed and tested by **research organizations**. Therefore, it is crucial to invest and progress technologically in research centers that are the lifeblood of the industrial system.

4. Opportunities of Industry 4.0

In Germany, Industry 4.0 was born in the direction of developing a collaboration of all stakeholders. Now, a new phase has started that aims to overcome national borders and establish new international collaborations, especially at the European level.

Figure 7 shows the main initiatives for Industry 4.0.

From a PWC analysis on a sample of 235 European companies (**Figure 8**), it is noted that an average about 3.3% of 4.0 investment revenue is invested in Industry 4.0 applications [26].

Only a quarter of the surveyed companies do not have the skills related to Industry 4.0. Intelligent industrial solutions enable to improve efficiency and reduce costs across the value chain. The investments of the analyzed companies correspond to 140 billion euros. Of these, 3.9% is intended for information and communication, and 3.5% is for industrial production and engineering (**Figure 9**).

Investment priority shows the supply chain at first, followed by engineering and services, while distribution takes on lesser values (**Figure 10**).

In 5 years, more than 80% of companies will have to digitize their value chain. The industrial Internet has now been added to the agenda of the majority of companies. One-fourth of the respondents already classify the current degree of digitization of their value chain as high. In concrete terms, this means that most of the companies are already using or have implemented industrial Internet solutions in different divisions (**Figure 11**).

Industry 4.0 affects different sectors, and this is one of its strengths. The major industrial sectors examined by Accenture and General Electric [27], which are heavily influenced by the industrial revolution, are manufacturing, oil and gas, power generation/distribution, railway, and mining.

The **economics opportunities** of Industry 4.0 are wide and affect the entire economies and countries. Several studies and figures have been published in recent years illustrating the value of these new developments. A survey developed by Accenture [28] predicts the IoT

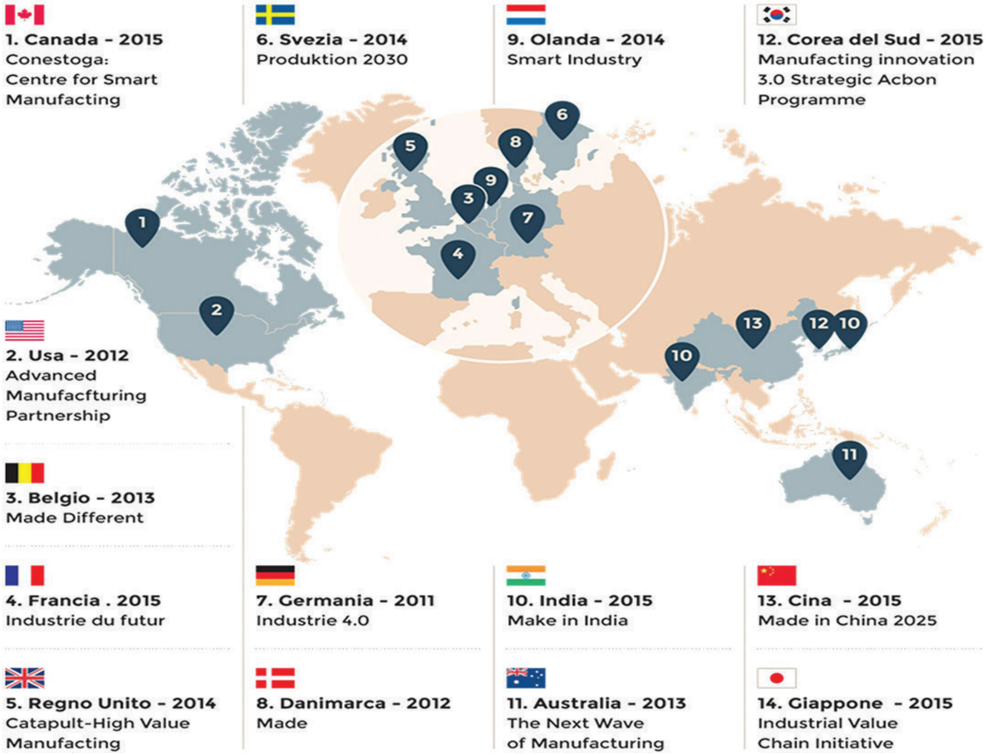

Figure 7. Main initiatives for Industry 4.0 (source: IL sole 24 Ore magazine).

value for countries including the United States, China, Germany, and the United Kingdom by 2030. The United States is likely to have the biggest benefits (US $ 7.1 billion) followed by China (US $ 1.8 trillion), Germany ($ 700 billion), and the United Kingdom ($ 531 billion). This study highlights the extraordinary opportunities offered by Industry 4.0. The significance becomes even more evident given the value added to GDP by the manufacturing sector in different countries. For example, the production contributed 22% of Germany's GDP in 2013 and 12% of US GDP in 2013 [28]. Another great opportunity created by Industry 4.0 is the strengthening of national production in Europe and North America. As a result, it could also convey the trend of the outsourcing industry to low-cost and low-income countries, due to changes in production requirements and factors [29].

To achieve **business opportunities** at the national level, manufacturing enterprises need to recognize the new possibilities that offer companies Industry 4.0 paradigm [30] that could exist in different fields, as follows:

- *Efficiency*: savings of raw materials and energy
- *Productivity*: intelligent technologies that are more productive
- *Flexibility*: use of cyber-physical systems

- *Individualization on demand*: integration of customer through network (cyber-physical systems)
- *Decentralization*: faster and data-driven decision-making

Other opportunities are related to the new technologies integrated into the 4.0 systems. The fourth industrial revolution is characterized by the merger of digitization and automation to make the machines intelligent, interactive, and easy to use. These new technologies will have a huge impact on working patterns. There will be new types of robots that can interact with humans. This technology will complement human activity, in particular cognition, combined with other emerging technologies to give us completely new computer models. Thus, *new skills* are needed to bridge the gap between engineering and computer science, automatic learning, and artificial intelligence. Industry 4.0 must also be a suitable tool for **eco-sustainable production**. This is because industry will continue to depend on resources and energy, and each country will play in the production and supply of resources and energy. In order to combat climate change, China has promised to reduce the intensity

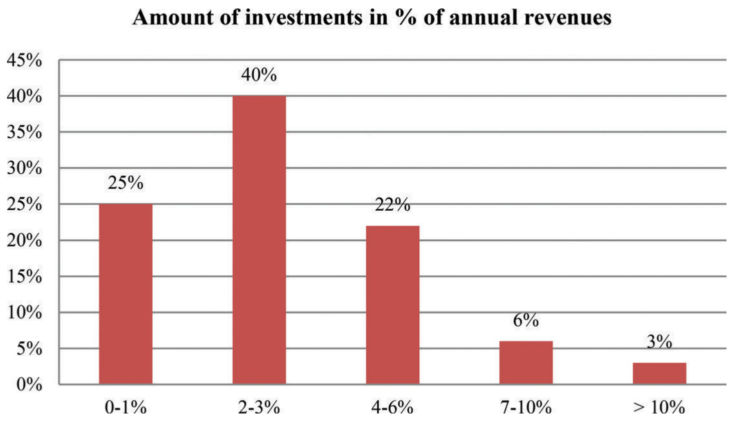

Figure 8. Average annual investments in Industry 4.0 applications (Source: PWC Industry 4.0, 2014).

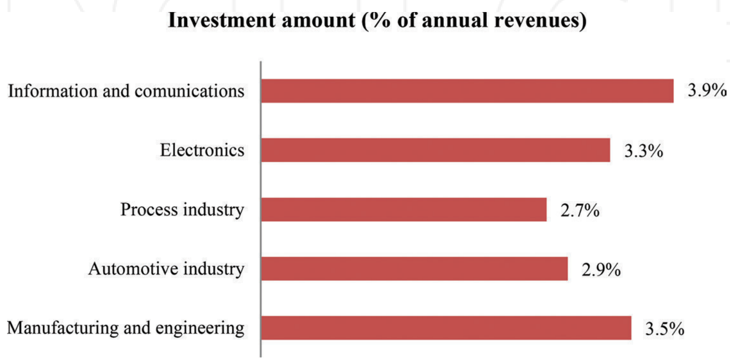

Figure 9. Annual investment in Industry 4.0 (Source: PWC Industry 4.0, 2014).

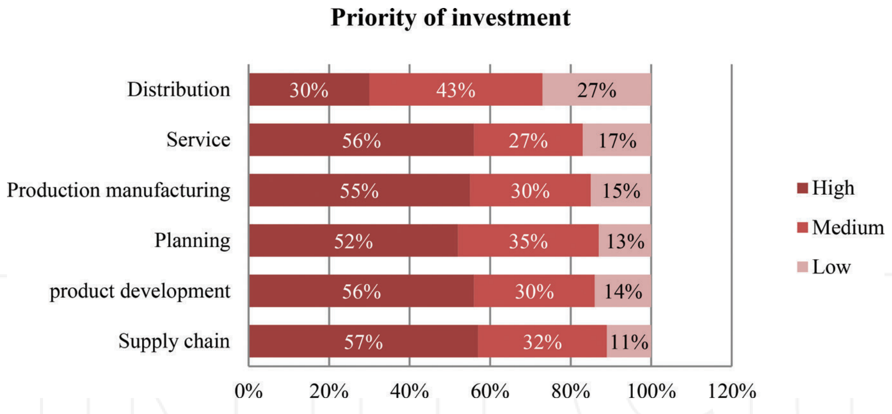

Figure 10. Priority of investments (Source: PWC Industry 4.0, 2014).

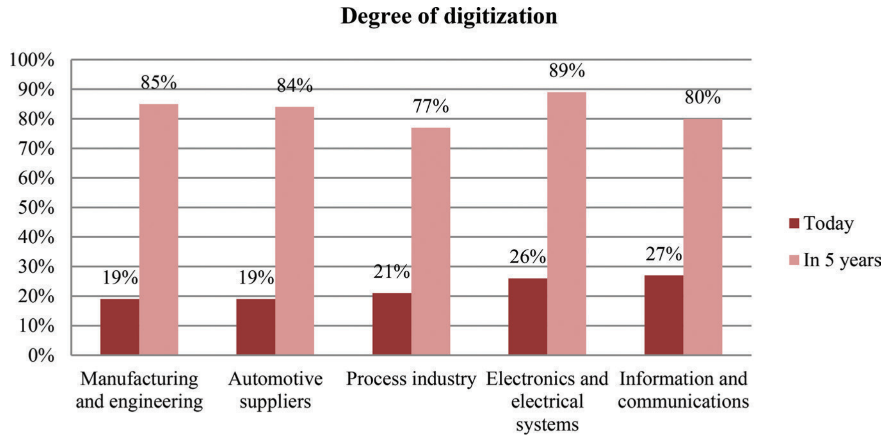

Figure 11. Degree of digitization of the value chain by industry sector (Source: PWC Industry 4.0, 2014).

of carbon dioxide emissions from 60–65% by 2030, compared to 2005. The main objective of the strategy is to ensure that Chinese production is geared toward innovation and green. It has ten priority development areas, including energy conservation and new energy vehicles, electrical equipment, and modern rail equipment, which aim to reduce carbon dioxide emissions. Some examples are energy-saving (mainly electric) vehicles, third-generation nuclear power plants, and the construction of new high-speed railways between Beijing and Shanghai, 1200 km away. The PWC survey reports the percentage of companies that have increased their efficiency and that have decreased costs. **Figures 12** and **13** show the quantitative effects of the benefits of Industry 4.0 applications, considering the efficiency increase and cost reduction, while **Figure 14** describes the quality benefits of Industry 4.0 applications.

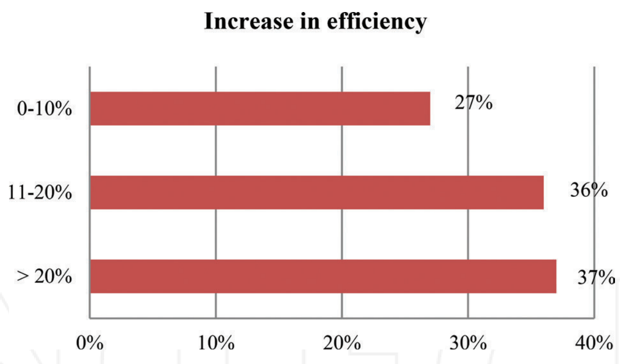

Figure 12. Increase in efficiency (Source: PWC Industry 4.0, 2014).

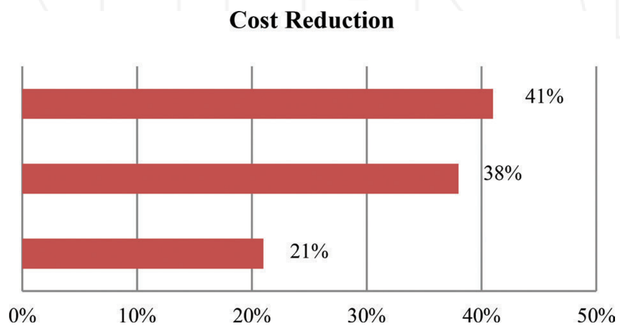

Figure 13. Cost reduction (Source: PWC Industry 4.0, 2014).

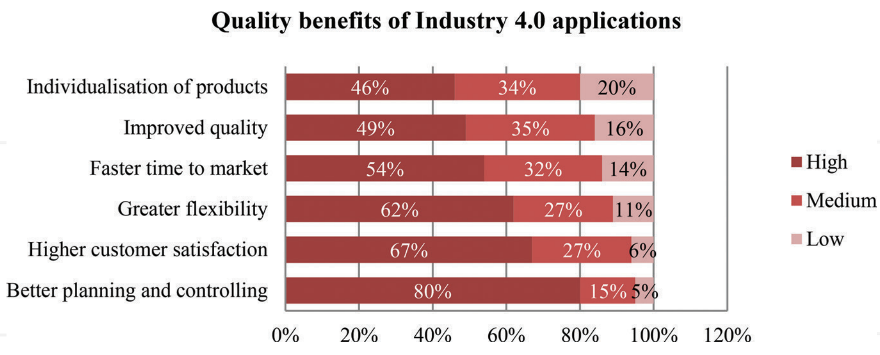

Figure 14. Quality benefits of Industry 4.0 applications (source: PWC Industry 4.0, 2014).

5. Qualification and skills of Industry 4.0

The work of the future will be very different from the traditional work, so traders will also have some different skills than those required today [31].

Influence on the human factor is linked to four elements: (1) tools and technologies, (2) organization and structure, (2) working environment, and (4) organizational cooperation.

In the future factory will increase the need for skilled digital work, will decrease the need for manual work, and will provide the worker with the exact information they need in real time or in a certain situation to perform their task efficiently. Workers are able to control and monitor production processes through the analysis of data and information supported by these devices. Intelligent systems will further make it possible for the worker to make qualified decisions in a shorter time. Collaborative robotics will share a work station with humans. These robots support the worker, for example, in situations that are critical with respect to ergonomics. Intelligent tools and technologies will become more autonomous and automated, but the supervision and efficient application of machines by humans will become more important than ever before.

Technologies can perform at high efficiency if the organization and structure of a company provide the right environment for them [32]. So, a significant change in the used technologies should and will proceed jointly with a significant change in organization and structure. Workers, capable of working with the information and data flow, will not necessarily be bound to a certain production area anymore, but the new operator skills will improve job management by making it more qualified, responsive, and more decision-making.

In the recent past, the world of industrial production was perceived from the outside as being a dark and dirty place with no windows where raw physical work is carried out by a horde of [33]. The perception of the working environment of the future will again be different. The future working environment will be an open and creative space. Work will be more flexible and transparent, more planned, and balanced. Surely, the homework will increase. Modern assistant systems will provide the workers with the ability for quick decision-making despite the increased complexity of their job contents. The work will be improved with respect to ergonomics. In particular, non-ergonomics processes are likely to become automated to improve the production workers' conditions.

In the factory of the future, intraorganizational cooperation and communication will be fundamental. Networking and interconnectedness are focal components of the Industry 4.0. Workers will collaborate and communicate real time without borders using smart devices. The Internet provides the possibilities to meet globally in virtual rooms at almost any time and to reach out for required information as needed. All kinds of information and data will be ubiquitous and at the fingertips of the workers leading to a whole new level of knowledge management. Humans communicate with other humans and with intelligent machines.

It is necessary to define a model to identify the skills of operators required in the factory of the future, from the school's point of view, and after school.

Here, below is a summary of the main phases required to ensure appropriate skills.

Phase #1: Education. It is necessary to attract the attention to the manufacturing topics already in the school education system. The ideal would be the creation of educational courses required for the introduction of the systems behind the factory of the future, to prepare future workers. Similarly, computer courses and foreign language that often are optional should be mandatory. The school placements should become more common, limiting the bureaucracy. Extension of the offer summer schools with enhanced programs to raise awareness of computer science. Fundamentals are also visits to smart factories, to introduce students to the company and to give the company the opportunity to present their technologies.

Phase #2: School (work transition). Professional development courses are crucial to giving a first technical qualification to future workers. Workshops are recommended as they strengthen technical skills and qualifications. Workshops cannot only tackle both technical issues but also refine soft skills (self-management, teamwork, stress management, etc.) that are fundamental to the worker. The collaboration of university companies that allows to adapt the student profiles with the demands of the companies is very important. Students will be in contact with companies through their university. Developing professional bachelor's degrees to train the intelligent factory operator and give more insights than those already provided in high school and to develop technical skills and soft skills.

Finally, the internships are very important, as they allow students to know experiences in the company. They include not only both technical aspects but also interdisciplinary models such as personal skills and teamwork.

Phase #3: Continuous training. The last phase involves the continuous training of the operator in the workplace. Companies can only be competitive by investing in continuous training and improvement. Accenture [34] reviewed more than 300 US manufacturing companies between 2013 and 2014 and found that 80% of companies invest around $ 1000 each year in training of each employee. Professional courses enhance technical and personal skills such as World Class Manufacturing or Six Sigma belt, which also enable certifications.

6. Conclusions

Several advanced economies are implementing the concept of Industry 4.0, marking the fourth industrial revolution. Increasingly, companies are applying innovative solutions, including through the "Internet of Things" (IoT), cloud computing, miniaturization, and 3D printing, that will enable more interoperability, flexible industrial processes, and autonomous and intelligent manufacturing. The new industrial revolution will be characterized by merging of technologies. Among the consequences of "Industry 4.0" and structural problems in the world, economy will be an escalation in competition at the geo-economic level. Industry 4.0 will concur to create new wealth and further improve living standards. The implementation of a 4.0 systems has considerable advantages. This chapter has analyzed a series of data showing efficiency increase and cost reductions for European companies that have implemented smart manufacturing systems. The implementation of a 4.0 system represents a real revolution within the company. In addition, the implementation of intelligent systems implies a considerable economic investment, and often the company cannot assess the economic return of that investment. For this reason, it is necessary to develop national or regional investment plans to encourage companies to invest in the 4.0 revolution. Companies that remain out of this revolution could disappear, as they would remain technologically obsolete with respect to their competitors. Before developing digitized systems, it is necessary to check if there are any prerequisites within the company to ensure the correct implementation of the new system. If there are no proper prerequisites, the first step to digitizing the company is to invest in training and information activities to train operators. As far as training operators in the chapter, the formation of the new working class 4.0 has been of great importance. Communication should start from high school, through school-work alternation and by providing basic knowledge of computer science and robotics, to make it clear to young workers what is the trend toward which we are moving. This chapter has also analyzed the various changes that companies will face, distinguishing between developed countries and developing countries. In addition, business, economic, and financial opportunities that can be exploited by implementing Industry 4.0 systems have been described. The chapter also presented softly the most important intelligent factory technologies such as big data and cloud data analysis systems, cyber-physical systems that allow self-regulating operations run by intelligent robots, simulation systems and virtual reality to train addicting operators, and additive manufacturing to develop more and more customized products that meet customer needs. In conclusion it is worthy to note that to face the challenges of the future it is strategic to digitize manufacturing processes and implement intelligent automated systems that can self-manage. The commitment must be extended not only to companies but also to governments, whose task is not only to develop investment plans that are easy for companies wishing to renew their processes but also to train young workers from high schools by making compulsory modules of computer science, automation, and foreign languages, to create a new generation of "workers 4.0" who possess the hard and soft skills needed to operate within the intelligent factory. Only in this way, it will be possible to properly implement the new Industry 4.0 practices and to make technological advances to companies and the whole civilization.

Author details

Antonella Petrillo[1]*, Fabio De Felice[2], Raffaele Cioffi[1] and Federico Zomparelli[2]

*Address all correspondence to: antonella.petrillo@uniparthenope.it

1 University of Napoli "Parthenope" Centro Direzionale, Napoli (NA), Italy

2 University of Cassino and Southern Lazio, Cassino (FR), Italy

References

[1] Lee J, Ardakani HD, Yang S, Bagheri B. Industrial big data analytics and cyber-physical systems for future maintenance & service innovation. Procedia CIRP. 2015;**38**:3-7

[2] Erol S, Jager A, Hold P, Karel O, Sihn W. Tangible industry 4.0: A scenario-based approach to learning for the future of production. The 6th Conference on Learning Factories. 2016. Gjøvik, Norway

[3] Kolberg D, Zuhlke D. Lean Automation Enabled by Industry 4.0 Technologies. IFAC PapersOnLine 48-32015. pp. 1870-1875

[4] Zhou K, Liu T, Zhou L. Industry 4.0: Towards future industrial opportunities and challenges. In: 12th International Conference on Fuzzy Systems and Knowledge Discovery. 2015. 2147-2152

[5] De Felice F, Petrillo A, Zomparelli F. Design and control of logistic process in an Italian company: Opportunities and challenges based on industry 4.0 principles. Summerschool "Francesco Turco"; 2016; Napoli

[6] Varghese A, Tandur D. Wireless requirements and challenges in Industry 4.0. In: International Conference on Contemporary Computing and Informatics; 2014. 634-638

[7] Lasi H, Kemper HG, Fettke P, Feld T, Hoffmann M. Industrie 4.0. Germany; Springer Fachmedien, 2014. pp. 239-242. DOI: 10.1007/s12599-014-0334-4

[8] VINT. The Fourth Industrial Revolution: Things to Tighten the Link Between IT and OT. 2014. Available from: http://vint.sogeti.com/wp-content/uploads/2014/06/VINT-Sogeti-Internet-of-Things-Report-3.pdf

[9] Brettel M, Friederichsen N, Keller M, Rosenberg M. How Virtualization, Decentralization and Network Building Change the Manufacturing Landscape: An Industry 4.0 Perspective. International Scholarly and Scientific Research & Innovation. 2014; **8**(1):37-44

[10] The Economist. The Third Industrial Revolution. 2012. Available from: http://www.economist.com/node/21553017

[11] Berger R. Industry 4.0: The New Industrial Revolution–How Europe will Succeed. 2014. Available from: https://www.rolandberger.com/media/pdf/Roland_Berger_TAB_Industry_4_0_20140403.pdf

[12] Berger R. Think Act: Coo Insight – Industry 4.0. 2014. Available from: http://www.rolandberger.com/media/pdf/Roland_Berger_TAM_COO_Insights_E_20150113.pdf

[13] Capgemini Consulting. Digitizing Manufacturing Ready, Set, Go! 2014. Available from: https://www.de.capgemini-consulting.com/resource-file-access/resource/pdf/digitizing-manufacturing_0.pdf

[14] Lee J, Bagheri B, Kao H. A cyber-physical systems architecture for industry 4.0-based manufacturing systems. Manufacturing Letters. 2014;**3**:18-23

[15] Davis J, Edgar T, Porter J, Bernaden J, Sarli M. Smart manufacturing, manufacturing intelligence and demand-dynamic performance. Computers and Chemical Engineering. 2012;**47**:145-156

[16] Posada J, Toro C, Barandiaran I, Döllner J, Vallarino I. Visual computing as a key enabling technology for industrie 4.0 and industrial internet. IEEE Computer Graphics and Applications. 2015;**35**(2),7064655:26-40

[17] Kang HS, Lee JY, Choi S, Kim BH, Noh SD. Smart manufacturing: Past research, present findings, and future directions. International Journal of Precision Engineering and Manufacturing–Green Technology. 2016;**3**(1):111-128

[18] Yue X, Cai H, Yan H, Zou C, Zhou K. Cloud-assisted industrial cyber-physical systems: An insight. Microprocessors and Microsystems. 2015;**39**(8):1262-1270

[19] Germany Trade & Invest. Industrie 4.0: Smart manufacturing for the future. 2014. Available from: http://www.gtai.de/GTAI/Content/EN/Invest/_SharedDocs/ Downloads/GTAI/Brochures/Industries/industrie4.0-smart-manufacturing-for-the-future-en.pdf

[20] Jazdi N. Cyber Physical Systems in the Context of Industry 4.0. Automation, Quality and Testing, Robotics. IEEE International Conference; 2014:1-4

[21] Haiping Z, Yu L, Qin L, Yunqing R. Cloud service platform for big data of manufacturing. Applied Mechanics and Materials. 2014;**456**:178-183. DOI: 10.4028/www.scientific.net/AMM.456.178

[22] Industry 4.0: Opportunities and Challenges of the New Industrial Revolution for Developing Countries and Economies in Transition. Available from: https://www.unido.org/fileadmin/user_media_upgrade/Resources/Publications/Unido_industry-4_NEW.pdf

[23] PwC Strategy. Industry 4.0: Opportunities and Challenges of the Industrial Internet. 2014 Available from: http://www.strategyand.pwc.com/media/file/Industry-4-0.pdf

[24] Accenture and General Electric. Industrial Internet Insights Report. 2015. Available from: https://www.gesoftware.com/sites/default/files/industrial-internet-insights-report.pdf

[25] Lee J, Kao H, Yang S. Service innovation and smart analytics for industry 4.0 and big data environment. Procedia CIRP. 2014;**16**:3-8. DOI: 10.1016/j.procir.2014.02.001

[26] PWC. Industry 4.0 – Opportunities and Challenges of the Industrial Internet; 2014. Available from: https://www.pwc.nl/en/assets/documents/pwc-industrie-4-0.pdf

[27] Accenture. Winning with the Industrial Internet of Things; 2015. Available from: https://www.accenture.com/t20150523T023647__w__/pl-en/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Dualpub_11/Accenture-Industrial-Internet-of-Things-Positioning-Paper-Report-2015.pdf

[28] The World Bank. Manufacturing, Value Added (% of GDP); 2015. Available from: http://data.worldbank.org/indicator/NV.IND.MANF.ZS/countries/1W-US-DE?display=graph

[29] Gneuss M. Als die Werkstücke Laufen Lernten. In Reflex Verlag Industrie 4.0 Die Vierte Industrielle Revolution; 2014. Available from: http://www.gfos.com/fileadmin/news/PDF/Ref_Industrie40_HB.pdf

[30] König C. Forschung für die Fabrik der Zukunft, In Reflex Verlag Industrie 4.0 Die Vierte Industrielle Revolution; 2014. Available from: http://www.gfos.com/fileadmin/news/PDF/Ref_Industrie40_HB.pdf

[31] Hirsch-Kreinsen H. Wandel von Produktionsarbeit Industry 4.0. Soziologisches Arbeitspapier; 2014. 38. Available from: http://www.industrialinternetconsortium.org/

[32] Cardoso R, Pinheirro de Lima E, Gouvea da Costa SE. Identifying Organizational Require-ments for the Implementation of Advanced Manufacturing Technologies (AMT). Journal of Manufacturing Systems. 2012;**3**(31):367

[33] VDI. Industry 4.0: A discussion of qualifications and skills in the factory of the future. A German and American perspective. 2015

[34] Accenture, Manufacturing Institute. Accenture 2014 Manufacturing Skills and Training Study–Out of Inventory Skills Shortage Threatens Growth for US Manufacturing. 2014. Available from: http://www.accenture.com/SiteCollectionDocuments/PDF/Accenture-2014-Manufacturing-Skills-Training.pdf, last retrieved 2015-01-18

Chapter 2

A Research Agenda of Industry 4.0 from the Czech Perspective

Pavel Adámek

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.71798

Abstract

Although the Czech Republic ranks among the most industrialized countries in Europe, it is not prepared for the coming of technological changes. For a country to take advantage of emerging technologies and the GDP growth and jobs they bring, it must be highly digitalized. Therefore, the chapter is intended to provide the Czech Republic Industry 4.0 approach with the latest issues to the Fourth Industrial Revolution. The chapter aims not only to point out possible directions of development, to define proposals for measures that can support the economy and industrial base, but also to help prepare the stakeholders from the public and private sector for technological change. This chapter is based on information gathered through extensive documents using print media and research databases of European Commission focused on digital economy and society, and we also employed the available Digital Transformation Scoreboard, Digital Transformation Monitor, Europe's digital Progress Report, Digital Index of Roland Berger, and Czech strategic digital transformation documents to systematize a research agenda of Industry 4.0. The chapter is expected to help in reviewing national digital performance strategies, and an overview of the collected outputs may help other entities to the process digitizing a society efficiently.

Keywords: Industry 4.0, digitalization, digital transformation performance, national digital agenda framework, Fourth Industrial Revolution

1. Introduction

Europe is currently at digital crossroads, with a unique chance to either capture an immense opportunity or see the region fall behind other nations. The Fourth Industrial Revolution (FIR) or Industry 4.0 is called to pull applications and push technologies enabling a high degree of sustainability needed in the factories of the future [1, 2]. As explained by [3], Industry 4.0 solves today challenges related with resources and energy efficiency, urban production, and demographic change, enabling continuous resource productivity and efficiency. The critical parameters in the introduction of Industry 4.0 are the design of the process landscape and the identification of the employee qualification profiles that will be required in the future. This is preceded by the development of a comprehensive Industry 4.0 strategy and an investment plan [4], both at a national and European level.

Due to the focus of the Czech "industrial" economy, the impact of Industry 4.0 is significant. Therefore, at a national level, the Czech government should develop digital agendas, to reach national competitiveness in leveraging digitalization and new technology to drive economic growth and job creation. A shift in response to materiality and development can be observed in the main pushed Internet-based technologies and Internet of Services, favored by new developments in computational power, leading to cloud computing and services. These technologies have the potential to give rise to a new generation of service-based industrial systems whose functionalities reside on-device and in-cloud [5]. In order to succeed developing these technologies and applications, talented personnel, comprehensive IT infrastructure, economic strength, and enlightened manufacturers will be needed [6]. Therefore, creating new agendas must cover areas such as the rapid digitization of business and government services, pushing national SME's to become European regarding market ambitions, and improving digital skills, and they should be nurtured in a smart policy environment in which innovative technologies and business models can be developed and grown.

Being digital is a shift in mind-set [7]; therefore, we grabbed the issues of technological changes, because we have to prepare not only the industry but also the whole society for the economic and societal changes related to the FIR and to enhance the competitiveness of the Czech Republic. Digitization constitutes a transformative shift in technology across industry and society in general. While the positive impact of digitization is expected to benefit the entire continent, some EU nations stand to gain more than others and therefore should help pull Europe toward a more digitized economy for the benefit of all. These same nations also have more to lose from a lack of progress in European digitization. The Czech Republic is not represented among frontrunner countries nor Big 5 countries but plays a significant role when the Czech Republic has one of the highest shares of industrial production per GDP among EU countries (approximately 32% GDP) [8].

The aim of the current chapter is to provide the Czech Republic Industry 4.0 approach with the latest issues to the Fourth Industrial Revolution not only to point out possible directions of development, to define proposals for measures that can support the economy and industrial base, but also to help prepare the stakeholders from public and private sector for technological change. This chapter is based on information gathered through extensive documents using print media and research databases of European Commission focused on digital economy and society, and we also employed the available Digital Transformation Scoreboard, Digital Transformation Monitor, Europe's digital Progress Report, Digital Index of Roland Berger, and Czech strategic digital transformation documents to systematize a research agenda of Industry 4.0.

There is a considerable concern to the European digital single market (DSM) which encompass more than 500 million consumers and is expected to add €415 billion in annual GDP to the EU. The more digitized frontrunner nations (the group consisting of Denmark, Belgium, the Netherlands, Sweden, Estonia, Ireland, Finland, Norway, and Luxembourg) would see the most significant benefits from a more digitized European economy, with their average GDP growth rate potentially increasing by 40% until 2020, double the increase in the growth rate of EU Big 5 countries for the same period [8].

In this chapter, we summarize planned measures that will help the development of the digital economy in the Czech Republic, both regarding national factors in the Czech Republic and in terms of initiatives at the level of the European Union.

This chapter covers the following topics:

- How digitalization drives value
- The current state of the digital "emerging" economy in the Czech Republic
- Digital transformation performance
- A national digital agenda framework
- Policy practices and case studies

2. The Czech Republic in a nutshell

The Czech Republic displays a moderate level of digital transformation with a high position in the area of ICT start-ups. The Czech Republic's performance is slightly under the average's line of the EU member states in most of the dimensions. The fields of entrepreneurial culture, e-leadership, and supply and demand of digital skills provide scope for improvement. The Czech government launched several programs seeking to support digital transformation further. The measures aim to promote entrepreneurship, support new business ideas, provide assistance in obtaining new technology, and enhance cooperation and knowledge transfer.

The Czech Republic has one of the highest shares of industrial production per GDP among EU countries (approximately 32% GDP) [8]. Furthermore, the country has high industrial ties with Germany, which is its strategic business partner, thus integrating into the German industrial supply chain. The Czech economy duplicates its development in Germany according to its dependence, so it is necessary to respond quickly to the changes. Therefore, the national initiative "*Průmysl 4.0*"—P40—(Industry 4.0) has arisen as a national approach aiming to maintain and enhance the competitiveness of the Czech Republic in the wake of the Fourth Industrial Revolution. The concept was first presented during the 57th *International Engineering Fair in*

Brno, September 2015, and approved by the Government of the Czech Republic on 24 August 2016. The *Ministry of Industry and Trade* (MIT) plays a vital role in the implementation process. However, there is a robust interdisciplinary cooperation between the ministries, social and industrial partners, and academia [9].

Objectives of the policy are based on the national strategy developing the vision of a fully digital economy toward the real cyber revolution within the Czech Republic. The conceptual proposal is based on data and information collected by the experts and provides recommendations for next steps in several areas. The focus is on building data and communication infrastructure, the adaptation of the education system, introduction of new tools in the labor market, adaptation of the social environment, and financial help for the companies related to the introduction of new technologies and know-hows. There are three primary objectives [9]: first, to enhance the ability of Czech companies to be involved in the global supply chain; second, the implementation of the Industry 4.0 principles will lead to more efficient manufacturing, meaning faster, cheaper, and resource-effective production; third, to enhance the cooperation with R&D and industry association, universities, and Academy of Sciences of the Czech Republic for the development of software solutions, patents, production lines, and export know-hows.

According to *Roland Berger Industry 4.0 Readiness Index* based on industrial excellence (production process sophistication, degree of automation, readiness workforce, and innovation intensity) and value network (focus on high value-add, industry openness, innovation network, and internet sophistication), the Czech Republic is included into "*traditionalists*," that is, countries (for example Slovenia, Slovakia, Lithuania, and Hungary) that benefit from a high-quality industrial base but have not yet introduced initiatives to shift the industry to a new era [10]. Czech businesses benefit from active participation in online trade and belong to the countries with high manufacturing share, but with a low level of readiness to Industry 4.0. Moreover, a significant share of enterprises' total turnover derived from e-commerce contributes to a stable position of the Czech Republic in the area of e-commerce among the EU member states. To sum up, according to Ref. [11], following dimensions show similar tendencies, including digital infrastructure, integration of digital technology, investments, and access to finance and ICT start-ups. On the other hand, Czech Republic faces challenges regarding entrepreneurial culture and the supply and demand of digital skills.

2.1. How digitalization drives value

The paradigm of Industry 4.0 is essentially outlined by three dimensions [12–14]: (1) horizontal integration across the entire value creation network, (2) end-to-end engineering across the entire product life cycle, and (3) vertical integration and networked manufacturing systems. Based on these dimensions, it can be defined that digitalization creates value for individuals, corporations, and society alike. On the corporate side, it can expand reachable markets for companies both domestically and internationally, increasing sales potential. The business also benefits from the productivity increase that comes with the digitalization of corporate processes, for instance, in digitized supply chains, automated production lines, and digitized distribution systems [8]. Digitalization is a challenge for each country, and Alm et al. [8] represents that digitalization drives values for nations and is a crucial driver for GDP growth and also have a positive net impact on job creation. From a government point of view could be found positive effects in increasing productivity in government operations (for example, tax collection and data management), to identify and analyze societal trends with big data tools, and more efficient communication with citizens and businesses.

There are also identified values for companies in areas of access to the more significant market (increasing sales), though digitization of business processes and business models that increase productivity potential and also open access to government data can spur innovation and better access to talents (digital channels). Society, especially citizens, could drive values in increased competition (consumers can find the best products at the lowest price-point), in access to new types of products and services (sharing economy), in better employment possibilities, and in facilitating access through e-government services [8]. Based on these identified values follows the next part of the chapter that defines and identifies the current state of the digital economy in the Czech Republic.

3. The state of the digital economy in the Czech Republic

Regarding the current state of the digital economy in the Czech Republic, in *Digital Economy and Society Index* 2016 (DESI), the Czech Republic has an overall score of 0.5 and ranks 17th out of the 28 EU member states (see **Table 1**). An international view of the state of the digital economy in the Czech Republic offers the *Digital Development Index*. The index focuses on the period 2008–2013 and takes into account the four sets of factors: supply, demand, innovation, and institutions [15].

The Czech Republic, according to this index, lags behind the average, especially in the area of innovation and quality of institutions; on the contrary, better than the average result is confirmed in the field of digital infrastructure. By individual countries' results, there is a risk of deepening stagnation in the context of international competition, which the Czech Republic is indeed threatening if the digital economy is not further developed and the state administration will not receive the appropriate attention on this topic.

Therefore, the crucial task is, to sum up, the way of government policy direction and the key measures that individual government officials take to prepare for the development of the digital market. Creating approaches in the form of strategic documents could not replace existing and approved conceptual documents, but preferably cover them. In some areas, the

	Rank	Score	Cluster score	EU score
DESI 2017	18	0.5	0.54	0.52
DESI 2016	17	0.46	0.51	0.49

Source: Europe's Digital Progress Report (EDPR) 2017, Country Profile Czech Republic.

Table 1. DESI ranking.

state administration has not yet been prepared, and therefore it will be necessary to prepare a situational analysis on some topics first, which will show which approach is best suited to select. One of the critical elements of the *Czech Digital Agenda* concept [16], which the Czech Republic is also promoting in the EU, is the emphasis on smart regulation based on quality data and arguments assessing the need for regulatory measures. Any state intervention in this sector must not hamper the dynamic development of digital technologies.

Consequently, to maintain the synergy effect, it is necessary to create the role of *coordinator* for the purpose to oversee and link governmental activities to support the digital agenda and to ensure intensive cooperation within public administration and communication with the professional and nonprofessional public. The following are among the umbrella principles that will be linked to all the activities of the coordinator and will be at the core of the entire coordination activity [16]: (1) digital by default—support for modern public administration, which takes priority of digital means of communication, both inside and outside of the authorities, (2) supporting the digital economy by setting up a legislative environment that does not impede the dynamic development of this sector promotes fair and equitable market conditions and protects consumers' rights, (3) reduces administrative burdens for citizens and entrepreneurs, (4) openness of public administration, which the digital age allows well—making data accessible to the public not only helps to increase the transparency of the state apparatus but also supports the development of innovation, which builds on open state data.

3.1. Digital progress

We employed the results of the *Europe's Digital Progress Report* [15] (EDPR) that tracks the progress made regarding their digitization, combining quantitative evidence from the *Digital Economy and Society Index* (DESI) with qualitative information on country-specific policies. A comparison of the subfactors is shown in **Figure 1**, which contains European countries, including the European average (EU). EDPR is structured around five chapters [15]:

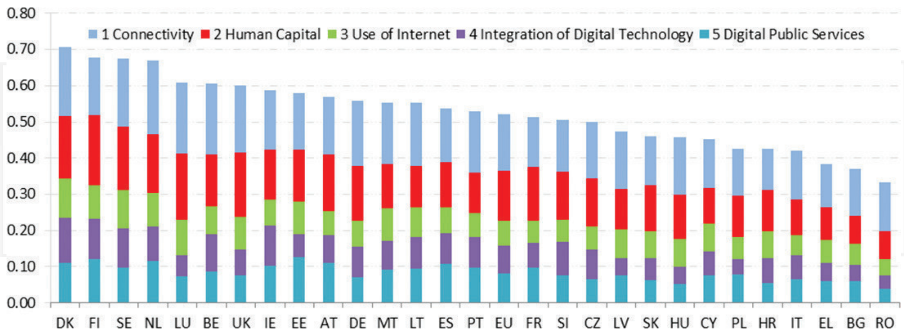

Figure 1. Digital Economy and Society Index 2017 ranking. Source: Europe's Digital Progress Report (EDPR) 2017, Country Profile Czech Republic (CZ).

1. Connectivity—fixed broadband, mobile broadband, broadband speed and prices
2. Human capital—Internet use, basic and advanced digital skills
3. Use of Internet—Citizens' use of content, communication, and online transactions
4. Integration of digital technology—business digitization and e-commerce
5. Digital public services—e-government

Over the last year, the country progressed in *digital public Services*, remained stable in *human capital*, and worsened its ranking in the other dimensions. The country performs best in *integration of digital technologies by Businesses*, mostly because many SMEs embrace e-commerce. The Czech Republic is well positioned regarding *4G coverage* (94%), but overall performance in the *connectivity* dimension is stagnating. The country's highest challenge is to improve the use of Internet services, in particular for e-government, entertainment, and social purposes. These problem areas are the result of a not-too-active government that is supposed to create the conditions for broader use of the Internet and the digitization of public services. The Czech Republic belongs to the *medium-performing cluster of countries* (the group consisting of Latvia, Czech Republic, Slovenia, France, Portugal, Spain, Lithuania, Malta, Germany, and Austria) [15].

The Czech Republic's overall performance in the *connectivity* dimension has been stagnating relative to the EU average, with insufficient progress since the previous year. While the *fixed broadband* full coverage target has almost been met, *NGA coverage* has not improved much, keeping the Czech Republic in 20th position across the EU. The relative increase in the fixed broadband price might explain the decreasing number of fixed broadband subscriptions.

On a more positive note, the country is well positioned regarding *4G coverage* (9th place), and progress in the assignment of the harmonized spectrum is promising in this respect. Take-up is growing more slowly. The growth of subscriptions to fast broadband is achieved mainly in the (well-developed) urban areas. In the rural areas, the lack of infrastructure is expected to be tackled through structural intervention cofinanced with EU funds within the *Operational Program Enterprise and Innovations for Competitiveness* (OPEIC).

More generally, however, the actual level of competition has hardly stimulated *FTTB/FTTH* (fiber laid all the way to the building/home) deployment. While ESIF funds are used for deployment of NGA in rural areas, it remains to be seen whether the current approach is sufficient to achieve *digital agenda* targets. The regulatory support to NGA deployment is not entirely in place as the transposition of the *Cost Reduction Directive* is subject to significant delays. Finally, next to funding in areas of market failure, targeted policies and measures might also be useful to increase user demand.

In the *human capital* dimension, the Czech Republic ranks 13th, a stable position compared with last year. In 2016, more people are online and use the Internet regularly compared to 2015. However, there is a slight decline in the level of the population's digital skills. In an economy close to full employment and where demand for professional profiles is high, recruitment of ICT specialists is increasingly tricky: in 2016, 66% of enterprises reported having had difficulties in hiring ICT specialists, the highest level in the EU and up from 47% in 2012.

Beyond formal and informal training, digital literacy of Czech citizens is also promoted through the *Digital Literacy Strategy* for 2015–2020 to prepare people to exploit the potential of digital technologies for their lifelong development. *The Action Plan of the Digital Literacy Strategy 2015–2020* was approved in 2016, and it details the thematic actions to be implemented by the end of 2020. These include equipping workers with the digital competencies needed to enter the labor market and retraining employees facing changes due to digitization and globalization. Actions also target training of employees of SMEs and self-employed, civil servants, as well as employers for the introduction of teleworking and remote work. The digital literacy strategy and in particular its strategic competitiveness goal count on employers' active collaboration for the implementation of the measures. On 24 October 2016, the "*National Coalition for Digital Jobs*" was signed by the Ministries of Education, Labor and Social Affairs, Industry and Trade and the Czech ICT Alliance (ICT sector representatives). The successful implementation of the actions above will significantly benefit the country's human capital.

Regarding the propensity of individuals to use *Internet services*, the Czech Republic over the last year made little progress and fell from rank 21 to rank 22. Although well above the EU average, in 2016, there were fewer Czech Internet users reading news online (82%) than in 2015. Czech Internet users performed banking transactions online more than other Europeans (63% compared to 59%) and increasingly shopped online, although still not in line with the EU average (57% compared to 66%). They used the Internet for entertainment (music and video) and communication (social networks) less than the average European. Video on demand use was unusually low, placing the country at the bottom of the ranking in the EU.

The Czech Republic over the last year made little progress in the dimension concerning the *integration of digital technology by businesses*. However, this is the dimension where the country performs best. Czech enterprises increasingly take advantage of the possibilities offered by online commerce: one-quarter of SMEs sell online, half of them cross the border, and they are second in the EU for e-commerce turnover. However, RFID, use of e-invoices, social media, and cloud are below EU average. To catch up with digital technologies, an open laboratory-testing facility will be established to support SMEs at the *Czech Technical University* (CTU). The representatives of Germany and Czech Republic met to sign an agreement on cooperation on the Industry 4.0 project. Czech Republic was represented by the *Czech Institute of Informatics, Robotics and Cybernetics*, while Germany was represented by the *German Research Centre for Artificial Intelligence* (DFKI).

The area of *digital public services* is the dimension where the Czech Republic has progressed the most, although it is still below average in all indicators: it ranks 22nd among EU countries. Online interaction between public authorities and citizens is one of the lowest in the EU: only 15% of Czech Internet users actively engage in the use of e-government services, although this figure has improved. The increase in the use of e-government services suggests that measures taken to improve their supply are having a positive impact: the availability of prefilled forms and the level of online service completion have indeed also increased.

The Czech government has launched in 2016 the *Initiative 202020*, which aims to make the Czech Republic one of the top 20 countries in Europe for the use of e-government services by 2020. The initiative—jointly run by the private sector and the Czech authorities—focuses on the promotion of existing e-government services and support for the development of new services. Despite the progress in both demand and supply of e-government services over the past year, the performance of *Czech Digital Public Services* remains below EU average. Also, the drawdown of available EU funds for the development of e-government services has been low so far. The actions put in place by the country to improve availability, quality, and promotion of e-government services could contribute to improvements in this dimension.

We also employed the *Digital Transformation Scoreboard* [11], which is part of the *Digital Transformation Monitor* (DTM). The DTM aims to foster the knowledge base on the state of play and evolution of digital transformation in Europe. A clustering analysis of enabling conditions and outcomes of digital transformation was performed with the objective of grouping countries based on their similarities regarding enabling conditions leading to digital transformation. This analysis helped define four principal groups of countries based on their enabling conditions: best enabling environment; good enabling environment; moderate enabling environment; modest enabling environment [11].

Geographic clustering of EU digital transformation enabling environments and the Czech Republic is included into "*moderate*" enabling environment (the group consisting of Cyprus, Estonia, Italy, Lithuania, Portugal, Slovakia, and Slovenia) [11]. Developed *Digital Transformation Enablers' Index* (DTEI) indicates that, in general, the higher a member state ranks in the DTEI, the higher it is likely to rank in the *Digital Technology Integration Index* (DTII). In **Figure 2**, we can rank the Czech Republic with a higher score for the DTII and slightly lower DTEI, meaning that there is potential for development of enablers but needs to improved digital technology integration.

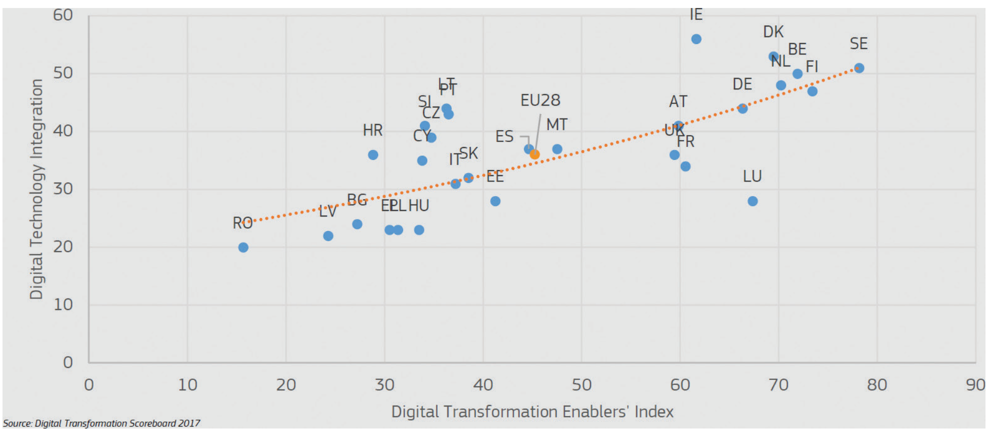

Figure 2. Digital transformation scores as a function of enabling condition cores.

The Czech Republic performs in line with the EU member states average in three (*integration of digital technology*, *changes in ICT start-up environment*, and *investments and access to finance*) out of seven dimensions (the remaining four ranks are *entrepreneurial culture*, *supply and demand of digital skills*, *e-leadership*, and *digital infrastructure*). Despite high marks in *e-leadership* at the national level, in comparison to the EU partners, the country is still slightly below the EU average. In the dimension entrepreneurial culture, the country scores significantly below the average of EU member states, to be precise 36% lower. Similarly, there is a shortfall regarding supply and demand of digital skills, the country's performance is around 18% below the EU average. The Czech Republic scores slightly above the average of the EU member states regarding investment and access to finance. Overall, the country performs broadly in line with the EU average. However, there is room for improvement in entrepreneurial culture and supply and demand of digital skills.

4. A national digital agenda framework

The subchapter is subdivided from the general definition of requirements for the creation and the national digital agenda framework, where the main areas are presented: enable digital and technology innovation; stimulate entrepreneurship; improve access to capital; regulate for the future, and build the skills and talent of tomorrow [8]. Then the *Czech Digital Agenda* is introduced in primary areas of focus, and then we employed the policy practices for practical reflection on what could be with what exists.

According to Ref. [8], enabling digital and technology innovation is based on the support of the development of innovation clusters with digital infrastructure, connecting start-ups to leading national companies and universities and attracting leading technology multinational corporations to establish national operations through tax subsidies.

In all introduced areas are stated the strategic priorities. In enabling digital and technology, innovation plays a role [8]:

- *Enable digital and technology innovation*—fully digitize government processes; invest in IT, telecommunication, and digital infrastructure; drive the SME transition to digital and mobile-first; support digital and technology clusters; attract leading technology MNCs; invest in IoT and big data; harmonize ICT standards for new technologies.
- *Stimulate entrepreneurship*—tax stock options as capital gains, steer public tenders and procurement toward SMEs and start-ups, link up tertiary education and start-up communities, introduce digitization and technology vouchers for SMEs, recognize and promote significant entrepreneurial activity at national level.
- *Improve access to capital*—attract world-leading and regional venture funds, introduce tax breaks on angel investments, simplify public funding structures, use public funds for matching venture capital investments, shift a significant part of pension funds' investment mix to established venture capital funds.

- *Regulate for the future*—review data protection legislation, push for a European digital single market, promote and creatively approach the sharing economy and new business models, increase labor market flexibility, simplify legal conditions for SMEs and start-ups, support and allow for experimentation with new technology.
- *Build the skills and talent of tomorrow*—rethink primary and secondary education, promote equality and integration throughout the educational system, differentiate tertiary education and launch cross-disciplinary programs, launch visa programs aimed at entrepreneurs, perform strategic workforce planning for digital at the national level.

Many of these topics could be implemented on a cross-national basis, either as agreed upon best practices or with one nation taking inspiration from another. This recommended overview for the creation of national digital agenda framework is then added by a realistic reflection that already exists in the Czech Republic.

4.1. Czech digital agenda

The updated *Action Plan on the Development of Digital Market* [16] includes the initiative "*Society 4.0*," which is an umbrella for the various sectoral strategies, e.g., in education, labor, and industry. The emergence of the so-called FIR will increasingly lead to significant changes not only in manufacturing but also in an intertwined way in the labor market, education, and other areas. These changes are associated with the development of the Internet of things, the use of digitization, and the Internet in all areas of economic and social life.

Therefore, innovation in each of the above sectors must be carried out simultaneously and in a coordinated manner, and it is necessary to examine the issue in its social dimension, as "*Society 4.0*." On 15 February 2017, the Government approved the establishment of the Alliance Society 4.0, whose primary task will be to ensure coordination of agendas related to FIR. The *Alliance* will act as a coordination mechanism allowing the involvement of economic and social partners and representatives of the academic and scientific communities. At the end of June 2017, the *Alliance Society 4.0* will submit to the government an *Action Plan for Society 4.0*, which will include actions in specific areas of industry, education, and the labor market. Regarding priority areas, the *Digital Agenda* identified six headings under which individual measures are identified and developed, namely the following six areas. The first is so-called cross-cutting priorities, including, for example, legislation on legislation and assessment of its impact on the *Digital Agenda* for the *Company's activities 4.0*. Other priorities are e-skills, e-commerce, e-government, and e-security. The last round is e-challenges that include open data or shared economy measures.

For the coordinator's role, the following priorities were set [16]:

1. *Cross-border priorities*
    - Analytical activity—cooperation in updating Study Czech Internet Economy; extending the membership of relevant working committees on law professionals and digital agenda processes; extension of the RIA membership base; creating a submethodology for drafting legislation and assessing the impact of regulation from a digital agenda point of view.

- Company 4.0—establishment of Alliance Company 4.0; introducing the Work Initiative Study 4.0; developing Education Initiative 4.0; research projects within Company 4.0; action plan for Company 4.0.
- Measuring the evolution of the digital economy.

2. *E-skills*—creating a platform for discussion on digital education; mapping of digital education projects
3. *E-commerce*—organizing a conference on e-commerce; mapping market players active in the field of e-commerce to communicate with the state administration and to set up a functional communication channel; coordination of the activities and opinions of individual national gestors in the area of e-commerce
4. *E-government*—developing an analysis of procedural legislation; setting up an internal methodology for using digital tools within ministries and other central government authorities; research of already functional and planned digital services; communication with economic and social partners, ministries, the European Commission, and the public; collaboration with self-government in e-government project development and implementation
5. *E-safety*—privacy and privacy protection; cybersecurity
6. *E-challenges*—open data; shared economy and online platform; smart cities

We also involved the following sector priorities [16]:

1. *Infrastructure development*—Internet networking, revision of the EU regulatory framework for electronic communication networks and services, digitization of television broadcasting, ensuring cybersecurity.
2. *The development of digital competences*—initial education, improving digital literacy of citizens.
3. *Access to goods and services*—online data protection, copyright revision, reducing administrative burdens for businesses.
4. *Development of electronic public administration*—electronic communication with authorities, electronic health service, electronization of social services, and electronization of justice.
5. *New trends*—Company 4.0, Open Data, Smart Cities.

By the areas mentioned above, it can be stated that the Czech Republic has set the assumptions in the theoretical level, but on the practical level, it is common that the partial steps are only in the "progress report" state but lack the achieved outputs that have been set. There is also a shift away from the desired (for example, the framework of digital agenda presented above) from reality.

4.2. Policy practices

The long-term goal of the initiative *Industry 4.0* is to maintain and enhance the competitiveness of the Czech Republic at the onset of the Fourth Industrial Revolution. The measure was introduced by the *MIT* and approved by the *Czech government* in 2016. The initiative aims to indicate possible trends and outline measures that would not only boost the economy and industrial base but also help prepare the entire society to absorb this technological change. The document contains mapping and measures to promote investments, applied research, and standardization and deals with issues related to cybersecurity, logistics, and legislation. The measure serves as a regulatory framework providing information on the need for urgent changes related to the FIR for the government, ministries, and social partners to promptly apply specific measures. The initiative *Industry 4.0* simultaneously aims to mobilize the business community and the stakeholders to become actively involved in the implementation process.

In January 2017, the government established the *Alliance Society 4.0* as a coordination platform working on the Action Plan (Society 4.0). The platform was established under the *Digital Coordinator of the Czech Digital Agenda*, established by the government office. The platform brings together economic and social partners, representatives from the academic and scientific communities, and experts from private and public sectors. The *Action Plan Society 4.0* is a practical implementation of several agendas related to P40 to coordinate activities of individual ministries and other relevant governmental bodies. Moreover, the *Alliance* is also developing a system of information and feedback in public administration to promote and disseminate the implication of the Fourth Industrial Revolution. Simultaneously, this is an opportunity to inform and educate the general public about the topic and related changes [9].

Society 4.0 will include in particular new approaches in the field of new technologies, industry, manufacturing and services, energy, healthcare, SmartCities, regional development, e-government, broadband infrastructure, the Internet of Things, and Services. Implementation of new technologies in these areas and overall digitalization on all levels require particular attention on cybersecurity to be included in the *Action Plan*. Similarly, the strategy will address the necessary modifications linked to the labor market, education, R&D, and fiscal and monetary policy. The *Alliance* is structured into strategic, managerial and working, and coordination level.

Regarding barriers to the implementation of P40, two main aspects were identified. So far, a positive development of the Czech industry leads to a reluctance to change, even though it is only a short-term perspective. The Fourth Industrial Revolution cannot be stopped, and its implications are irreversible. Furthermore, the society is not entirely familiar with the concept of Industry 4.0, and the misleading, insufficient knowledge about the subject is reinforcing the reluctance to change [9]. There is a deficient coverage of the broadband connection in some of the regions in the Czech Republic. A high-speed broadband connection across the whole country is a necessary condition for the smooth implementation of P40.

4.3. Public financing via existing operational programs

Public funding is based on the financial tools already in place. The *operational programs* and subsidy programs of the ministries and the *Technical Agency* are available to support P40-related projects. The government is currently looking into making changes to investment law for the benefit of the initiative. The financial resources allocated in the program OP PIK (€4.5 billion) administrated by the MIT already offers several suitable programs to support P40 activities. Several programs focus on the promotion and funding of scientific activities and the building of partnerships between the business sphere and R&D organizations, e.g., *Potenciál*

(Potential), *Aplikace* (Application), *Partnerství znalostního transfer* (Knowledge transfer partnership), and *Proof of Concept* for commercialization of the research results. *Služby infrastruktury* (Infrastructure Services) and *Spolupráce* (Cooperation) support development of the clusters, technology platforms, cooperation networks, innovation centers, and incubators [9].

The program *Pro-Commercial Public Procurement* provides funds and subsidies for innovative solutions for the public sector. Business entities can benefit from the program *ICT a sdílené služby* (ICT and shared services) providing financial aid to support data center operation and development of software or *Inovační vouchery* (Innovation vouchers) for obtaining know-hows. The *Operational Program OP VVV* (Ministry of Education, Youth, and Sports) and the *Operational Program OP Z* (Ministry of Social Affairs) are planned to finance the activities related to the education and social system.

In the light of facts, we have identified the program *Technology* [17] targeting beneficiaries such as start-ups, microenterprises, and SMEs; the program focuses on the acquisition of new machinery and technological equipment. Regarding the territorial dimension, the program focuses on the economically troubled regions and areas with high unemployment rate and urban areas with presumed participation in the integrated territorial investments [17]. The main objective of the program is to provide support to increase the number of new business projects implemented by start-ups and microenterprises. The program falls under the SME support programs for the period of 2015–2020, implemented by MIT of the Czech Republic with a cooperation of *Czechinvest* (Investment and Business Development Agency). The total budget available for the program is 220,795,917 EUR. The subsidy for each project may vary from 3700 EUR (microenterprises) and 37,000 EUR (SMEs) up to 740,000 EUR. The maximum aid intensity is equal to 35% (medium enterprises) or 45% (small and microenterprises) of the eligible costs. *Technology* is a support program within the *OPEIC* (Operational Program Entrepreneurship and Innovations for Competitiveness) [17]. Further programs *Trio* (€140 million), *Gama*, and *Epsilon* administrated by the MIT are considered as other options of the funding for the realization of the P40 activities. These programs aim to improve knowledge transfer between the industry and R&D institutions. At this stage, no model for private financing is in place. The government is planning to explore different possibilities.

The next part introduces selected companies, best practices, and their related issues with Industry 4.0 in the Czech Republic. We have identified many examples of companies that are very active in the area of Industry 4.0 that we have made a categorization of selected companies with a level of penetrating technological development.

5. Best practices in the Czech Republic related to Industry 4.0

In the Czech Republic, concrete examples of the implementation of Industry 4.0 elements are observed in many industries, but the Industry 4.0 deployment rate is very miscellaneous, reflecting the diverse structure of the industry. Robotics and automation are the fastest in the automotive and electrotechnical, pharmaceutical, or chemical-technological industry or services. Technology development and robotization of human activities are progressively

http://dx.doi.org/10.5772/intechopen.71798

reflected in other sectors. While it was primarily about replacing manual work, robotization is currently taking place in other segments, such as replacing work with accounting software solutions, automated logistics, maintenance, IoT, or customer approaches (chatbots, software solutions in banking, managed CRM approaches, etc.). A number of examples of companies were identified with a different level of industry introduction rate of 4.0 or their business is directly related to Industry 4.0 and we give examples.

First, we introduce the leaders in digitization, automation, and robotics (the most advanced technologies, in collaboration with technical research centers, they determine trends, they give direction), and companies are characterized by the implementation of Smart Manufacturing systems leading to Smart Factory. As an example in these high-tech issues is *ABB Czech Republic*—a leading supplier of industrial robots, modular manufacturing systems, and services. The company focus is on manufacturers to improve productivity, product quality, and worker safety. ABB has installed more than 250,000 robots worldwide, e.g., in Zetor Kovárna a.s., where hot materials are processed by a robot; at Composite Components a.s., where a fully automated workplace for milling fiberglass parts is installed; and the installation of the YuMi robot at the Low Voltage Plant in Jablonec nad Nisou. YuMi is the world's first robot enabled to work with people. The company is a partner of the Czech Institute of Informatics, Robotics and Cybernetics.

As a leader in automotive is *ŠKODA AUTO, a.s.* which implemented approaches in a big data analysis (visualization of the processes across platforms, lean process management, security principles); strategy, methods, and standards for IIoT in production; sensitive robotics—robot KUKA iiwa; system integration; predictive maintenance, system integration, additive manufacturing, and augmented reality. The company's leading projects implemented are: *Smart Maintenance* upgrade in the PKT/4 Central Maintenance Department: this innovation relates to the maintenance of machinery and equipment; *Mobile solution* with installation of *Smart components* that track their own status and report an error or failure; *Transparent Factory*—an automatic data acquisition system (processing and evaluating large data requirements) from all workplaces; *Digital Factory*—using digital models, simulations, methods, and 3D visualizations to efficiently plan, implement, manage, and continuously improve all processes and resources within the plant; and the TECNOMATIX and Siemens digital solutions portfolio that enables simulation, testing, and studies.

Second, the following companies represent the high progress in software solutions, maintenance, and high technology development areas, for example, *SIMPLECELL NETWORKS a.s.*—the first Czech public mobile operator of the SIGFOX technology network for the Internet of things; *SERVODATA a.s.*—focused on business and technology solutions, with the main domain of the portal solutions (e-shops, e-commerce, and portals), project and IT management, business process management, Intranet, Extranet, DMS, (CRM, E-contracts), and business intelligence. The leader in electrical power solutions is *ELCOM a.s.* with drivers, power inverters, industrial power systems, automated test systems, visual inspection, monitoring systems and electrical network analyzers, and activity in software development (instrument drivers and application development.

The *CERTICON a.*s. company is involved in the innovation and development of software and hardware solutions for the areas of healthcare, telecommunications, and the automotive and aeronautical industries. This company very closely cooperates with top technical universities and research laboratories throughout the EU. Focused areas of interest are: SmartCity (analysis of images from security cameras, detection of parking spaces, marketing of shopping centers); automotive (software for vehicle diagnostics—e.g., D-PDU API, RP 1210, ODX, OTX, and automotive SPICE); healthcare (monitoring of patient safety, analysis of biosignals, EPIQA smart scheduler for healthcare, and physiotherapy tools); telecommunication; and industry (predictive maintenance, capacity planning, and crisis plan).

The biggest Czech steelmaking company with domestic capital and produce the largest amount of steel in the Czech Republic are *Třinecké železárny* together with *Moravia Steel*, ranks among the most significant industrial groups in Middle Europe. The company implements production lines and units at a high degree of automation therefore mainly data are automatically available on systems, SCADA (InTouch), Manufacturing Information System (MIS), ERP (SAP); advanced planning system (APS); maintenance planning and management—ERP and MES; data interconnection between production facilities and nonproduction facilities—central data management system, system wireless coverage, machine-readable product marking, automatic nondestructive tests, modern security technology for IT perimeter.

A company with high progress is *Brisk Tábor* using, for example, automatic welding machine for side electrodes, burning of the insulator, 3D measurement, and modular assembly line for final assembly of the spark plugs. The company is preparing for the gradual transition of all company processes to fully electronic digital platform by bidirectionally linking the flow of information from production technologies to the information system to create fully new control systems and robotic workplaces.

Best practices are identified and there are hundreds of successful examples in the Czech Republic, but they share the fact that these companies use modern technology, know-hows, and large capital investment and dispose of the "will" of the CEOs to closely cooperate and implement issues to Industry 4.0. Also we include companies such as: *AVG*; *Avast* (software security); and *Minerva*—leader in ERP in EMEA region; and automotive and electronic leaders (*Continental Automotive Czech Republic s.r.o.*, *Siemens*, *Bosh*, and *Toyota Peugeot Citroën Automobile* [TPCA]). According to EY [18], 76% of Czech manufacturing companies continue to see Industry 4.0 as an opportunity to grow business. Czech companies associate the benefit of the new industrial revolution most often with productivity gains (51%), efficiency gains (47%), or the provision of data for production control (40%). One-third wants to allocate more than a tenth of its total investment spending over the next 3 years in Industry 4.0 technologies and tools and 57% of companies considered lack of qualified staff the biggest obstacle to implementing Industry 4.0. (*A total of 102 major Czech manufacturing companies took part in the survey.*)

6. Conclusions

For an industrial country like the Czech Republic, Digital Technologies and the Fourth Industrial Revolution represent an opportunity and should be taken as an advantage for the next development. The Czech Republic ranks 18th in DESI 2017. Compared to last year, the country progressed in Digital Public Services and remained stable in human capital but worsened its ranking in other dimensions. The country performs best in integration of digital technologies by businesses, mostly because many SMEs embraced e-commerce. The country's most significant challenge in digitalization is to improve the use of Internet services, in particular for e-government and entertainment and social purposes.

Overall, however, the Czech Republic is at the start of the road to Industry 4.0. As was demonstrated, since 2015, the FIR has become more significant and was also reflected in crucial strategic documents from the Ministry of Industry and Trade and Alliance Society 4.0 for spreading policy practices supporting operational Programs. It can be argued that the debate about Industry 4.0 brought a new stimulus in the spreading and usage of new technologies in society. But there are two levels of view—many companies in the manufacturing, financing, and service sectors see great potential, but there is currently a still significant "hesitation" of companies (e.g., SMEs) with Industry 4.0.

The Fourth Industrial Revolution also brings some problems, such as shortage of skilled workers. Companies call for the reform of the education system. Many Czech companies already use and fulfill some of the elements of the Industry 4.0 concept. In addition to companies in the automotive industry (as top leaders in technological and digitalization in the country), we mention, for example, the electrotechnical, pharmaceutical, or chemical-technological industries. Technology development and robotization of human activities are progressively reflected in other sectors. While it was initially primarily the replacement of gross manual work, robotization is currently taking place in other segments, such as replacing work with accounting software solutions. In summary, a trio of German companies in the Czech Republic is leading the way with the 4.0 revolution. They are Volkswagen-owned Škoda Auto, Continental, and Siemens.

In this chapter, we have explored that the Czech Republic comprised in the moderate enabling group and is in a position of catch-up and convergence. The Czech Republic performs well in the dimension of ICT start-ups. The success lies in the country's extensive access to IT skills obtained through formal education or offered by inwork ICT skills training. Czech businesses benefit from active participation in online trade. Moreover, a significant share of enterprises' total turnover derived from e-commerce contribute to a stable position of the Czech Republic in the area of e-commerce among the EU member states.

We considered some of the basis of the low performance in the area of entrepreneurial culture derives from a negative image of entrepreneurship in the Czech Republic. Recent data show a preference toward employment rather than self-employment. Also, the majority of the population has a low interest in setting up a business or taking over an existing one. Overall, the country tends to have a negative perception of entrepreneurship. The demand for digital skills also provides an opportunity for further enhancement, particularly regarding the demand for ICT skilled personnel.

Acknowledgements

This chapter was supported by the Ministry of Education, Youth, and the Sports Czech Republic within the Institutional Support for Long-term Development of a Research Organization in 2017.

Author details

Pavel Adámek

Address all correspondence to: adamek@opf.slu.cz

School of Business Administration in Karvina, Silesian University in Opava, Karvina, Czech Republic

References

[1] Kagermann H. Change through Digitazation-value creation in the age of the industry 4.0. In: Albach H, Meffert H, Pinkwart A, Reichwald R, editors. Management of Permanent Change. New York: Springer; 2015. pp. 23-45

[2] Lasi H, Privatdozent PF, Kemper HG, Feld T, Hoffmann M. Industry 4.0. Business & Information Systems Engineering. 2014;**6**:239-242. DOI: 10.1007/s12599-014-0334-4

[3] Kagermann H, Wahlster W, Helbig J. Recommendations for implementing the strategic initiative Industrie 4.0 [Internet]. 2013. Available from: http://www.acatech.de/de/publikationen/stellungnahmen/kooperationen/detail/artikel/recommendations-for-implementing-the-strategic-initiative-industrie-40-final-report-of-the-industr.html [Accessed: 11-08-2017]

[4] KPMG. The Factory of the Future—Industry 4.0: The challenges of tomorrow [Internet]. 2016. Available from: https://assets.kpmg.com/content/dam/kpmg/pdf/2016/05/factory-future-indus-try-4.0.pdf [Accessed: 13-10-2017]

[5] Ganzarain J, Errasti N. Three stage maturity model in SME's towards industry 4.0. Journal of Industrial Engineering and Management. 2016;**9**(5):1119-1128. DOI: http://dx.doi.org/10.3926/jiem.2073

[6] Karnouskos S, Colombo AW, Bangermann T. Trends and challenges for cloud-based industrial cyber-physical systems. In: Colombo A, et al, editors. Industrial Cloud-Based Cyber-Physical Systems. Cham: Springer; 2014. p. 231-240. DOI: https://doi.org/10.1007/978-3-319-05624-1_11

[7] Skilton M. Building the Digital Enterprise. England: Palgrave Macmillan; 2015. DOI: 10.1057/9781137477729

[8] Alm E, Colliander N, Deforghe F, Lind F, Stohne V, Sundstrom O. Digitizing Europer – Why northern European frontfunners must drive digitization of the EU economy. The Boston Consulting Group [Internet]. 2016. Available from: http://image-src.bcg.com/BCG-Digitizing-Europe-May-2016_tcm22-36552.pdf [Accessed: 18-04-2017]

[9] Demetrius K, Conrads J, Rasmussen M, Probst L Pedersen B, European Commission Digital Transformation Monitor – Czech Republic: "Průmysl 4.0". Digital Entrepreneurship Monitor (EASME/COSME/2014/004) [Internet]. 2017. Available from: https://ec.europa.eu/growth/tools-databases/dem/ [Accessed: 02-06-2017]

[10] Roland Berger Industry 4.0 Readiness Index [Internet]. 2016. Available from: https://w3.siemens.com/topics/global/de/partnerprogramm/branchenveranstaltungen/Documents/endcustomerforumfub/1_Roland%20Berger_KS_%20Industrie%204%200%20in%20FaB.pdf [Accessed: 14-05-2017]

[11] Digital Transformation Scoreboard [Internet]. 2017. Available from: https://ec.europa.eu/growth/tools-databases/dem/monitor/scoreboard [Accessed: 14-07-2017]

[12] Plattform Industrie 4.0: Industrie 4.0 Whitepaper FuE-Themen [Internet]. 2015. Available from: http://www.plattformi40.de/I40/Navigation/DE/Industrie40/Handlungsfelder/ForschungInnovation/forschung-und-innovation.html [Accessed: 01-08-2017]

[13] Acatech: Umsetzungsstrategie Industrie 4.0 Ergebnisbericht der Plattform Industrie 4.0 [Internet]. 2015. Available from: http://www.bmwi.de/Redaktion/DE/Downloads/I/industrie-40-verbaendeplattform-bericht.html [Accessed: 16-09-2017]

[14] VDI/VDE-GMA: Statusreport Referenzarchitekturmodell Industrie 4.0 [Internet]. 2015. Available from: https://www.vdi.de/artikel/vdi-schreibt-referenzarchitektur-fuer-industrie-40-fort/ [Accessed: 10-09-2017]

[15] Europe's Digital Progress Report (EDPR). Country Profile Czech Republic [Internet] 2017. p. 2017. Available from: https://ec.europa.eu/digital-single-market/en/news/europes-digital-progress-report-2017 [Accessed: 20-06-2017]

[16] National Initiative – Industry 4.0, Ministry of Industry and Trade [Internet]. 2015. Available from: https://www.mpo.cz/assets/dokumenty/53723/64358/658713/priloha001.pdf. [Accessed: 02-08-2017]

[17] Technology [Internet]. 2015. Available from: http://www.mpo.cz/cz/podnikani/dotace-a-podpora-podnikani/oppik-2014-2020/vyzvy-op-pik-2016/technologie---vyzva-v--222187/ [Accessed: 04-06-2017]

[18] EY survey: Industry 4.0 from the point of view of Czech practice [Internet]. 2016. Available from: http://www.ey.com/cz/cs/newsroom/news-releases/2017_ey--76---ceskych-vyrobnich-spolecnosti-stale-povazuje-prumysl-4-0-za-prilezitost-pro-rozvoj-podnikani [Accessed: 14-10-2017]

INTECH

Chapter 3

Human Capital in the Smart Manufacturing and Industry 4.0 Revolution

Joseph Evans Agolla

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.73575

Abstract

The purpose of this chapter is to highlight the important role of human capital management in the Smart Manufacturing and Industry 4.0 revolution. Two hundred years ago, industrial revolution in the west has transformed or evolved from mechanical production driven or powered by water, and to date, we are in an era characterised by cyber physical systems. This transformation or industrial revolution has been driven by humans using creative minds to solve problems that were confronted. The Industrial 1.0 Revolution around 1700 AD, mass production was carried out by mechanical production powered by water (steam engines), which was labour intensive. The more manpower an industrial organisation has, the more goods and services would be produced, though this could take long to reach the market but that was the industrial system at that time. From mechanical production powered by steam engines between 1700s and 1800s to the second Industrial Revolution mass production powered by electricity between 1800s and 1900s to the third Industrial Revolution powered by electronic and IT automation and finally to Industry 4.0 Revolution cyber systems in 2000 and beyond, human capital has generated innovative solutions to human problems more than ever before. Today, human capital is not only creative, but rather a super human capital.

Keywords: human capital, cyber physical space, Industry 4.0 revolution, innovation, management, virtual organisations

1. Introduction

The chapter is structured as follows: first, an overview of Smart Manufacturing and Industry 4.0 revolution, which is followed by the future competencies required of human capital, conceptual framework for Smart Manufacturing and Industry 4.0 revolution, rewarding human capital in Smart Manufacturing and Industry 4.0 revolution and conclusion.

1.1. An overview of Smart Manufacturing and Industry 4.0 revolution

Ever since the origin of Industry 1.0 revolution in the seventeenth century till to date, the world has systematically gone through different phases of rapid industrial revolution with each marked with something totally different from the others. From Industry 1.0 revolution to Industry 2.0 and to Industry 3.0, countries have witnessed and experienced fast pace of technological changes. In Industry 1.0 revolution mass production was by powered steam powered or water engines that characterized it at that time. However, today no country or organisation can afford to take backseat and watch without being actively involved in Smart Manufacturing and Industry 4.0 revolution. The ingenuity of human beings in today's world has surpassed any human definitions of creativity, as human has transformed into super beings. Humans now possess great knowledge and how organisations will trade in such knowledge will make the difference in Smart Manufacturing and Industry 4.0 revolution.

Smart Manufacturing and Industry 4.0 revolution are characterised by Mobile, Cloud, Big Data analytics, Machine to Machine (M2M), Man to Machine Interactions (M2MI), 3D Printing, Robotics and many more that will require organisations with specific expertise. It is also said that Industry 4.0 revolution goes far beyond these. Digital networks to Cyber-Physical Systems (CPS) are simple physical objects with embedded software and computing power. In Smart Manufacturing and Industry 4.0 revolution, it is predicted that more manufactured products will be smart products and Cyber-Physical Systems (CPS). This is based on the connectivity and computing power, leading to self-management capabilities. Today, most of the manufacturing equipment transform into Cyber-Physical Production Systems (CPPS), which is software enhanced machinery. This equipment has its own computing power, capitalising on a wide range of embedded sensors and actuators, which is beyond connectivity and processing power. The CPPS act and know their state, capacity and different configuration options and are able to take decisions independently just like human beings. This gives way to a mass production, which in turn gives mass customisation, each product at the end of the supply chain. The mass customisation ensures unique characteristics as defined by the end customer. The characteristic of the Smart Manufacturing and Industry 4.0 revolution supply chain is extremely visible, integrated and the physical flows continuously mapped on digital platforms. This makes individual service provided by CPPS available to achieve the needed activities to make each tailored product. Therefore, characteristics of Smart Manufacturing and Industry 4.0 revolution are as follows:

- **Cyber-Physical Systems** (a fusion of the physical and the virtual worlds) CPS.
- **Internet of Things** (IoT) – comprises communicating smart systems using IP addresses. This communicates objects based on Internet technologies. Also, detect and identify using IPv6 addresses (128 bit address space). The advantage of this is that the detection, identification and location of physical objects and it communicates through connectivity.

http://dx.doi.org/10.5772/intechopen.73575

- **Internet of Services** (IoS) – this is new approach to provide Internet-based services, concepts for product specific on demand, knowledge provision and services for controlling product behaviour. Interaction between people, machines and systems improve added value.
- **Internet of Data** (IoD) – in this scenario, data is managed and shared using Internet technologies. This is because Cyber-Physical Systems are producing big data. There is the development of a holistic security and safety culture.

The future of production is forecasted in Smart Manufacturing and Industry 4.0 revolution as one that is characterised by significant efficiency gains mainly through consequent digital integration and intelligentization of manufacturing processes [1]. This integration takes place on the horizontal axis across all participants in the entire value chain and on the vertical axis across all organisational levels [2]. In Smart Manufacturing and Industry 4.0 revolution, fully integrated and networked factories, machines and products act in an intelligent and partly autonomous way that requires minimal manual/human interventions [2]. Currently, Smart Manufacturing and Industry 4.0 revolution have introduced new concepts such as: Internet of Things (IoT), Industrial Internet (II), Cloud-based Manufacturing (C-BM) [3] and Smart Manufacturing addresses this vision of digitally enabled production and are commonly subsumed by the visionary concept of Industry 4.0 revolution [4]. In Smart Manufacturing and Industry 4.0 revolution, these concepts are related to recent technological progress where the Internet and supporting technologies (e.g. embedded systems) serve as the mainstay to integrate or create human-machine interface, materials, products, production lines and processes within and beyond organisational boundaries to form a new kind of intelligent, linked and agile value chain [2].

In Smart Manufacturing and Industry 4.0, learning organisations prove to be an indispensable means for educating students and professionals regarding practical application of production management principles and concepts. Lean management as a learning subject has clearly dominated the scene in the last decades. However, the current and future production scenarios in the sense of Smart Manufacturing and Industry 4.0 revolution also need other competencies to be addressed in order to enable today's managers and workers of organisations to deal with the challenges of an increasingly digitalised production system [5].

1.2. Future competencies for smart manufacturing

The Smart Manufacturing and Industry 4.0 is characterised by small decentralised, digitalised production networks, autonomously acting and capable of efficiently controlling their operations in response to changes in the environment and strategic goals [2]. The nodes of such a network are referred to as Smart Factories/Smart Manufacturing (SF/SM). This type of network is linked to a larger value chain network with the responsibility to fulfil a certain customer demand. In addition, assets such as machines and materials are situated at the underneath line of the whole automation pyramid, but are all well integrated through standardised interfaces. Last but not least, during manufacturing process, machines and products are inimitably identifiable and situated at all times in their entire lifecycles. These smart materials and products are custom-built to a large extent at the costs of mass production in Smart Manufacturing and Industry 4.0 revolution.

1.2.1. Personal competencies

The question that one may want to ask is what type of personal competencies, skills and abilities is needed to fit well in Smart Manufacturing and Industry 4.0 revolution? Such competencies can be viewed as the ability of a person to act in a reflective and autonomous manner [2]. In nutshell, such competence comprises the ability to learn (develop cognitive abilities), to develop an own attitude and ethic value system that a person may possess. In addition, at the level of a worker, Smart Manufacturing and Industry 4.0 have created an increased automation of routine tasks never witnessed before. Today's workers have to face the fact that their present tasks no longer exist in the future, because the future promises uneven playground. The workers tasks keep on changing rapidly and there is a need to upkeep with the changes in the tasks. The rationale is that the digitals, Internet of Things and Networked Systems have eradicated some or most of the tasks, the worker currently performs [6]. This may require the ability to look at a person's own task perspective taking into account the bigger picture of the society as a whole (the challenges, resource scarcity, opportunities and wealth). In addition, opportunities for a person's own development and the commitment to lifelong learning should be the responsibility of both the individual and the organisation [3]. However, rather than developing naïve technology, devoutness as a critical attitude towards technological developments is a key asset for the future worker and organisation in Smart Manufacturing and Industry 4.0 revolution [2].

Personal flexibility with respect to work time, work contents, workplaces and mindsets are prerequisites competencies for an agile production, to respond quickly to market need and environmental situations. In addition, today and future managers need the ability to transform their management and leadership styles from power-driven to value-driven [7], as the teams of the Smart Manufacturing and Industry 4.0 are diverse both in culture, education and geographical location.

1.2.2. Social/interpersonal competencies

This is conceived as an individual who is embedded in a social setting, for example, like human beings and organisations also need the ability to communicate, cooperate and establish social connections, structures with other individuals and groups [6]. This is because organisations are social systems where interactions take place between different players (human-machines, human-human, etc.). The full digital integration and automation of the Smart Manufacturing processes in the vertical and horizontal dimension entails as well an automation of communication and collaboration mainly along standardised processes. Consequently, workers are responsible for a broader process scope and need the capability to comprehend the relations between processes, information flows, possible disturbances and potential solutions to such interfaces. The increase in scope and complexity of Smart Manufacturing and Industry 4.0 require a mindset geared towards building and maintaining networks of experts that are capable of cooperating in finding the ideal solutions to a particular problem. Currently, human work now concentrates at the edges of interfaces in which human flexibility in problem solving

http://dx.doi.org/10.5772/intechopen.73575

and creativity is strategic. Therefore, allowing creative activities to be performed in distributed social settings, involving heterogeneous interdisciplinary and inter-organisational teams, require the ability to communicate complex problems in different languages as well [4].

Therefore today, managers must build or act as mediators that permit social processes such as mutual decision processes, which is not only within customary organisational borders but also for the whole network [8]. Social media play a key role as supporting technology in the Smart Manufacturing and Industry 4.0 revolution [2]. Managers, engineers and workers now have to show literacy, skills, knowledge and abilities with different tastes of technical communication and support systems [9].

1.2.3. Action-related competencies

Action-related competencies of a worker can be understood as 'the ability to take individual or socially constructed ideas to action' that transforms dreams into reality in Smart Manufacturing and Industry 4.0 revolution. It is the ability of an individual to integrate concepts into its own agenda, to successfully transfer plans into reality, not only on the individual but also on an organisational level [6]. It is worth noting that these concepts could be in their abstracts forms and therefore need to be reflected in their real sense of meanings.

Digitalisation production inevitably leads to high financial and technological efforts for the Smart Manufacturing and Industry 4.0 revolution. The inherent risk associated with such efforts needs pragmatic thinkers and actors to bring down the 'sky-high' vision of Industry 4.0 revolution to the shop floor, where majority of the workers are engaged [4]. Both managers and workers require strong analytical skills and ability to find domain-specific and practicable solutions without losing the overall goal, which is the key competencies. To accomplish this, therefore, managers must break down complex concepts into realistic work packages, to find and to assign appropriate people and teams [2]. Smart Manufacturing and Industry 4.0 are not a straightforward methodology or technology. Managers are required to encourage taking new routes but also take into account the risk of failures. For workers and managers alike a strong interdisciplinary "out-of-the box" orientation is likely to facilitate solutions finding in complex environments [2].

1.2.4. Domain-related competencies

This is referred to the ability to access and use domain knowledge for a job or a specific task [6]. The key elements of the domain knowledge are methodologies, languages and tools that are designed for problem solving or business domain and reaches beyond marginal. A core element of Smart Manufacturing and Industry 4.0 revolution is the full digitalisation of planning and the exploitation of data. The full digitalisation acts facilitates intelligent planning, control production processes and networks [2]. Production processes and networks (also those in the future) have domain peculiarities that require domain-specific competencies. Digitalised and intelligently managed production processes require works that are capable to understand the basics of network technologies and data processing [4]. Therefore, workers need to appraise whether the subsystems are performing as expected and must be able to interact with such systems through suitable interfaces. In case of disruptions, workers and engineers must be able to analyse complex systems through specialised software [6]. Engineers are required to acquire skills, knowledge and abilities about state-of-the-art software architectures, modelling and programming techniques [4]. In addition, statistical methods and data mining techniques are key capabilities for future production engineers [10].

In summary, human-machine interfaces in the Smart Manufacturing and Industry 4.0 revolution have to be developed based on the user-centred approach with a task- and situation-orientation.

2. Human capital in Smart Manufacturing and Industry 4.0 revolution

Human capital is considered critical for the success of organisations in today's world, however in Smart Manufacturing and Industry 4.0 revolution, researchers and management practitioners are already predicting this scenario to take a different shape, given the characteristics of the changes anticipated. The characteristics of human capital that are key to success are education, experience and knowledge that organisations need to tap into to achieve success in the competitive world. Human capital theory considers that knowledge brings greater cognitive skills to individuals, thus impelling their productivity and efficiency potential to develop activities [5, 10]. From the national perspective, human capital can be defined as:

"*Human capital can be defined as a set of knowledge, abilities and skills, used in activities, processes and services that contribute to stimulate economic growth*" [9].

However, from this [9] definition, the author coins the definition that matches human capital in an organisation as:

A set of education, experience, knowledge and skills possessed by employees and that is used to create value for the success of the organisation. In these two foregoing definitions, we can see how experience, knowledge, skills and education are critical for human capital in the organisations, which in essence underscore the importance and role of human capital in the Smart Manufacturing and Industry 4.0 revolution.

Smart Manufacturing and Industry 4.0 requires not only just workforce, but also human capital nurtured in competitive education systems that is well prepared for creative work environments. No organisations require physical and tangible humans, as the present and future seems to offer a plethora of challenges to organisations and humanity. Therefore, as humans embrace to usher in Smart Manufacturing and Industry 4.0, it has become imperative for nations as well as organisations to embark on education systems that are more focused on knowledge beyond what the world currently preach. This may require teaching creativity to children at an early age (Early Childhood Education) right up to university levels. A move away from traditional education systems of writing, reading, cramming and memorising as mode of passing an examination that never produce thinkers, creators and ingenuity should be a thing of the past. Therefore, nations need to revolutionise their education systems that produce super humans capable of surviving in Smart Manufacturing and

Industry 4.0 revolution. Education revolutions require a national culture that is supportive to such initiatives from government, where the citizens feel they have something to contribute towards achieving Smart Manufacturing and Industry 4.0 revolution goals. Hence, result in producing human capital that is capable to benefit Industry 4.0 revolution needs for Smart Manufacturing competitiveness.

3. Education in Smart Manufacturing and Industry 4.0 revolution

There is enough evidence that a country's education system plays an important role in its social, economic and political development. Most successful countries are successful because of their education system, for example, Japan education system requires that from class one to three, children are only taught Japanese moral values and nothing else. This is to ensure that they are imbibed with the Japanese's culture and education system that is supportive of Japanese's work environment ethics. Classrooms should foster quality environment capable of creative thinking and divergent views among children irrespective of their ages and stages of their education. Embracing technologies at an early age make such children more adaptable to the needs of Smart Manufacturing and Industry 4.0 revolution as opposed to adoptions and diffusions of such technologies at a later stage. Education for Smart Manufacturing and Industry 4.0 revolution is defined by technology literacy, information literacy, media creativity, social competence and responsibility, workplace skills and civic engagement. This is because the information made available dramatically increase, hence requiring people to have new skills to critically access and process content to ensure the best social communication and interaction. Smart Manufacturing and Industry 4.0 revolution present an opportunity as well as challenges to nations' education systems and only those nations whose education systems are anchored in inclusiveness and technologies imperatives will remain competitive. It is evident that, Smart Manufacturing and Industry 4.0 revolution rely more on the convergence of networks and devices to build bridges between people and countries. On the one hand, nations are already moving towards digital democracy to make their citizens productive and engaged participants in democracy. While on the other hand, in the workplace, more people are needed with technological skills to meet the demand of digital workplace worldwide. To meet all these demands for Smart Manufacturing and Industry 4.0 revolution, lifelong learning is necessary to ensure that everyone can stay informed. Universities have to lead research efforts not only to identify the skills but also to produce calibre of workforce that have the skills needed in the Smart Manufacturing and Industry 4.0 revolution. The questions that we need to address are: what sort of education systems is conducive for the Smart Manufacturing and Industry 4.0 revolution? How can we match education, knowledge and skills with that of Smart Manufacturing and Industry 4.0 revolution?

The evaluation of the competitiveness in the higher education sector should apply the approach that appraises the competitive advantage of the present systems with its legal, political, economic, social and technological factors [11]. The appropriateness of this method is based on the growth of a higher education environment that inspires, allows and safeguards a competitive higher education system. This takes an active part in increasing the standard of public (society) welfare and satiating the public interests through innovative approaches [11] as shown in

Figure 1. A model of human capital for Smart Manufacturing and Industry 4.0 revolution. Source: Author's own illustration.

Figure 1. Not only the competitiveness of higher education system that plays critical role, but also right from early childhood education (Pre-school), primary, secondary, vocational and tertiary education that ensures a country's competitiveness in its overall education system.

The effectiveness of higher education system stresses the element of human capital (scholars, higher education managers, educators, academics, students, etc.): the overall effectiveness evaluation system is based on the human competencies, ensuring the performance of higher education institutions, its evaluation, quality assurance frameworks, potential demand or final outcomes [11]. This is where most developing countries should focus to revolutionise their education for knowledge and innovative society that results in the national competitiveness. Good and competitive education system ensures a country of creative and knowledgeable population that contributes immensely at national innovation systems (NIS) as individual or organisation. In this study's conceptual (**Figure 1**), this relationship has been demonstrated.

Any education system or policy should focus learning outcomes that stimulate the three components of creativity (creative-thinking skills, expertise and cognitive) at any level of the education. When these people are nurtured under this type of education system, then that assures a country of not only creative, but also knowledgeable society [7].

Education systems that encourage and promote learners to question what they have been taught in formal as well as informal classrooms is an ideal for innovation-driven economy as it develops calibres of society where creative thinking is the norm of the day. This type of behaviour should be entrenched in the society as a whole, for example, early childhood education development level. When children are allowed to questioning, it leads to knowing, which develop their mental faculty to reason and analyse things from different perspectives. However, in most developing countries, particularly sub-Saharan-Africa countries, the cultural practices are that a child must not question anything coming from an adult person, as this is considered to be rude. In addition, it is viewed as a taboo and such children are seen as disrespectful to adult persons. But to create innovation-driven economy, any education policy should be such that it foster and nature creativity of the learners right from early childhood education development to higher education. This equips a country with creative and knowledgeable population that is capable for innovation imperatives. An attempt has been made to demonstrate three components of creativity that any education systems should focus on given creativity is a precursor to innovation. Education systems in the developing countries are products of colonialism that was developed without most of the developing countries people's participation, since then little has been done to reflect the changes that have taken place in the world.

A country's capacity to absorb new technologies depends on upgrading the skills of the human capital, to produce goods and services that can reach standards of quality and performance acceptable in international markets. Such a country engages with the rest of the world in ways that create value. This requires the higher education system's collaboration with the labour market, private, public and secondary education among others. In order for higher education system to contribute successfully to a country's competitiveness, it needs to work hand in hand with all of them [12]. In particular, developing countries' national innovation policy should focus on an education system that is able to develop basic analytical and problem-solving skills, creativity, imagination, resourcefulness and flexibility of its people [8]. These skills and knowledge are critical and relevant to the Smart Manufacturing and Industry 4.0. Such countries and organisations that invest and reward their people effectively compete in Smart Manufacturing and Industry 4.0 revolution.

4. Organisation culture

Culture is the glue that glued a particular people together. In defining culture, several scholars have offered different definitions; however, of interest is that of [13] who defined culture as *"the shared ways in which groups of people understand and interpret the world"*. While on the one hand, Ref. [14] states that culture is something that is learned and therefore is entrenched in a society or nation. It is akin to a "mental programme" that is developed early in life and fortified through a widespread programme of socialisation. "The usual act of idea is greatly changed by culture" [15]. This is because of the effect, culture has on the lives of people; it provides a structured and highly consistent way of living that is not deliberately constructed [15]. Tse [13, 14] postulates a real-world application of culture to living, implying that culture can be perceived as an "onion" in which the central represents the value systems and the covers growing out of it denote customs and rites expected from values. The question that bog us are how does a national culture promotes and hinders a country's innovation capacity? Throughout history and civilisations, those involve in innovation are gifted people who take creativity and risk. Others work independently, while some with groups and organisations. But, in almost cases, these persons want support and infrastructure to transform their concepts and creative ideas into something concrete and marketable. While individual instinct, inventive ability and tendency are instrumental in moving innovation projects forward, the surrounding environment and culture serve as the incubator that aids or inhibits innovation [16]. It is common to see in developing countries' people laugh at innovators or inventors simply because they failed to make ingenuity materialise or their experiment could not see the light of the day. This is what I call "great killers of creativity and innovation". Such innovators, inventors or creators need moral support irrespective of the outcomes of their experiments. Otherwise, the would-be innovators will naturally shy away from such innovation endeavours in future fearing to be turned into a laughing stock by the society in which they live. The support from the society and the government naturally make these innovators, creators and inventors to aspire for more of innovative ventures. Therefore, supportive national culture irrespective of success or failure will motivate more innovators to come forward and offer something new, which in turn can be transformed into innovation imperatives.

Innovative culture is a tolerance of ambiguities, failures, divergent views and people are praised for trying out something new irrespective of the outcomes of such experiments. Much creativity has been killed due to the culture of intolerance to failures, as people are laughed at whenever they failed to achieve something they are experimenting with. Organisations as well as nations that want to be competitive in Smart Manufacturing and Industry 4.0 revolution must be at the forefront to encourage diverse ideas as a way to foster creativity.

5. Government

The role of government in innovation pervades all the sectors of the economy. As the sole regulator of the economy, government can either promote or hinder innovation. Government promotes innovation through the formulation of user-friendly legislation and policies that are supportive to both creative and innovative endeavours in the economy. At the national level, government is responsible for pulling all the sectors of the economy towards a common purpose to achieve economic development. But how does a government achieve this in the first place?

In other countries, Malaysia for example, the government is committed to a lower carbon footprint and reduction of air pollution in order to improve the health of its citizens and create a better environment [17]. To achieve this, the Malaysian government has established the Malaysia Green Technology Corporation (MGTC) to promote green technology under a national green technology policy [17]. This policy has encouraged Malaysian industries in the economy to explore innovative ways to improve development of new products, production processes, firm productivity and ecological improvements. This is a typical government promoting innovation through policy creation and implementation at a national level, which results in new start-ups/industries [18].

Innovation at a national level requires efforts from all the sectors of the economy to be spearheaded by a committed government and political will. Countries that have experienced rapid innovation have succeeded doing so because of the government taking the front lead in areas such as policy formulation, funding, openness to external ideas (open innovation) and joint-ventures in large undertakings of projects. For example, the Chinese government encourages firms to source external knowledge by acquiring foreign technology through the enactment of various legislations, policies and reforms [19]. Innovation policy at a national level that covers a broad spectrum of industrialisation and development needs of a country through financial, tax, industry, trade and Science and Technology (S&T) should serve as a link that connects all relevant players/actors at various levels of NIS [19].

The policy imperatives should define specific types of innovation at NIS such as inbound Open Innovation (OI), Outbound Open Innovation (OOI) and Closed Innovation (CI). This guides players/actors at different levels of the NIS as they engage in innovation endeavours at a national level. The innovation policy should also cater for how the resources of the NIS are shared among the actors, given that some innovation ventures require substantial resources that may not be within individual or organisational reach. Collaboration and engagement of government and citizens in NIS is paramount for an innovative nation [20].

To tap on the creativity of the entire population, outreach and other mechanisms need to be put in place that involves citizens. It is a bottom-up approach to problem solving. Governments should be ready to reward and incentivise innovators in the economy through appropriate legislations and policies as a way to promote innovation at a national level [21]. Such recognition of innovativeness strengthen and motivate innovators to come up with more creative approaches to solving real societal problems such as unemployment, poverty, infrastructure issues, health issues and other myriad problems facing a country.

It is unquestionable that the government plays a significant role in encouraging and stimulating innovation in the economy. This is achieved through various ways such as enactment of legislation that is pro-innovation as well as sustainable economic development. Government, too, can change the state of happiness, commitment and dedication in a society towards innovation [18].

6. National knowledge management

Since the beginning of Adam and Eve, knowledge has always existed and the co-existence of knowledge and humanity is shown in different human-made exploits [22]. Such exploits can be seen from Pyramids of Egypt, Taj Mahal in India and many others. Just like an organisation, a country's capability to innovate hangs on its domestic (within the boarder) competencies such as its own knowledge, organisational and technological base as well as its skills in discovery, embracing, developing and expanding knowledge generated within its boarders and collaborations with its proximate environment [23]. Knowledge-grounded development in today's global economy has become an arsenal and the ability of nations to generate, transfer and apply knowledge, but also to "tap external knowledge as well as adapt such knowledge for specific needs" locally [24]. For sustained (knowledge) development to take place, countries need to establish mechanisms that facilitate the circulation of data, information and knowledge across developing and developed nations [25].

In the twenty-first century, new organisations are emerging where knowledge is the primary production resource as opposed to capital and labour [26]. It is now believed that efficient utilisation of existing knowledge could create wealth for organisations. Knowledge management (KM) refers to the process of enhancing organisation performance by designing and implementing tools, processes, systems, structures and culture to improve the creation, sharing and the use of knowledge [27, 28]. Knowledge is increasingly becoming more valuable because management is taking into account the value of creativity, which allows for the transformation of one form of knowledge to the next. The perception of the existing relations among numerous systems elements leads to new interpretations and this means another knowledge level where a new perceived value is generated [29]. This relationship denotes that innovation highway hangs on the knowledge development [29, 30]. This relationship has well been captured in the proposed conceptual framework (**Figure 1**).

Previous studies [24] have shown that knowledge generation or acquisition, knowledge sharing and knowledge leverage or utilisation build employees' skills are relevant to the process of innovation. Knowledge management that facilitates collaboration between employees and sectors enhances the knowledge sharing and utilisation, which in turn increase innovation (see **Figure 1**). Therefore, knowledge sharing plays an important role in innovation imperatives. Encouraging knowledge sharing between employees and incorporating KM into strategies lead to gain competitive advantage, customer focus and innovation [24, 31]. Organisations also could trigger off the sharing, application and the deployment of knowledge to facilitate innovation, because KM has a positive effect and contribution to transform tacit knowledge into innovative products, services and processes, which improve innovative performance as shown in **Figure 1**. Some studies showed that there is a relationship between organisational innovation and knowledge transfer as well as reverse knowledge transfer, but its effect depends heavily on learning orientations [24]. In gist, two key elements are important in the definition. From the review of the literature, there is evidence that knowledge is the core component of innovation – not technology or finances.

In a nutshell, strategic human capital practices are deployed in Smart Manufacturing and Industrial 4.0 revolution to ensure a competitive advantage by focusing extensively towards the human capital and build the knowledge base for a sustained growth. From the strategic human capital management perspective, a set of integrative human capital practices that support organisation's strategy produces a sustainable competitive advantage (**Figure 1**).

7. Rewarding human capital in Smart Manufacturing and Industry 4.0 revolution

Human capital management in the Smart Manufacturing and Industry 4.0 revolution provide workers with clearly defined and consistently communicated performance expectations. In Smart Manufacturing and Industry 4.0 revolution, managers are responsible for evaluating their employees' performance. This evaluation takes into account a fair rating, rewards and holds worker accountable for achieving specific business goals. The sole aims of such evaluation is crafting innovation and supporting continuous improvement). In Smart Manufacturing and Industry 4.0 revolution, human capital management is viewed as an approach to organisation staffing that values workers as assets. Such organisation perceives human capital as assets whose current value can be measured and future value can be enhanced through investment [32]. Human capital acts as a catalyst to increase productivity in Smart Manufacturing and Industry 4.0 revolution. Smart Manufacturing and Industry 4.0 revolution cannot survive if there are no human capital with the necessary skills, knowledge and abilities to transform concepts and abstracts thinking into reality that add value to the organisation. The success or failure of Smart Manufacturing and Industry 4.0 revolution depends entirely on how human capital contributes in his or her own way in its success and productivity. Human capital represents the collective value of Smart Manufacturing and Industry 4.0 revolution's competencies, knowledge and skills. This renewal is the source of creativity and innovation that imparts to Smart Manufacturing and Industry 4.0 revolution, the ability to change. Workers are the facilitators who stimulate the physical, inert forms of knowledgeable human capital and the docile forms of tangible capital, materials and equipment to improve Human capital as the most vital asset in Smart Manufacturing and Industry 4.0 revolution and managing it is the greatest challenge facing modern managers and organisations [32]. For Smart Manufacturing and Industry 4.0 revolution to succeed, it is critical to map the workers centric approaches with that of Smart Manufacturing and Industry 4.0 revolution strategies.

In Smart Manufacturing and Industry 4.0 revolution, it is not possible to just get rid of them (employees). In fact, unless organisations learn to get the best out of their creative employees, they will sooner or later end up filing for bankruptcy. Similarly, if organisations just hire and elevate workers who are friendly and easy to manage, such organisations will be mediocre at best. This is because suppressed or stifled creativity is harmful organisational growth. While every organisation claims to care about innovation, very few are ready to do what it takes to keep their creative people happy or at least, productive. So what are the keys to engage and retain creative employees? In whatever form or structure, rewards must be seen to motivate and retain the creative human capital for the Smart Manufacturing and Industry 4.0 revolution.

7.1. Spoil them and let them fail

Like parents who rejoice their children's chaos: show your creative absolute encouragement and inspire them to do the illogical and flop. Innovation can originate from uncertainty, risk and experimentation if you know it will work, it is not creative. Creative people are the natural experimenters, so let them try and test and play. This is because there are costs associated with experimentation but these are lower than the cost of not innovating [32].

7.2. Surround them by semi-boring people

Managers must not find themselves doing the worst by forcing a creative employee to work with someone like them. Such action is likely to flop because employees will compete for ideas, brainstorm eternally or simply ignore one another at the end. That being said, managers should not surround creative worker with colleagues who are really boring or conventional, they would not understand them and fall out. In line with this, recent research suggests that teams consist of diverse members who are open to take each other's viewpoint and perform most creatively [32].

The response, then, is to support creative workers with their colleagues who are too conventional to challenge their ideas, but unconventional enough to collaborate with them. These colleagues will need to pay attention to details, mundane executional processes and do the dirty work.

7.3. Involve them in meaningful work

Innovators naturally tend to have more vision. They see the bigger picture and able to comprehend why things matter (even if they cannot explain it). The downside to this is that they simply will not involve in worthless work. This all or nothing approach to work reflects the bipolar character of creative artists, who perform well only when is fuelled by value. This approach can also apply to other employees because everyone is more creative when driven by their honest interests and a hungry mind.

At the same time, in any organisation there are employees who are less interested in, well, doing interesting work; they are satisfied with simply clocking in and out and are incentivized by external rewards. Organisations should ensure that frivolous or meaningless work is assigned to these employees [32].

7.4. Eliminate pressure from employees

Smart Manufacturing and Industry 4.0 revolution require that workers be given more freedom and flexibility at work as this usually enhances creativity, which is a precursor innovation. It cautions managers in Smart Manufacturing and Industry 4.0 revolution against leaning towards structure, order and predictability, terming such managers as probably not creative. This is because workers are more likely to perform more creatively in spontaneous and unpredictable situations. Managers should not constrain creative employees or force them to follow processes, rules, procedures or structures. Smart Manufacturing and Industry 4.0 revolution require workers to work remotely and outside normal hours; the emphasis is managers must not ask where employees are, what they are doing or how they do it. Workers left to decide what, when and how to perform a particular task is the calibre of employees needed in Smart Manufacturing and Industry 4.0 revolution.

7.5. Do not overpay employees

There is evidence suggesting a relationship between intrinsic and extrinsic motivation. Over the past two decades, psychologists have provided persuasive support for the so-called "over-justification" effect, namely the process whereby higher external rewards weaken performance by lowering a person's genuine or intrinsic interest [32]. Most notably, two large-scale meta-analyses reported that, when tasks are naturally meaningful (and creative tasks are certainly in this condition), external rewards weaken commitment. This is true in both adults and children, especially when people are rewarded merely for performing a task. However, providing positive feedback (praises) does not harm intrinsic motivation, so long as the feedback is perceived as honest. The moral of the story! The more you pay people to do what they love, the less they will love it. In the words of Czikszentmihalyi [33]:

"The most important quality, the one that is most reliably present in all creative individuals, is the ability to enjoy the process of invention for its own sake" [33].

More significantly, workers with talent for innovation are not motivated by money. Evidence suggests quite clearly that the more imaginative and inquisitive workers are, the more they are motivated by appreciation and absolute logical inquisitiveness rather than commercial needs.

7.6. Surprise employees

Few things are as frustrating to creative as tediousness. The characteristics of creative people are that they naturally seek persistent change, even when it is of less value. They take a different route to work every day, sometimes they get lost on the way and never repeat an order at a restaurant or hotel, even if they really loved it. Creativity is linked to higher tolerance of ambiguity [32, 34]. Creative and inventor love complexity and like making simple things

http://dx.doi.org/10.5772/intechopen.73575

complex rather than vice-versa. Instead of searching for the solutions to a problem, they usually prefer to generate a thousand solutions or a thousand problems. It is therefore necessary that managers keep surprising their creative employees; failing that, managers should at least let them generate enough chaos to make their own lives less predictable.

7.7. Make employees feel important

"Most of the problem in this world is as a result of people seeking to be important" in organisation. And the reason is that others fail to appreciate their worth. Justice is not treating everyone the same, but like appreciating and giving them what they are worth. Every organisation has high and low potential employees, but only competent managers and leaders can identify such employees. If managers or leaders fail to recognise such employees' creative potential, employees will switch to other organisations where they feel more valued in terms of contributions [32]. Therefore, in Smart Manufacturing and Industry 4.0 revolution, organisations need to change their way of rewarding and managing these new generations of employees in order to successfully compete.

A final warning: Being able to manage your creative employees perhaps may not mean that managers should let creative employees manage others. Evidence suggests that natural innovators or inventors are hardly talented with leadership skills to warrant them handed leadership of other fellow employees. This is because the profile for good leaders and those of creative people are rather different. Example of such creative people who could not relate well with other people, but doing well with gadgets can be drawn from Steve Jobs. In addition, most Google engineers are completely not interested in the position of leadership or management. It is been proven that the orthodox view that corporate innovators or intrapreneurs demonstrate many of the psychopathic features that inhibit them from being successful leaders: they are uncontrollable, anti-social, self-seeking and often too low in responsiveness to other employees' welfare. But if these creative employees are managed well, motivated and incentivized, then their inventions will delight many [32, 34].

8. Conclusion

The chapter provides a strong evidence of the important role human capital plays in the Smart Manufacturing and Industry 4.0 revolution. In Smart Manufacturing and Industry 4.0 revolution, the success or failures of most organisations largely depend on how their human capital is managed. This is because Smart Manufacturing and Industry 4.0 revolution provides a space where employees to machines interactions are the order of the day. There is interconnectedness among various players and actors. The interfaces created become the connecting points between workers and machines. The features of Smart Manufacturing and Industry 4.0 revolution require creative and inventive workers. These are workers who are not creative but also knowledgeable and have techno how to work in such environments. Such workers are nurtured through an education system, where creativity, inventiveness, knowledge and technology flourish and entrenched in the national culture.

A concept concerning all activities regarding employing and managing people in Smart Manufacturing and Industry 4.0 revolution is considered human capital management or more in a narrower sense human resource management [34]. Developing a workforce to meet present and future market needs proposes the identification of required competencies [34]. Competencies such as skills, abilities, knowledge, attitudes and motivations an individual needs to cope with job-related tasks and challenges effectively as defined by Smart Manufacturing and Industry 4.0 revolution cutting edge. In addition, Smart Manufacturing and Industry 4.0 revolution require people who are well entrenched into Technology of Things (ToT), human-machine interactions, technology-technology interfaces, good understanding of networked systems, creativity and innovative.

Author details

Joseph Evans Agolla

Address all correspondence to: nyagonya2009@gmail.com

Botswana Open University, Gaborone, Botswana

References

[1] Zhou J. Digitilisation and intelligentilisation of manufacturing industry. Advance Manufacturing. 2013;**1**(1):1-7

[2] Enrol S, Jäger A, Hold P, Ott K, Sihn W. Tangible Industry 4.0: A scenario-based approach to learning for the future production. Procedia CIRP. 2016;**54**:13-18

[3] Monostori L. Cyber-physical production systems: Roots, expectations and R&D challenges. Procedia CIRP. 2014;**17**:9-13

[4] Gao L, Wang L, Teti R, Dornfield D, Kumara S, Mori M, Helu M. Cloud-enabled prognosis for manufacturing. CIRP Annuals-Manufacturing Technology. 2015;**64**(2):749-772

[5] Maguire K. Lean and IT – Working together? An exploratory study of the potential conflicts between lean thinking and the use of information technology in organisations today. In: Chiarini A, Found P, Rich N, editors. Understanding the Lean Enterprise. Springer; 2016. pp. 31-60. Available from: www.springer.com/gp/book/9783319199948 [Accessed: Sep 10, 2017]

[6] Lanza L, Haefner B, Kraemer A. Optimisation for selective assembly and adaptive manufacturing by means of cyber-physical system based matching. CIRP Annuals-Manufacturing Technology. 2015;**64**(1):399-402

[7] Anderson N, Potočnik K, Zhou J. Innovation and creativity in organisations: A state-of-the-science review, prospective commentary, and guiding framework. Journal of Management. 2014;**40**(5):1297-1333

[8] Cabrilo S, Nesic LG, Mitrovic S. Study on human capital gaps for effective innovation strategies in the knowledge era. Journal of Intellectual Capital. 2014;**15**(3):411-429

[9] Neeliah H, Seetanah B. Does human capital contribute to economic growth in Mauritius? European Journal of Training and Development. 2016;**40**(4):248-261

[10] Berger R. Industry 4.0 – The New Industrial 4.0 Revolution. 2014. Available from: https://www.rolandberger.com/.../pub_industry_4_0_the_new_industrial_revolution. [Accessed: Oct 10, 2017]

[11] Stonkiene M, Matkeviciene R, Vaiginiene E. Evaluation of national higher education system's competitiveness: Theoretical model. Competitiveness Review. 2016;**26**(2):116-131

[12] Ramoniene L, Lanskoronskis M. Reflection of higher education aspects in the conception of national competitiveness. Baltic Journal of Management. 2011;**6**(1):124-139

[13] Trompenaars F. Riding the Waves of Culture: Understanding Diversity in Global Business. Beverly Hills, CA: Sage; 1994 (Burr Ridge, IL: Irwin Professional Publishing)

[14] Hofstede G. Culture's Consequences: International Differences in Work-Related Values. Beverly Hills, CA: Sage Publications; 1980

[15] Hall ET. Beyond Culture. Garden City, NY: Anchor Press; 1977

[16] Ali AJ. Innovation, happiness, and growth. Competitiveness Review. 2014;**24**(1):2-4

[17] Fernando Y, Wah WX, Shaharudin MS. Does a firm's innovation category matter in practising eco-innovation? Evidence from the lens of Malaysia companies practicing green technology. Journal of Manufacturing Technology Management. 2016;**27**(2):208-233

[18] Sim YL, Putuhena FJ. Green building technology initiatives to achieve construction quality and environmental sustainability in the construction industry in Malaysia. Management of Environment Quality: An International Journal. 2015;**26**(2):233-249

[19] Fu X, Xiong H. Open innovation in China: Policies and practices. Journal of Science and Technology Policy in China. 2011;**2**(3):196-218

[20] Hoe SL. Defining a smart nation: The case of Singapore. Journal of Information, Communication and Ethics in Society. 2016;**14**(4):323-333

[21] Sadik-Rozsnyai O. Willingness to pay for innovation an emerging European innovation adoption behaviour. European Journal of Innovation Management. 2016;**19**(4):568-588

[22] Moustaghfir K, Schiuma G. Knowledge, learning, and innovation: Research and perspectives. Journal of Knowledge Management. 2013;**17**(4):495-510

[23] Obeidat BY, Al-Suradi MM, Masa'deh R, Tarhini A. The impact of knowledge management on innovation: An empirical study on Jordanian consultancy firms. Management Research Review. 2016;**39**(10):1214-1238

[24] Chou PB, Pessarini K. Intellectual property rights and knowledge sharing across countries. Journal of Knowledge Management. 2009;**13**(5):331-344

[25] Kumpikaitė K. Human resource development in the knowledge society. Ekonomika ir: aktualijos ir perspektyvos. 2007;**2**(9):122-127

[26] DeLong D, Fashey L. Diagnosing cultural barriers to knowledge management. Academy of Management Executive. 2000;**14**:113-127

[27] Rosset A. Knowledge management meets analysis. Training and Development. May 1999;**53**(5):63-68

[28] Carneiro A. How does knowledge management influence innovation and competitiveness? Journal of Knowledge Management. 2000;**4**(2):87-98

[29] Du Plessis M. The role of knowledge management in innovation. Journal of Knowledge Management. 2007;**11**(4):20-29

[30] Mas-Machuca M, Costa C. Exploring critical success factors of knowledge management projects in the consulting sector. Total Quality Management and Business Excellence. 2012;**23**(11/12):1297-1313

[31] Olaniyan DA, Okemakinde T. Human capital theory: Implications for educational development. Pakistan Journal of Social Sciences. 2008;**5**(5):479-483

[32] Chamorro-Premuzic T. Seven Rules for Managing Creative-But-Difficult People. 2010. Available from: https://hbr.org/2013/04/seven-rules-for-managing-creat?goback=.gde_3044917_member_229811488

[33] Csikszentmihalyi M. Creativity: The Work and Lives of 91 Eminent People. 1996. Available from: http://psychologytoday.com/articles [Accessed: Aug 10, 2017]

[34] Heclau F, Galeitzke M, Flachs S, Kohl H. Holistic appraocah to human resource management in Industry 4.0. Procedia CIRP. 2016;**54**:1-6

Manufacturing Transformation toward Mass Customization and Personalization in the Traditional Food Industry

Daisuke Kanama

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.72312

Abstract

Digital transformation of the manufacturing process in high-tech has been underway for a long time. On the other hand, the transformation in low-tech and traditional industries progresses more slowly. Especially, the human factor is greater in the food manufacturing industry, which retains many more labor-intensive elements. This is because the development of foods was traditionally customized to the cultures of particular regions, so many foods were not suitable for mass production, which has led to the high level of personal skills. However, new trends have been shown recently in the sake manufacturing industry. Head craftsmen at a sake brewery, known as Toji, have managed the entirety of the manufacturing process and determined the length and timing of each process for hundreds of years. In these circumstances, some sake breweries have started to make sake in a new way that breaks with tradition. They implement smart manufacturing and customization to respond to diversified customer needs without altering the product price through the digitization of the manufacturing process and the formalization of personal skills. This chapter also discusses the prospects of this transition and considers its effects on the industry with theoretical framework and social background of manufacturing transformation.

Keywords: manufacturing paradigm, food industry, digital transformation, sake brewery, mass customization

1. Introduction

The digital transformation of the manufacturing process has been underway for a long time, as seen in innumerable examples [1–3]. In the high-tech sector—for example, in the electronics industry—digitization is rapidly progressing, as demonstrated by the advent of 3D printers [4, 5].

However, digital transformation in low-tech and traditional industries is progressing more slowly. The human factor is greater in the food manufacturing industry, which retains many more labor-intensive elements than other manufacturing industries [6]. This is because regionality is a major factor when differentiating foods from each other. Traditionally, the development of foods was customized to the climate and cultures of particular regions, so many foods were not suitable for mass production (except for certain kinds of foods that were consumed globally), which has led to the high level of personal skills in the food manufacturing industry.

The existing literature has noted that the food manufacturing industry is not deploying innovation activities as actively as other manufacturing industries [7–9]. Moreover, the industry's research and development intensity is also low [10–13]. In the traditional Japanese food manufacturing industries producing miso, soy sauce, tofu, sake, etc., quality control based on sensory-oriented skills continues to be performed by professional craftsmen. In some cases, the skills of these craftsmen, known as Takumi ("artisans"), have been handed down unchanged for hundreds of years.

In this chapter, we focus on new trends in the sake manufacturing industry. The head craftsman at a sake brewery, known as Toji, manages the entirety of the manufacturing process and determines the length and timing of each process, all of which greatly affect quality. Therefore, sake quality, including taste, scent, and texture is determined by the skills of the Toji.

However, in these circumstances, some sake breweries have started to make sake in a new way that breaks with tradition. This new approach represents a transformation from traditional production to mass customization and personalization. Some breweries are implementing smart manufacturing and customization to respond to diversified customer needs without altering the product price through the digitization of the manufacturing process, the formalization of personal skills, and the strengthening of the customer relationship.

After considering several advanced companies, we conducted a case study of the Sekiya Brewery Co., Ltd. (Sekiya), in the Aichi Prefecture of Japan. This pioneering company has developed a mechanized integrated system at the head factory and a custom-made sake-brewing system at its workshop. This company also switched from the external head Toji system to an internal Toji system. In the old Toji system, most Toji had a part-time contract. If the Toji changed, the taste of the sake might dramatically change. However, in the company's internal system, regular employees serve as Toji, thus enabling the long-term production of sake of a consistent quality.

This chapter makes two contributions to previous studies: one is for academic communication and the other is for the food industry. First, it shows and discusses the advanced customized manufacturing process. As mentioned below, the manufacturing paradigm has been shifting to mass customization; but the speed is different from industries. The most advancing industries for the paradigm shift are chemistry, automobile, and electronics, which have been driven by digitalization and remarkable innovations such as a 3D printer. And now, we can see that the traditional food industry also challenges the manufacturing paradigm shift, and they succeed.

Second, if the traditional food industry achieves the new manufacturing paradigm, it would be a great opportunity for SMEs in this industry because the case study this chapter will discuss is the very medium-sized manufacturer. SMEs and even large companies could learn from the case about how the traditional manufacturer created a new manufacturing system and realized a new business model.

The structure of this chapter is as follows. In the next section, we summarize the theoretical background of process innovation, which has changed from mass production to mass customization, along with the transition of the traditional Japanese food industry. Next, we conduct a case study of sake breweries that have attempted to develop new manufacturing processes and provide added value. Finally, we discuss the prospects and problems of this transition and consider its effects on the industry.

2. Theoretical framework and social background of manufacturing transformation and mass customization

The manufacturing paradigm has always experienced ongoing shifts. The first paradigm was that of the handcraft in which core processes were executed by highly skilled craftsman. When tools were required, the master of those tools generally possessed the needed skills. As wealth accumulated and market demand increased, the manufacturing paradigm changed to a wholesale handicraft manufacturing system. However, in the wholesale system, it was difficult to manage the equipment which was distributed to each manufacturer. Later, this system changed to employ hand-based factories that brought the equipment and the laborer together.

On the other hand, there are cases that have retained a household-based handcraft industry. Typical cases include traditional crafts industries across the country. The following three items are common aspects of such industries: (1) manufacturing regional products, (2) requiring skills that are difficult to mechanize, and (3) manufacturing products with a low price elasticity. Sake brewing, the main target of this chapter, is a traditional craft industry that features all three of these aspects.

Society then entered the Industrial Revolution. Important examples of this revolution include technical innovations in the process of cotton fabric, economic growth in the iron and steel industry, and reform for power source from the development of the steam engine. This revolution also established factory-based industry.

Both manufacturing and selling were limited to local geography during the age of handcraft manufacturing, as the steam engine had not yet been invented. Since it became possible to deliver products further, the industrialization process moved to mass production achieved through the rapid development of a production system. Factory-based industry realized mass production at a lower cost than before.

Nevertheless, the product types available were limited, and in the latter half of the 1980s, society had seen a change from an era in which many people wanted the same products to an era in which people expressed a diversity of interests; as a result, manufacturing industry competition evolved to provide high product variety, known as mass customization. Mass customization is a flexible manufacturing system that creates custom-made options. It is a system that combines the mass production process of low cost with flexible personalization.

The concept of mass customization first appeared in 1987 [14]. Tseng and Jiao [15] defined mass customization as the creation of products and services that meet customers' needs while maintaining productivity at a level close to that of mass production. There are already many examples of mass customization [16], including software based on product configurators that can both add to and change the function of a core product.

Mass customization is a stage of new business competition in the manufacturing and service industry. The service industry also enables various customizations without increasing cost. For example, a call center adopts agent-based voice technology to process customers' inquiries. The agent does not change everything every time, but he or she does change the response process depending on the customer's inquiries and needs.

Pine II [17] identifies four types of mass customization:

- Collaborative customization

Firms talk to individual customers to determine the precise product offering that best serves the customer's needs. This information is then used to specify and manufacture a product that suits that specific customer.

- Adaptive customization

Firms produce a standardized product, but this product is customizable in the hands of the end user.

- Transparent customization

Firms provide individual customers with unique products without explicitly telling them that the products are customized. In this case, there is a need to accurately assess customer needs.

- Cosmetic customization

Firms produce a standardized physical product but market it to different customers in unique ways.

Another production system, called a personalized system, reduces the distance between the customer and company and reflects a customer's idea. From a historical point of view, this method has existed since the time of the household-based handcraft industry. As a new approach in recent years, customers take part in the design stage [18]. Because customers have various needs, they actively join the design process, paying a price to affect the product's quality. Developing a ubiquitous network environment and a flexible process management method in manufacturing has made this possible.

Thus, to meet these customers' needs, manufacturers need to build new architecture with an open manufacturing platform [19]. In such an on-demand manufacturing system, product simulation, responsive, and cyber-physical systems have already been realized [20]. A more rapid assembly process might be necessary to respond to customers' requests. Hu [21] describes this paradigm as personalization and distinguishes it from both mass production and mass customization.

3. Japan's sake industry and market

Sake is defined by the Liquor Tax Act as an alcohol drink made from rice, water, and rice malt that is fermented and strained. Currently, it has two classifications: specific classes and other than specific classes. The specific classes are also divided into eight categories based on differences in ingredients and processes (**Table 1**). Generally, the specific classes are priced higher than the other classes.

Figure 1 shows the amount of sake production in Japan. Production peaked in 1975 and has gradually decreased. The share of sake in total alcohol drinks has also declined slowly, reaching 6% in recent years. This is because other alcohol drinks other than sake became popular. Beginning in the late 1970s, alcoholic drinks such as wine and whiskey were introduced to the market, and drinking places such as beer gardens and wine bars also became popular.

High-quality, high-priced sake in specific classes, for example, Jumnai and Ginjo, thwarted this trend in the late 2000s (**Figure 2**). At the time, some consumers began to express interest in local small- and medium-sized sake breweries. These breweries produced unique and original sake in specific classes based on local materials and techniques. Consumers across the country enjoy those characteristics and diversities.

Sake breweries are dispersed across Japan. Facilities producing less than 100 kl count for 60% of all sake breweries and those producing more than 300 kl are only 15% of the total. In terms of the market share, the top sake brewery, Hakutsuru, has almost 10% of the sake market, and the top five breweries have 37% of the market (**Figure 3**). Compared to the beer market, almost 99% of which is composed of the top four beer companies (**Figure 4**), we see how much the sake market is diversified and does not show oligopolization.

It seems that small- and medium-sized sake breweries have different market targets than large sake breweries, which continue to make their products at lower prices using mass production techniques. Although the amount of sake production has continued to decline for 40 years, high-value products made by small and medium breweries prevent the total market size from decreasing. These local breweries are also challenged to create new techniques and skills. In the next section, we study one typical brewery.

% of added alcohol	Rice-polishing ratio by weight			
	More than 70%	Less than 70%	Less than 60%	Less than 50%
0%	Sake other than specific classes; Junmai	Specific Junmai	Junmai-ginjo	Junmai-dai-ginjo
Less than 10%	Sake other than specific classes	Hon-jozo; Specific hon-jozo	Ginjo	Dai-ginjo
More than 10%	Sake other than specific classes			

Table 1. Classification of sake.

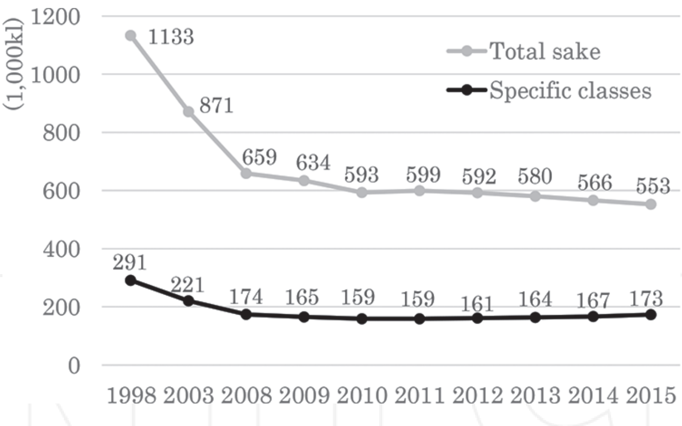

Figure 1. Amount of sake production in Japan.

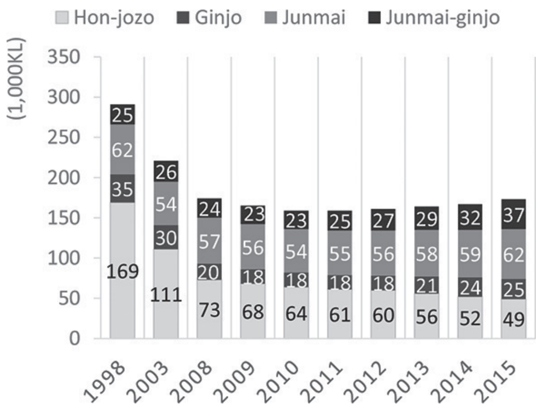

Figure 2. Amount of specific classes.

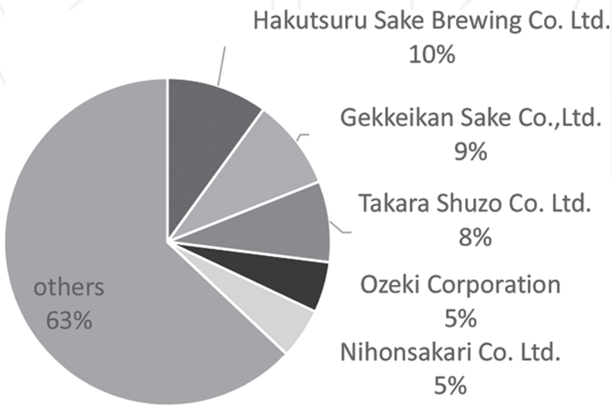

Figure 3. Market share of sake in Japan in 2016.

http://dx.doi.org/10.5772/intechopen.72312

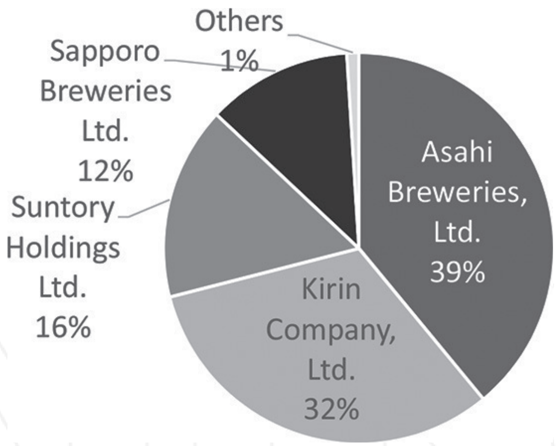

Figure 4. Market share of beer in Japan in 2016.

4. A case of new mass customization and personalization in the sake industry: Sekiya Brewery Co., Ltd.

4.1. Characteristics

Sekiya was founded in 1864 in the southeast prefecture of Aichi in Japan. Since then, Sekiya has been manufacturing high-quality sake using both traditional Japanese skills and advanced techniques. Sekiya has 53 employees and 1.7 billion yen of sales in 2016 (**Figure 5**); it is a middle-ranking company among Japan's sake breweries.

The goal of the company is to brew high-quality sake that explores the possibility of sake flexibly. Their brewery is actively implementing new technology and does not have the atmosphere

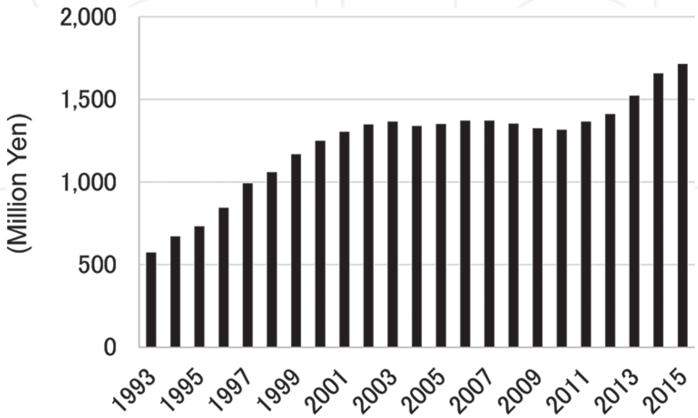

Figure 5. Sales of Sekiya.

of a traditional brewery. They decided to mechanize both so they could proactively rationalize the process that requires high labor costs and so they could closely monitor the details that need a great deal of work to pass down traditional sake-brewing skills to future generations. They devoted continuous efforts to controlling the machines as tools for the brewers and collecting elaborate amounts of data to utilize in future brewing (**Figures 6** and **7**).

4.2. The process of manufacturing sake

Table 2 shows Sekiya's process of manufacturing sake. Sekiya thinks that one of the most important steps in sake brewing is "grand design." This concept does not refer to the usual designs of manufacturing products, but instead to designing all the components that are required to explain the product's concept and ideal taste to customers. Sekiya assumes a scene in which customers consume its products and decides what kind of rice to use, how much to shave the outside of the rice, what kind of yeast and koji to choose, and how to ferment. These processes are included in the concept of "grand design."

4.3. Digital transformation and mechanization in the sake-brewing process

Sekiya divides its brewing processes into two types. One is the process that should be carried out by employees, and the other is the process that utilizes mechanization for higher quality. For example, Sekiya mechanized the transportation process to reduce heavy labor and make it easy for women and the elderly to work.

By digitizing and automatizing procedures such as temperature control, it became possible to manufacture products without requiring employees to work all night. As described in the next section, this technological improvement has had a substantial impact on the company.

By mixing handwork and digitalization, Sekiya created a sake-brewing process that is not affected by external conditions such as temperature and humidity. The company also learned to control the quality of its products with diversified raw material rice. Moreover, various data related to each process accumulate through mechanization, leading to the standard products being of stable quality.

Figure 6. Sekiya Brewery Co., Ltd.

http://dx.doi.org/10.5772/intechopen.72312

Figure 7. Various Sekiya products.

1.Milling	The brown exterior of rice is polished to make it white rice. Rice is one of the most important factors in determining the quality of sake; Sekiya polishes its own rice on site.
2. Washing / Soaking	Polished rice is washed and soaked at the same time in an amount of water consistent with the desired purposes. Since highly polished rice absorbs water quickly, the soaking time must be controlled.
3. Rice Steaming	In general, there are 2 types of sake brewing, one with cooked rice and the other with steamed, although the water content is approximately the same whether it is steamed or cooked. When the rice is cooked, it has the advantages of not being sticky on the surface, so it is easy to handle. Because it will not stick on the tools and hands, it is easier for koji mold to grow on it. Sekiya uses Koshiki, which has the same mechanism as a steamer.
4. Kojimai	Kojimai is made by planting Koji bacteria on the steamed rice. The bacteria are then cultivated for approximately 50 hours in a special temperature- and moisture-controlled room called the Koji room. Koji changes the starch contained in rice to glucose (sugar).
5. Shubo	In sake brewing, it is necessary to have Koji, which converts starch into glucose, and yeast, which converts glucose into alcohol. The process for cultivating the high grade yeast is called Shubo making.
6. Moromi	Shubo is then transferred into the tank and water, Kojimai, and steamed rice are added three times to the preparation. The preparation involves three steps. In Moromi, the saccharification of starch by Koji and glucose fermentation to alcohol by Shubo occur simultaneously. In general, Toji perform a delicate task from the top of the tank on TV. Moromi creates various Tura (meaning "face" or the surface, such as bubbles), so it is a critical job of Toji to determine temperature control while considering the appearance, taste, and results of composition analysis.
7. Joso / Sake less	Moromi is finished in 25 to 40 days. Next, it is separated into sake and sake less by Joso (pressing). Although this percentage depends on the type of sake, 10% to 20% typically becomes sake less. Sekiya's Daiginjo class leaves about half of the rice that was used for brewing as sake less.
8. Pure sake / Heating	Pressed sake is filtered pure sake. All fresh sake is pure sake. Pure sake is still fermenting in very small amounts, so it is heated to stop the fermentation if necessary. Heating is also effective in killing bacteria that can cause spoilage during storage.
9. Storing / Maturing	Sake is stored in storage tanks. The storage period is from six months to 3 years, and low-temperature maturation eliminates hardness and roughness and makes the sake deep and mild in flavor.
10. Bottling / Delivering	Sekiya uses a cold-storage warehouse from bottling to shipping. Sekiya thinks that it is important to control the temperature, even while the bottled sake is delivered to the liquor store.

Table 2. Manufacturing process of sake in Sekiya.

Sekiya used to brew sake that relied on an external Toji like any other sake brewery. Most Toji were so-called migrant laborers. They made rice in the summer and worked at sake breweries in the winter. Considering the period necessary for making rice, external Toji could stay at a sake brewery from December to March. Sekiya hired Toji from Niigata, a site of mass rice production. However, Sekiya faced a difficult situation, in that migrant Toji from Niigata markedly decreased after 1993 because of aging. Inevitably, Sekiya switched to brewing sake by employees, and Sekiya was the first company to make sake without external Toji in the Aichi prefecture.

When introducing the brewing system by employees without external Toji, the problem of techniques and skill transfer of high-skilled professionals is often raised. Sekiya was no exception to this problem and had modified this system for three generations. Advancing digitalization attracts a strong impression that machines substitute for the work that laborers do by hand, but what really matters is something else. Laborers, particularly experienced craftsmen, have sharpened senses. It is necessary to install sensitive information into the machine to optimize the next process. This is why computerization of sake brewing through mechanization was a difficult challenge. However, Sekiya has tried for years and achieved the ability to make sake of high and more stable quality.

Furthermore, the great advantage of digitalization and mechanization was a new brewing system for making sake three times a year. As mentioned above, the usual brewing period allows sake to be made only once a year, from December to March. Sekiya does three rounds of sake brewing within 10 months, except in July and August, when it performs maintenance on its machines.

Another achievement that should be noticed with the introduction of digitization is improvement of the labor environment. Sekiya employees go to work at 8 AM and leave before 6 PM. Therefore, unlike in ordinary sake brewing (especially among Toji), there are essentially no night shifts.

4.4. Introduction of custom-made system

Sekiya started an original sake brewery with a custom-made system. Very few sake breweries have a custom-made system. Sekiya's second factory, Ginjo factory, was built for the system in 2004. The Ginjo factory's capacity is only one-tenth that of the main factory. In the main factory, 12,000 l of sake are made in one lot. The Ginjo factory originally aimed at making small quantities of many varieties. A small tank serving as a single unit uses 60 kg of rice and produces approximately 100 l of sake. Sekiya receives a wide range of orders from individual consumers, companies, organizations, and restaurants in units of 720 ml × 100 bottles.

At the beginning of this project, there were very few orders. However, the custom-made system has gradually expanded into the market, and the current number of orders is approximately 220–230 tanks annually. Major customers are brides and grooms and their families, companies, and individual groups who want to celebrate their memorial anniversaries. These customers can send their original sake to someone as an expression of gratefulness and celebration. Customers can select a favorite container, label, and box.

5. Discussion

5.1. The impact of mass customization on sake breweries

According to the case study of Sekiya, the key factor in the success of the custom-made system over those of other sake manufacturing companies is the continuous challenge of digitalizing and transferring professional techniques and skills. Recently, many other sake breweries have attempted to transfer their technics and skills from Toji to employees and failed because they focused on transferring implicit knowledge and techniques without digitalizing and improving the manual tasks. In contrast, digitalization alone is not enough to create a major impact on their business because companies have to understand what kind of data is important for high-quality and stable production from experienced professionals.

Sekiya has faced the two challenges for a long time and succeeded. In this traditional and extremely old industry, it is incredible to receive more than 230 orders per year from original sake-brewing groups. Therefore, although other sake breweries have mimicked Sekiya's history, they have not been readily able to catch up.

In addition, Sekiya has tried to strengthen the relations with consumers to achieve the smart manufacturing and customization. In 2013, they opened up a directly managed restaurant, "Sake Bar Marutani," in the center of Nagoya which is the third largest economy in Japan. Marutani is the oldest business name of Sekiya, and they used 150-year-old storehouse as the restaurant. This restaurant has four important managerial factors: (1) introducing how to drink traditional sakes and enjoy differences such as glasses and seasons, (2) promoting communications between employees (technicians) in the factories and consumers, (3) conducting test marketing for new products and new lineups, and (4) investigating the trend of foods and tastes.

These factors are all aimed to intensify the connection with end users. By obtaining the feedbacks from end users for years, Sekiya has built a capability to determine which information is important (and which is *NOT* important) for the development of smart manufacturing and customization. Avoiding unnecessary information is also important as much as to acquire valid information for the smart system.

5.2. Theoretical review on the transition of manufacturing processes

Hu [21] illustrated the evolution of the manufacturing paradigms in **Figure 8** using a volume-variety relationship. As noted in Section 2, the first paradigm in manufacturing is described as craft production. These manufacturing processes were driven by professionals with highly skilled handcrafts.

Mass production began in Michigan with the introduction of the Henry Ford moving assembly line, which was built in 1913 and reached its peak after the end of the World War II, when demands for products became very high [21]. Next, Toyota invented a new manufacturing

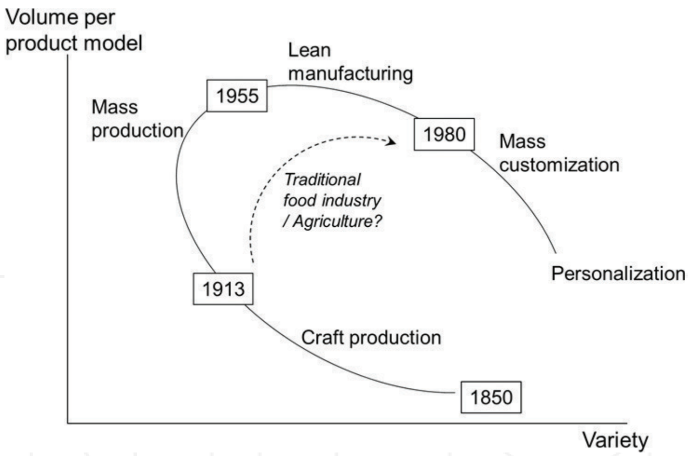

Figure 8. Evolution of manufacturing paradigms [21].

management philosophy called lean manufacturing. The goal of the management system was to minimize waste from the manufacturing process and maximize value of their customers simultaneously [22].

As mentioned above, Pine II [17] described the mass customization emerging in the 1980s as a new frontier in business competition. The main field of global competition evolved from high productivity with low costs to high customization, because the needs of consumers in advanced countries had been almost fulfilled with high-tech products. Those needs then changed from volume to quality and from singularity to diversity. Therefore, the number of varieties offered by consumer product manufacturers increased significantly. The manufacturers prepared various models of their products with combinations of each assembly line so that consumers could select among various options and enjoy original products.

Sekiya is one of emerging sake breweries creating a new and original mass customization manufacturing system. In a shrinking market, this brewery has developed a substantial business in Japan. Takeshi Sekiya, the CEO of Sekiya and its seventh-generation heir, notes that the brewery does not want to expand rapidly. Instead, it continues to develop productivity in its services.

Eventually, the manufacturing paradigm will enter the personalization phase in which consumers' roles include not only choosing and buying, as in mass customization, but also designing products by themselves with manufacturers (**Table 3**). At that point, the design process will involve either value creation or what consumers are willing to pay.

5.3. Design of open platform and future perspectives for food industry

The drivers of manufacturing processes have further evolved from manufacturers to customers driven by the huge power of digitalization and smart manufacturing. In this chapter, we see a small sign of the new paradigm, personalization, emerging in the traditional food industry. However, there are a few substantial barriers in the way of the growth of this new paradigm.

	Craft production	Mass production	Mass customization	Personalization
Price	High	Low	Middle	Middle
Main player (firm size)	Small	Large	Large and Medium	Large and Medium
Product value	Functionality	Functionality Brand	Functionality Variety Story	Functionality Variety Story Originality
Customer role	Buy Possess	Buy Consume	Buy Choose Combine	Buy Design Experience
Key manufacturing system	Handcraft Professional skill	Efficiency Low cost	Interactivity Reconfigurability	Open platform Flexibility

Table 3. Key differences between manufacturing paradigms.

First, although the volume per product model is insignificant compared to mass production, a certain level of volume must be produced to satisfy mass demand. A medium production volume is also needed to keep manufacturers active and strong. A small amount of production for a high price should be easier and can be realized by anyone. The production of a certain volume for a relatively low price will be the challenge. For this reason, the next two barriers are discussed.

Second, to realize mass customization and personalization, an open platform for communication and a sophisticated module design for manufacturing must be constructed [23, 24]. Not all processes and modules can be personalized at a low cost. Therefore, usually at least three kinds of modules are required: (1) a module similar to mass production; (2) a module that customers select, mix, and match; and (3) a module that customers design from the beginning with engineers and designers. The difficulty of realization increases from (1) to (3). Of equal importance is the meta-design, which is required to adopt a higher perspective through which to create these three modules in the end products. Since the most attractive point of personalization production is extreme differentiation, the combination of the three modules becomes even more important for product competitiveness and superiority.

Third, manufacturing companies must pay careful attention to the fact that customers need different levels of participation in the codesigning process, meaning that some customers may request deep participation with designers and others may not. Therefore, it is also very important for manufacturers to build a system to realize customer requests. Sophisticated visualization and prototype creation are good examples because they enhance the customer's imagination and clarify the customer's deeper needs. By doing so, customers have an experience that cannot be obtained with other manufacturers, thus increasing the degree of satisfaction. These manufacturers could also employ even more useful and competitive open platforms to communicate with their customers [25, 26].

The final barrier especially relates to the food industry and agribusiness. Mass customization and the rise of personalization have been realized in industries such as automobile manufacturing, chemical industry, electronics industry, and other high-tech industry. And the food industry and agriculture will be following. Food is based on organics that can be eaten, which means that manufacturers must see many limitations for its components and ingredients. This is one reason that 3D printers cannot make foods in bulk. Manufacturing also cannot overcome agriculture. Most of our foods are grown from the land, including grains, vegetables, feed for livestock, and even water. Although we have recently seen successful plant factories, most of which have focused on specific vegetables and do not produce in high volume. We must wait for ICTs to undergo further advancements and integration with biotechnology, botany, and environmentology.

6. Conclusion

Management in the shrinking traditional industry becomes harder and harder. It requires significant investment to upgrade "hardware systems" such as manufacturing equipment and capacity. It costs considerable risks to the manufacture as well. It also requires even more significant efforts to reform "software systems" such as distribution channels and employees' mindsets. In such circumstances, leaders have to make a decision to survive in the shrinking economy. Smart manufacturing and mass customization could give them a great opportunity to make a major progress.

Sekiya challenged these missions as a traditional sake manufacturer. They introduced digital transformation and mechanization in the sake-brewing process, which enabled Sekiya to expand the product lineups and distribution channels. The brewer also started an original sake brewery with a custom-made system. This challenge created a huge amount of fans who buy the high-quality products regularly. These fans also have been discovered through the direct channel to consumers with a restaurant in Nagoya. The restaurant has contributed to strengthen the connection with end markets. The feedbacks from end users have made Sekiya to build a capability to develop the smart manufacturing system and customization.

As you can imagine, these challenges should be related to each other deeply. In fact, we can find out from the case study that the smart manufacturing and digitalization have a big potential to generate a synergy effect for the manufacturers in the traditional food industry.

Author details

Daisuke Kanama

Address all correspondence to: dk205723@nodai.ac.jp

School of Economics, Kanazawa University, Kanazawa, Japan

References

[1] Polland D, Chuo S, Lee B. Strategies for mass customization. Journal of Business & Economics Research. 2016;**14**(7):101-110

[2] Kolarevic, B. Architecture in the Digital Age: Design and Manufacturing. NY: Spon Press; 2003

[3] Klinenberg E. Convergence: News production in a digital age. The Annals of the American Academy of Political and Social Science. 2005;**597**(1):48-64

[4] Berman B. 3-D printing: The new industrial revolution. Business Horizons. 2012;**55**(2): 155-162

[5] Bak D. Rapid prototyping or rapid production? 3D printing processes move industry towards the latter. Assembly Automation. 2003;**23**(4):340-345

[6] Kanama D, Kido T. The innovation strategy of a non-food-industry company regarding the traditional food supply chain. Agriculture & Food. 2016;**4**:687-695

[7] CIAA. Review of Key Competitiveness Indicators for the European Food Industry. Brussels: CIAA; 2008

[8] Avermaete T, Viaene J, Morgan EJ. Impact of knowledge on innovation in small food firms. Communications in applied biological sciences. Communications in Applied. Biological Sciences. 2002;**67**(4):46-50

[9] Menrad K. Innovation in the food industry in Germany. Research Policy. 2004;**33**(6-7): 845-878

[10] Traill WB, Meulenberg MTG. Innovation in the food industry. Agribusiness. 2002;**18**(1): 1-21

[11] Becheman M, Skjolkebrand C. Clusters/networks promote food innovations. Journal of Food Engineering. 2007;**79**(4):1418-1425

[12] Christensen JL, Rama R, Von Tunzelmann N. Study on innovation in the European food products and beverages industry. In: European Innovation Monitoring System, EIMS publication, 35 European Commission, Directorate General XIII, Luxembourg; 1996

[13] Martinez MG, Briz J. Innovation in the spanish food & drink industry. International Food and Agribusiness Management Review. 2000;**3**(2):155-176

[14] Davis SM. Future Perfect. Boston: Addison Wesley; 1987

[15] Tseng MM, Jiao J. Mass customization. In: Handbook of Industrial Engineering, Technology and Operation Management. 3rd ed. NY: Wiley; 2001. p. 685

[16] Kaplan AM, Haenlein M. Toward a parsimonious definition of traditional and electronic mass customization. Journal of Product Innovation Management. 2006;**23**(2):168-182

[17] Pine II J. Mass Customization: The New Frontier in Business Competition. Boston, MA: Harvard Business School; 1992

[18] Noguchi M, Hernàndez-Velasco CR. A 'mass custom design' approach to upgrading conventional housing development in Mexico. Habitat International. 2005;**29**(2):325-336

[19] Coletti P, Aichner T. Mass Customization: An Exploration of European Characteristics. Heidelberg, Germany: Springer; 2011

[20] Fogliatto FS, Da Silveira GJC, Borenstein D. The mass customization decade: An updated review of the literature. International Journal of Production Economics. 2012;**138**(1):14-25

[21] Hu SJ. Evolving paradigms of manufacturing: From mass production to mass customization and personalization. Procedia CIRP. 2013;**7**:3-8

[22] Morgan JM, Liker JK. The Toyota Product Development System. NY: Productivity Press; 2006

[23] Laursen K, Salter A. Open for innovation: the role of openness in explaining innovation performance among U.K. manufacturing firms. Strategic Management Journal. 2006; **27**(2):131-150

[24] Laursen K. Keep searching and you'll find: What do we know about variety creation through firms' search activities for innovation? Industrial and Corporate Change. 2012; **21**(5):1181-1220

[25] Cohen WM, Levinthal DA. Innovation and learning: The two faces of R&D. Economic Journal. 1989;**99**(397):569-596

[26] Cohen WM, Levinthal DA. Absorptive capacity: A new perspective on learning and innovation. Administrative Science Quarterly. 1990;**35**(1):128-152

Chapter 5

Time Factor in Operation Research Tasks for Smart Manufacturing

Leonid A. Mylnikov

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.73085

Abstract

The shift to the concepts Industry 4.0 and IIoT helps collect a vast amount of objective data about processes that take place in a production system, and thus, it creates background for taking advantage of theoretical results in practice; it is a trend towards synchronizing production system processes and external (market) processes in practice. In order for the target to be achieved, we use the methods that formalize management tasks in the form of predictive models, consider the cases with the computational solution of management models and decision making in production system tasks which are set based on time factor and are solved by approximate methods. We also take a look at the problems of probabilistic nature of gained decisions and address the cases, when by computational solution of tasks we need to take into account restrictions and select time step in order to obtain the decision in a table form of the function of time. The problems that we investigate help obtain and solve management tasks of production systems with help of forecasting data for a group of indices that are involved in decision making – this all helps enhance the sufficiency and quality of management decisions.

Keywords: production system, smart manufacturing, Industry 4.0, management, operation research, scheduling

1. Introduction

Presently, the information support of production systems management is mainly focused on the control and management of production systems (SCADA), the support of sales and production process (ERP, MRP, Just in Time), organizing production for known customers (CSRP), and product life cycle management (CALS). However, the aspects of tactical and strategical management get information support only on the stage of data preparation for decision making, yet on the stage when potential solutions are to be identified based on data we observe lack of information support. The integration of automatization and control systems, the trend towards Industry 4.0 and IIoT leads to an exponential growth of collected data. Hence, on the one hand, it can be expected that the use of big data might help obtain fundamentally new solutions due to their immense nature, but on the other hand, the issues of decision support automation become more acute as we face the trend of an ongoing automation expansion of production systems, and hereafter, can assume a concept of a virtual factory.

The use of the concepts Industry 4.0 outlines possibilities for the automation of production systems management taking into account the interaction of subsystems and the synchronization of their interaction with external factors. In the age of cutting edge innovation products we cannot talk about the stability of production processes since life cycle of such products is short, the number of modifications and parts is high, and power intensity and resources consumption is much higher. This proves the necessity of collecting reliable information with help of IIoT. The presence of such data helps build predictive models and use preventive control actions as production system is an inertial management object that is not able to adjust the ongoing processes instantaneously. Besides, the change of processes requires additional time resources, financial resources, labor competence, and organization resources.

The implementation of the concepts Industry 4.0 and Industrial Internet of Things [that deals with collecting information about each production unit and provides operation management over production processes in PS] [1] opens new possibilities for developing industrial engineering methods [2].

Taking into account long decades, when production systems were examined only on the basis of general data, data engineers had limited data to develop methods for decision making and took advantage of expert evaluations, i.e. the methods of utility theory (considering customer preferences as maximization of expected utility, probability models (see the works of O. Morgenstern), axiomatic theory of D. Savage that enables measure the utility and subjective probability simultaneously; decision tree approach that partitions the tasks into certain subtasks (look the works of H. Reif); multiple-criteria utility theory (developed in the works of R. Keeney); prospect theory methods, Electre methods (worked out by the French School on MCDA headed by B. Roy), hierarchy analysis method proposed by Saaty [3], heuristic methods (for instance, the method of the weighed sum of its evaluation ratings, compensation methods etc.), the models of bounded rationality by A. Rubinstein, the technic for order of preference by similarity to ideal solution (TOPSIS) [4].

The appearance of a big amount of statistical data encouraged the development of the methods of mathematical formalization used to solve tasks for the management of materials, parts, operations, and choice of suppliers [5] with the consideration of stochastic factors, probability approaches to measure risks taking into account different nature of examined events (joint, correlative, inconsistent and interdependent) used to solve planning tasks taking into account the dynamics of examined processes.

The consideration of random factors and the use of probability approaches help measure risks with help of models. There are planning risks (the risks related to decision making based on

http://dx.doi.org/10.5772/intechopen.73085

models [6] that depend on the current state of market (change in price, sales volumes etc.)) and production risks (the risks related to equipment mortality, failures in the delivery of necessary materials or parts etc.).

The use of probability models is based on the use of risk metrics [7], Bayes' Theorem [8] or Monte-Carlo Method [9].

2. Methodology aspect of management task setting in production systems

Production system is regarded as management object that is placed in a state space. The coordinates on this n is the dimensional space are represented by the management parameters that are considered significant for achieving the targets, and their values describe the current state and remoteness from the selected targets.

If we mark target goal indexes by the vector P_p, and the current state by the vector P_a, we will receive a mathematically measurable metric (P_p, P_a) that shows how the current position deviates from the goal position that is deemed a sign of progress for project implementation (the end of implementation, $P_p = P_a$). However, to know the metrics (P_p, P_a) is not enough for management, we also need to know the vector of the parameters Y that greatly affect the state of project and consist of the values that describe project, production system and the environments in which project is implemented as well as dynamics of change and prognostic values of all these parameters. It should be noted, that the achievement of the goal values $P_p = P_a$ does not always mean the achievement of the vector values Y expected for this state.

In management tasks values and parameters can be classified in four groups [10]: parameters and values that describe a current state $P_p^{(i)}$, values and parameters that describe the action (external factors and control action – $Y = A \cup \Theta$, the A is the set of control actions, Θ is the set of environment values), values and parameters that describe a goal state $P_a^{(i)}$, values and parameters that describe the output of system operation by shifting from the state $P_p^{(i)}$ into $P_a^{(i)}$ - R and time $T^{(0)}$.

Therefore, management has to use an automaton where the consecutive state is defined by experts based on the current state and the state that was planned to be achieved on the previous stage and the time when it has to be done – $\left(P_p^{(0)}, P_a^{(0)}, T^{(0)}\right)$, $\left(P_p^{(1)}, P_a^{(1)}, T^{(1)}\right)$, …, $\left(P_p^{(n)}, P_a^{(n)},\ T^{(n)}\right)$. In order for a new state to come, action $A^{(i)}$ has to be defined. We can determine such action with help of the production system model that implements innovation projects $\varphi_j = \{U, S\}$, where U is the vector of management parameter, S is the set of project resource needs, j is project number.

This approach helps work out hierarchically coordinated managerial decisions by taking into consideration system-interrelated external and internal factors that interact. Management process is considered then as a holistic undetermined process.

In general, the model can be presented in a form of a tuple:

$$\psi = \{Y, P_p, P_a, T, R, \varphi\} \tag{1}$$

where $\varphi = \{\varphi_1, \varphi_2, \ldots, \varphi_n\}$ is the projects' vector, Y is the action vector on each step, R is the outcome vector on each step, P_p is the vector of system states, P_a is the vector of system goal states, T is the vector of decision points.

The use of the model (1) is described by an undetermined algorithm [11] see **Figure 1**.

As a result, management task becomes more transparent. However, it opens new sub-tasks, i.e. to determine decision points, to define the set of indexes and their values for each stage of project implementation, to build a model of production system by implementing the projects (φ) in order to define the vector of control actions Y.

At the same time, the more formalized is the description of tuple parts (1) (less ambiguity), the higher is the quality of management [according to system properties].

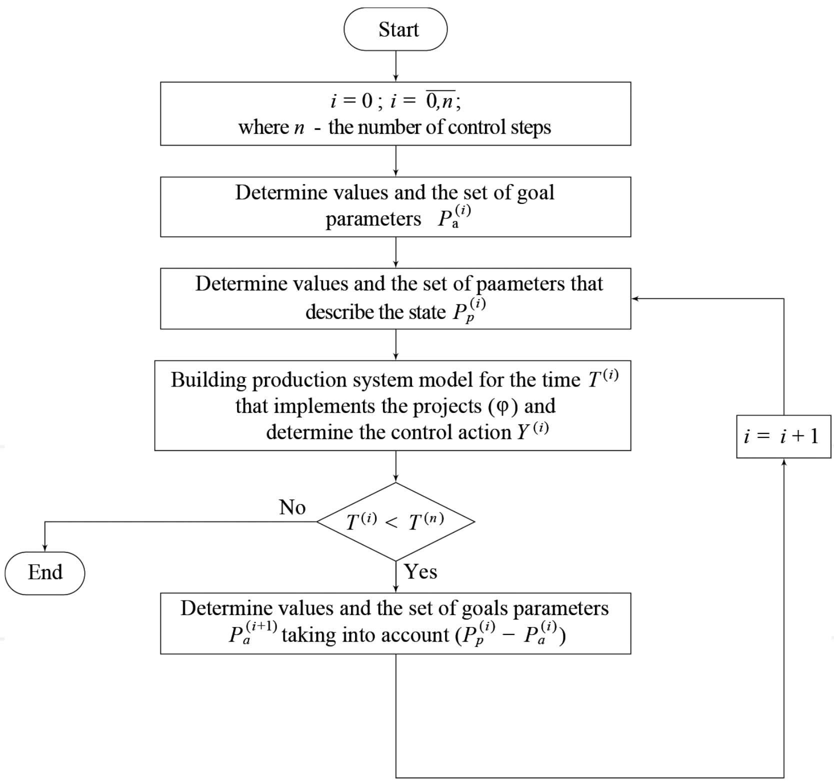

Figure 1. The algorithm to manage a production system that implements projects φ.

Decision points can be defined in case if we know the set of controlled parameters [12], and have additional information that characterizes the production system that we manage (equipment maintenance periods, internal technological cycles etc.) [13].

The setting of management tasks taking into account time factor $T^{(i)}$ leads to formalizing the models $Y^{(i)} \to M^{(i)}\left(A; \Theta; \overline{T^{(i-1)}, T^{(i)}}\right)$. The structure of the model sets formal interrelations between its parameters, and on each step the type of the model will depend on the managerial task that we consider (whether we forecast properties and behavior of the investigated management project; or when dealing with object management we select best actions by testing them on the model, investigate the object and look for the ways to improve management object).

The model itself can use both non-causal (component-oriented) and causal (block-oriented) modeling, and model components can set requirements to their development tool (for example, the possibility to 1) work with big data volumes set by time series 2) use the methods that are applied for incomplete data 3) solve tasks set in a form of mathematical programming 4) employ methods to work with probabilistic models etc.).

The specialization of models $Y^{(i)}$ brings the problem of choosing approaches and ways for formalization based on the set of already known approaches, ways, methods and models [14] that will be collected as a composition (the compatibility of input and output areas).

For the implementation of each project in the considered production system, the model formation that is presented in a general form is as follows $\{R, \varphi, A, \Theta\} \to M^{(i)}\left(A, \Theta, \overline{T^{(i-1)}, T^{(i)}}\right) \to \left\{m_j^{(i)}(U, \mathfrak{P}, \Pi)\right\}$, where $\mathfrak{P}$ is the vector of external parameters that exert impact on the system, Π is the vector of system parameters, $m_j^{(i)}$ is the components or blocks of the model for time $T^{(i)}$).

Despite the apparent simplicity of the approach, underlying this approach is a necessity to work out managerial decisions taking into account different levels (institutional, managerial, technical) and management types (finance management, production management, goods management, launch management, sales management, R&D management, institutional management), and subsystems of production system – all of that generates a whole group of managerial tasks that have to be solved together for each time period $T^{(i)}$; the interrelation of the tasks is demonstrated in **Figure 2**.

Work with a model structure means that we need to consider several subtasks related to forecasting parameters of the considered project [15] and to formalizing an optimization task in a form of mathematical programming [16].

The examples of tasks that are considered in decision points can encompass the tasks of production and client analytics taking into account time factor, such as demand forecast and sales planning, volume planning, stock and procurement planning (including working life), equipment selection taking into account maintenance costs; these can be the tasks of optimizing stock work and minimizing the volumes of working assets, and obtaining optimal machine utilization and work force.

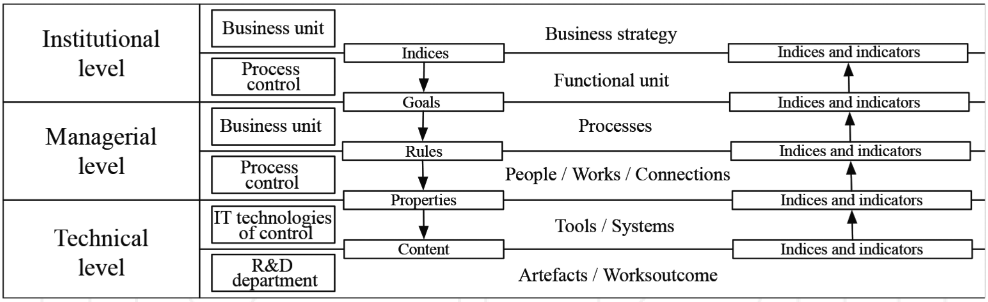

Figure 2. The interrelation of management levels and management tasks to be solved by using parameters and indicators for developing decision support models.

In this case, each of tasks can be described by a separate criterion; the use of a reflexive approach enables their joint solution as a set of optimization tasks that have common parameters and use forecast-based data.

3. Solving management tasks with help of predictive models

Let us now consider a general task of formalizing management processes for project implementation in PS. This task can be handled as a task of defining decision points and a cyclic solution of prognostic models that are represented by optimized formalizations based on forecast data and elaboration done on each step of processing data in order to make consecutive iterations with new data, and calculation results.

In order for the tasks to be formalized as tasks of optimal control, we have to input a set of indices, variables and parameters of management [9], for instance, like: i is the supplier's index; j is the index of production system/stock (PS); m is the part index or the demand in materials; n is the index of end item; k is the index of production operation; g is the index of machine or instrument; p is the index of operation; t is the time; x_{ijm} is the number of parts m received from the supplier i for PS j; y_{jn} is the number of parts n produced in PS j; r_n is the number of returned items n for utilization; o_m is the number of reused parts or materials m; d_m is the number of items or materials m sent to utilization; ref_{jm} is the number of reused items or materials m in PS j; bd_n is the binary variable that possesses the value equal to 1 in case if it can be repeatedly used for the item n and 0 if not; Δt is the time step; $sell_n$ is the item's market price n; $cost_{jn}$ is the item's production cost n in PS j; $price_{im}$ is the price of the part m received from the supplier i; $ship_{m/nij}$ is the delivery cost of the part/ item m/n from the station i to the station j; inv_j is the storage cost in PS j; $setdis_n$ is the preparation cost to get the parts out of the item n; $disa_m$ is the preparation cost to get the part m out for reuse; $disp_m$ is the utilization cost for the part m; $refcost_{jm}$ is the preparation/recovery cost of the part m for reuse in PS j; $dem_{(j)n}$ is the need/demand in the item n, if there is the index j the consumer get then j; req_{mn} is the number of requested parts m required for the production of the item n; $costeq_{pgj}$ is the cost of the operation p on the equipment g in PS j; $timeeq_{pgj}$ is the time of operation performance p on the equipment g in PS j; $part_{mpgj}$ is the demand in parts/materials m in order to perform the operation p on the equipment g in PS j; eq_{pgj} is the demand in the equipment g in order to perform the operation p in PS j; $supmax_{im}$ is the maximum size of the batch of the parts m that can be delivered from the supplier i; $supmin_{im}$ is the minimal size of the batch of the parts m that can be delivered from the supplier i; $supmaxpart_{jm}$ is the maximum potential number of parts and components m that can be delivered for production in PS j; $supmaxeq_{jp}$ is the maximum potential number of equipment units for the operation p in PS j; $reuse_m$ is the maximum percentage of the parts m that can be reused.

The approach described above helps state a set of optimization tasks that can be considered both, as joint and separate tasks. Let us give the examples of feasible task formalizations:

- Profit maximization (production planning for demand), $\left(sell_n(t) - \sum_j cost_{jn}(t)\right) \sum_j y_{jn}(t) \rightarrow \max, \forall n$;
- Production cost minimization, $\sum_p \left(costeq_{pgj}(t) + \sum_m part_{mpgj}(t)price_{mi}(t) + \sum_m part_{mpgj}(t)ship_{mij}(t)\right) \rightarrow \min, \forall g, j$;
- The minimization of costs for goods' storage, $cost_{jn}y_{jn}(t) + inv_j(t)y_{1jn}(t) + ship_{nij}(t)y_{2jn}(t) \rightarrow \min$, $y_{jn}(t) = y_{1jn}(t) + y_{2jn}(t)$, $y_{2jn}(t) \le dem_{jn}(t)$, where y_{1jn}-the number of items stored in stock, y_{2jn} is the number of items sent to consumer;
- The selection of suppliers taking into account that certain components can be reused, $\sum_j \sum_n (sell_n - cost_{jn})y_{in} - \sum_i \sum_j \sum_m \left(price_{im} + ship_{ij} + inv_j\right)x_{ijm} - \sum_n setdis_n bd_n \sum_p \left(costeq_{pgj} - \sum_m (disa_m\, o_m + disp_m d_m) - \sum_j \sum_m refcost_{jm} ref_{jm} \rightarrow \max.\right.$

The tasks can be subject to different restrictions:

- Production capacity restriction, $\sum_g eq_{pgj}(t) \le supmaxeq_{jp}(t), \forall j, p, t$;
- The restriction related to delivery options of components and materials, $\sum_g part_{mpgj}(t) \le supmaxpart_{jm}(t), \forall j, p, m, t$;
- Non-negativity restriction on the volumes of goods, orders etc., $y_{jn}(t), x_{ijm}(t), r_n(t), o_m(t), d_m(t), ref_{jm}(t) \ge 0, \forall j, n, i, m, t$;
- Demand volume restriction, $\sum_j y_{jn}(t) \le dem_n(t), \forall n, t$;
- The description of technological process, $\sum_n req_{mn} y_{jn}(t) = \sum_i x_{ijm}(t) + ref_{jm}(t), \forall j, m, t$, $\sum_j ref_{jm}(t) + d_m(t) = o_m, \forall m, t$, $o_m(t) = \sum_n req_{mn}(t) r_n(t), \forall m, t$;
- The restriction on the volume of orders, $\sum_j x_{ijm}(t) \le supmax_{im}(t) s_i(t), \forall i, m, t$, $\sum_j x_{ijm}(t) \ge supmin_{im}(t) s_i(t), \forall i, m, t$;

- The restriction on the volume of reused parts, $\sum_j ref_{jm}(t) \leq reuse_m(t) o_m(t), \forall m, t$, $d_m(t) \leq (1 - reuse_m(t)) o_m(t), \forall m$,t;
- etc.

The obtained tasks in their general form refer to a class of multi-parameter tasks with non-linear restrictions. In such tasks a part of parameters is set by time functions. The outcome of the solution of such tasks will be the function of time as well (by numerical solution in a table form). Since today we lack analytical methods to solve such tasks, we will build then the solution of this task on multiple cyclic determination of numerical solutions of a multi-parameter optimization task with the time period $\Delta t \leq \min_{i=\overline{1,n}} T^{(i+1)} - T^{(i)}$ that determines the accuracy of the description of the required function (see **Figure 3**).

Taking gradient calculation for finding solution was one of the first approaches to develop solution methods (gradient search method with the split of the step метод градиентного поиска с дроблением шага, steepest descent method, conjugate direction method, the Fletcher-Reeves method, the Davidon-Fletcher-Powell method). By these the goal function has to be differentiated two times and convex. The Newton's method and his modification the Newton–Raphson method is widespread. These methods also set the requirements to the goal function to be differentiated two times and be convex. Besides, these methods are sensitive to the selection of initial value. Moreover, in obtained optimization tasks we the cases can appear that are related with multiextremality, non-convex restrictions, multicoupling of the area of feasible solutions etc., and these methods cannot handle that appropriately. Modern methods can in general be split into three groups [17]: cluster methods, the methods of restrictions' distribution, metaheuristic methods. By choosing the solution method it is important to consider that the most significant feature of combinatoric optimization methods is their completeness and comprehension. A complete method ensures the finding of the task solution if it exists. However, the application of these methods can bring difficulties by a big dimension of search space, and we might not have sufficient amount of time that will be required for

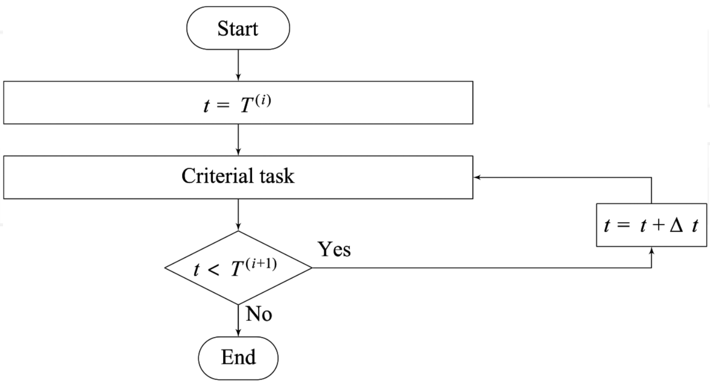

Figure 3. The scheme that clarifies the principle of defining calculation points (special states) by implementing projects in PS.

http://dx.doi.org/10.5772/intechopen.73085

search in this case (for instance, due to time restrictions for decision making). If we use heuristic methods in task solutions, and heuristic elements complement combinatoric methods, it is getting more complicated to prove that the applied method is comprehensive. The methods of heuristic search are, in general, incomplete.

In practice hybrid algorithms are often used. Besides, the outcome of any algorithm work can be improved by building a joint solver. Due to the lack of specialized solution methods, for the obtained formalization we assume that we can use a developmental approach – the method of stochastic search. The drawback of developmental approaches is that in some cases the results and optimization time are dependent on the selection of initial approximation. This drawback can be eliminated by using as an initial approximation the solution that was worked out by experts. That is why, as a universal solution we suggest to use the method of stochastic search taking into consideration expert knowledge and indistinct preferences. However, in this case we need to direct attention to the fact that for some tasks we can obtain formalizations that already have methods of their solution. Hence, the decision about what method to apply should be taken dependent on the targets, i.e. how accurate the solution is expected to be and whether we have time restrictions for solution search (the methods of stochastic search can be limited in time required for solution search, which is crucial in integrated systems and IIoT that operate in real time).

In heuristic methods of random search we can distinguish two big groups: the methods of random search with learning and developmental programming [18]. In practical use the methods differ in convergence speed and the number of iterations required for search of a feasible solution (several methods, for example, genetic methods, ensure finding an extremal value, but not obligatorily an optimal one). The complexity of selection task is that the efficiency performance of certain methods of stochastic search (in particular, genetic algorithm) is determined by their parameters. As an example let us examine the application of the method of random search with inhibits (Pareto simulated annealing) [19]; along that, we take into account the set values, that were obtained by forecasting during the modification of task for work with restrictions. Before we start perform numerical calculation we need to determine the area for feasible solutions. The algorithm will consist in five steps and an additional sixth step; the latter step allows solve tasks with the restrictions set by functions and forecast values with the set accuracy and the criterion that can also use the values obtained by forecasting.

Let us now consider the search option of parameter values x_i, $i = \overline{1, N}$ as points in space B_i Let us assign Λ^{**} to the set of all points x_i, that comply with the task restrictions: $\Lambda^{**} = \left\{ x_i^{(j)} \in B_i^{(j)}, j = \overline{1, N^{**}} \right\}$ (that are included in the area of feasible values), where N^{**} is the capacity of the finite set $B^{(N)}$, N is the number of components in the vector of unknown quantities. Consequently, the algorithm has the following sequence of steps:

1. Set N^{**} is the requested number of points from the set Λ^{**} (N^{**} is the parameter of algorithm). Depending on the certain task, the value N^{**} can alter.

2. Find N^{**} points for each parameter $x_i \in \Lambda^{**}$, scattered in the spaces $B_i^{(N)}$ randomly or by the use of expert knowledge, and use these points as an initial approximation.

3. For finding the solutions $x_i \in \Lambda_{D_i}$ (Λ_{D_i} is the set of feasible points) apply one of the heuristic methods of stochastic search. For this purpose, the point $x_i \in \Lambda^{**}$ is taken as a base point, and based on this point we build new points belonging to Λ^{**} where the criterion values are better than in a base point. Even if one such point is found, its base is used then for finding new values etc., and next search is done. All the points found this way $x_i \in \Lambda^{**}$ make the set Λ_{D_i}.

4. All points $x_i \in \Lambda_{D_i}$ are studied for optimal factor, after that they are used to form an optimal set of solutions Λ_P. The required sets are easily recovered from the labels of criteria in spaces.

5. The selection of the singular variant $\widehat{X}$, where X is the vector $\widehat{X} = (x_1, x_2, \ldots, x_N)$, from the Pareto-set is submitted to an expert, that has additional information that has not been formalized and neither taken into account in the model.

6. For an operational reaction to altering external factors we should perform several iterations for task solution (by modeling the deviations of forecasting values within the confidence interval) and do that cyclically with the time period Δt.

As a result, we receive altering in time span (corridor) of potential solutions for each time period. At the same time, as several functions describe the parameters that are set by forecasts, where accuracy depends on the planning horizon, we can encounter the case, when the obtained values can fluctuate either towards the increase or the decrease. Such behavior will bring additional organization expenses for PS; however, it is possible to manage such behavior (smoothly adjust the altered values) by changing the dimension within the obtained corridors and the time step Δt (as a rule, such deviation is described by a stochastic variable that obeys normal distribution law).

In the result of the solution we can determine the diapasons and the values of the values that can be presented in a suitable way to the decision-maker (for instance, in a form of the Gantt chart that is so widespread in management) [20].

4. The generation of the area of feasible solutions by solving the tasks for optimal control of projects and production systems

By the implementation of management tasks as dynamic management tasks, where the solution is the function of time, it should be noted that the restrictions can also change in time. It happens as the characteristics of production system can alter in time, the changes can affect the schedule of supplies, the volume of resources allocated for the implementation of a certain project etc. The restrictions can be shown as follows:

$$m_1(t) </\leq M </\leq m_2(t), m_1(t) </\leq M, M </\leq m_2(t), M \in m_3(t),$$

where M is the parameter or an expression with imposed restrictions, $m_1(t)$ and $m_2(t)$ is the restrictions set by the functions of time, $m_3(t)$ is the area of feasible values can also alter in time.

http://dx.doi.org/10.5772/intechopen.73085

The use of several criteria and a big number of restrictions often leads to the situation that we obtain an empty area of feasible values or the solution shows some deviations. In any case, in PS management tasks the final decision is taken by the expert. That is why, the restrictions can be presented by the functions $F(m_1(t), m_2(t), t)$ that can be represented in a form of additional criteria and used by performing the operation of criteria compression.

In case of discrete set values or if restrictions are set as an area of feasible values, the function $F(m_1(t), m_2(t), t)$ or $F(m_3(t), t)$ becomes piecewise-set. Hence, the values that belong to a feasible interval are maximum high by considering a maximization task, and the others become maximum low and vice versa by considering a minimization task. In general, for the consideration of all types of restrictions in one record the function can be written as $F(m_1(t), m_2(t), m_3(t), t)$. The membership with the area of feasible values can be validated then by calculating the value:

$$\sum_{i=1}^{n} F_i(m_1(t), m_2(t), m_3(t), t) \tag{2}$$

where n is the number of restrictions.

If this value is equal to the sum of minimal or maximal values $\sum_{i=1}^{n} \min/\max F_i(m_1(t), m_2(t), m_3(t), t)$ dependent on the type of the considered task (minimization or maximization), then it will belong to the area of feasible values. In practice, the restrictions can be considered not as stiff and we can determine the feasible deviation of values ($\mp \Delta$).

Such approach helps add restrictions to a criterial function as additive components that allows get rid of restrictions and apply for solution the methods that do not work with restrictions. Since restrictions can be destroyed in this case, so the obtained functions are to be ranged with help of weight coefficients K. As a result, we receive a final setting of the task for extremum in the following form:

$$J + \sum_{i=1}^{n} K_i F_i(m_1(t), m_2(t), m_3(t), t) \rightarrow opt, \tag{3}$$

where J is the criterial function.

5. The problems of obtaining solutions as functions of time

By solving tasks of optimal control taking into account time factor and some discrete time step Δt the solution will be a set function presented in a table form. In this case, the system interacts with the external environment and the found solution can be not achievable due to the changes of external or internal factors. According to Bayes' theorem [21] the probability of a successful transfer to another state (to a new solution) will depend on the previous state (the state that we are placed now). Hence, for selecting the path for project development it is useful to consider

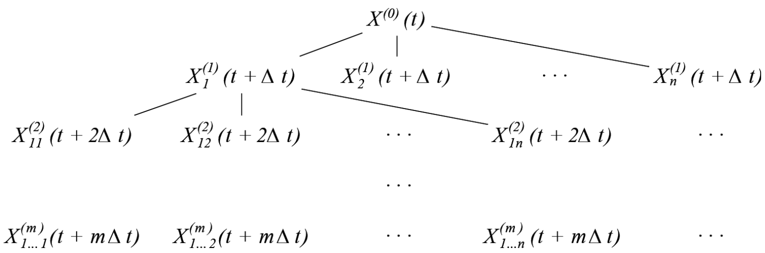

Figure 4. The tree of management task solutions taking into account time factor X is the vector of variable values received in the solution of an optimization task, $m\Delta t$ is the planning horizon, m is the number of task solutions, n is the number of solutions found on each step.

not just one solution, but a set of solutions that are Pareto optimal. So, the task solution will be a set of development paths that technically can be shown as a tree for each of the required parameter values (see **Figure 4**) that can be considered as Bayesian network.

The selection of a singular solution will be based on the choice of a path and on the potential of its implementation. The potential of each solution will be defined by chain rule [21]:

$$P\left(X^{(0)}, \dots, X^{(m)}\right) = \prod_{j=1}^{m} P\left(X^{(j)} | X^{(j-1)}, \dots, X^{(1)}\right). \tag{4}$$

Therefore, by the planning horizon in $m\Delta t$ and n solutions on each step we will obtain $\prod_{j=1}^{m} n$ probabilities for leaf nodes in the built tree that should satisfy the following conditions $\sum_{i=1}^{n} P\left(X_i^{(1)}\right) = 1$, $\sum_{i=1}^{n} \sum_{j=1}^{n} P\left(X_{ij}^{(2)}\right) = 1$, etc. for each solution step.

If we assume that all X are unique, then the implementation potential for each solution will be equal. However, in practice solutions can repeat. It is connected with the fact that we use the method of random search for solving a task; more than that, for modeling deviations we need a multiple solution of a considered task. In this case, the probability of a transfer from the state $X^{(0)}$ into the state $X^{(m)}$ will be determined by the sum of probabilities of repeated values, and this value will determine the probability of a transfer from one decision point to another one.

This probability will not be a random value since multiple calculations are performed, as parameters that are obtained based on forecast data can have random walk described by the functions of probability density; the latter ones are necessary to be used for generating new forecast values by multiple calculations.

$$\mu(x_1) = \frac{1}{\sigma_1\sqrt{2\pi}} e^{-\frac{(x-x_1)^2}{2\sigma_1^2}} \tag{5}$$

where σ_1 is the standard deviation, x_1 is the value obtained by forecasting. By a transfer to the consequent value the function will alter:

$$\mu(x_2) = \frac{1}{(\sigma_1 + \sigma_2)\sqrt{2\pi}} e^{-\frac{(x-x_2)^2}{2\left(\sigma_1^2+\sigma_2^2\right)}} \tag{6}$$

in a new formula we add σ_2^2 is the Gaussian perturbation of constant dispersion that is calculated by the formula [22]:

$$\sigma_2^2 = D[x] = M\left[x^2\right] = \sum_{j=1}^{m} x_{1j}^2 \mu(x_1) \tag{7}$$

where $D[x]$ is the dispersion, $M\left[x^2\right]$ is the mathematical expectation, x_{1j} is the possible values for x_1 (belonging to the interval σ in order to perform the validation for adequacy).

As a result, it is possible to define the probabilities of obtaining solutions and select the most probable ones.

The use of the probability density functions for modeling deviation helps measure the achievement probabilities of a series of consecutive states $s_1, s_2, \cdots, s_n$. If the probability $p_1^{(0)}$ indicates that we are placed in the state s_i and the state fully complies with the expected state (determined on the basis of previous stages), p_{ij} shows the probability of the transfer from the state s_i into the state s_j, and $p_i^{(1)}$ indicates the probability that the state s_i will be achieved. Then:

$$\left(p_1^{(1)}, p_2^{(1)}, \dots, p_n^{(1)}\right) = \left(p_1^{(0)}, p_2^{(0)}, \dots, p_n^{(0)}\right) \begin{pmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{12} & p_{22} & \cdots & p_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ p_{n1} & p_{n2} & \cdots & p_{nn} \end{pmatrix} \tag{8}$$

and the management task adds up to the selection of a desired state from the set of possible states and the determination of a path (the set of delta states) to achieve this desired state. Therefore, it is possible to define the probabilities for obtaining decisions that will be taken into account for further selection of the most probabilistic ones based on the method of dynamic programming (Bellman method) (see **Figure 5**).

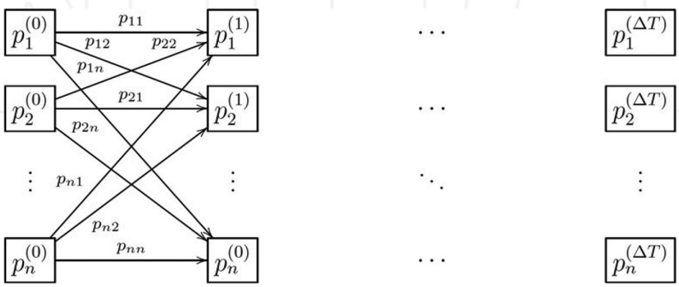

Figure 5. Decision tree for PS path selection task or project implementation.

Each state is determined by a risk metric (a value that is calculated on the base of the probability p_{ij} depending on the path that we have taken to land at the examined state) and the dynamics of the change in the criterion value by the transfer from one special state into another one (see **Figure 5**).

By obtaining the solutions as the functions of time on each step of calculations the time step Δt becomes an important algorithm parameter. On the one hand, as a step we can choose the time between the decision points $T^{(i+1)} - T^{(i)}$, from the other hand, by such approach the sensitivity of the system to altering external factors is decreasing (it becomes inertial). That is why, the selection of time step will be a trade-off between sensitivity and persistence of system. At the same time, time step can be an altering dimension ($\Delta t = f(t)$) but it should be placed in the diapason $\tau \le \Delta t \le T^{(i+1)} - T^{(i)}$, where τ is the minimal time required for changing production capacity, reset of technological cycle etc. (system characteristic), $T^{(i+1)} - T^{(i)}$ is the time for the next decision point. There can be any number of solutions between decision points.

Underlying a new calculation is the output of values of a forecast parameter outside the bounder of the confidence interval $\pm\sigma$. On the other hand, works related to changing production capacity, production and procurement scheduling etc., bring additional expenses for enterprise (in general, we encounter the situations, when production capacity is to be increased first and decreased afterwards, that in some cases can be balanced, particularly, by stocks. Therefore, we should consider this task as a separate management task and use the algorithm shown in **Figure 6**.

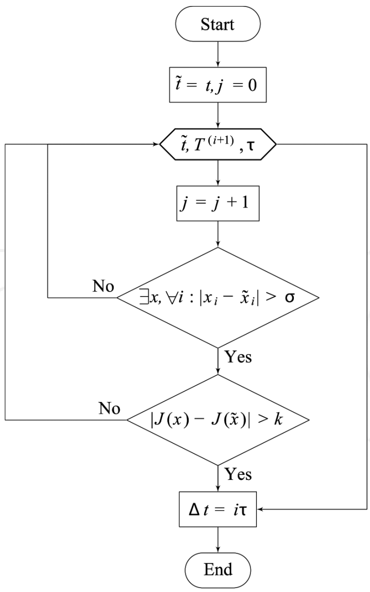

Figure 6. The algorithm for defining the step Δt for time moment $\tilde{t}$, where J is the criterion value, k is the amount of work expenses for changing production cycle taking into account economic criteria.

http://dx.doi.org/10.5772/intechopen.73085

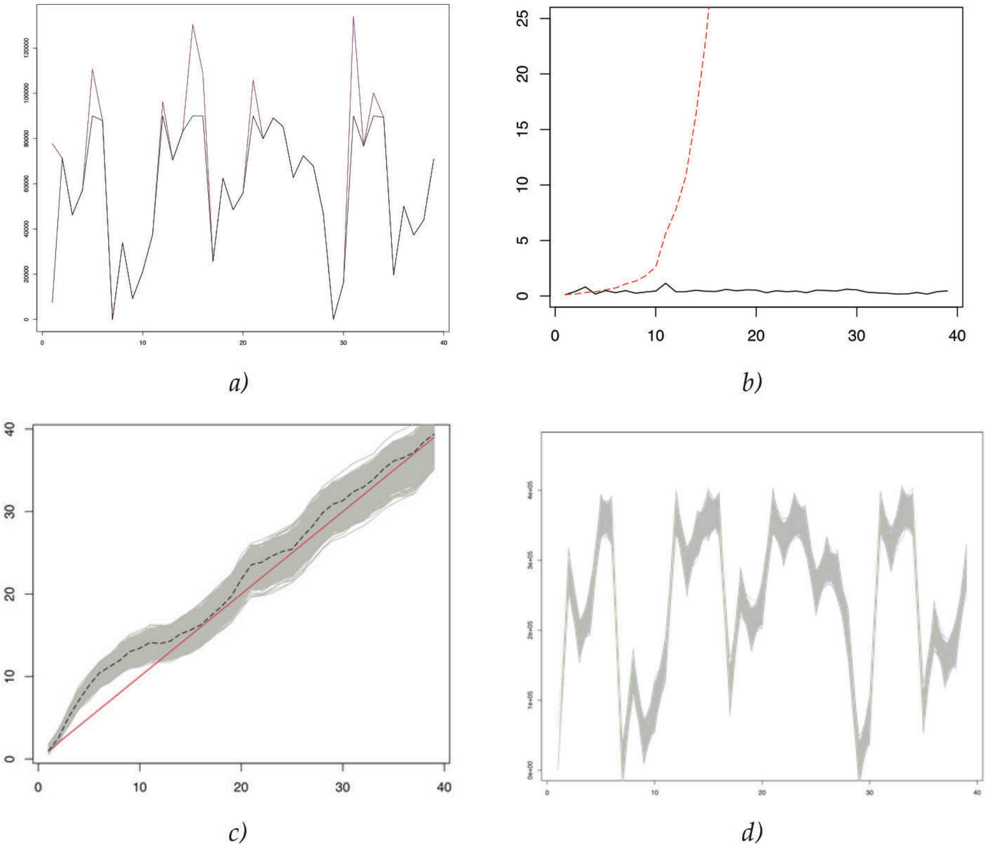

Figure 7. The solution results of volume planning and procurement management tasks based on the collected data about production system for a discrete production: (*a*) an example of production output volume for one of the products by the use of different forecasting methods, (*b*) the values of risk metrics (solid line) and progressive risk metrics (dotted line) connected with the use of planning data, (*c*) adjusted criterion value by the use of best forecast results and the corridor of possible deviations by the use of normal distribution for their modeling and its correlation with the retrospective data-based criterion value, (*d*) the need in one type of parts taking into account possible deviations in production plan.

The solution for the examined diapason $T^{(i+1)} - T^{(i)}$ by, for instance, joint consideration of the tasks of volume planning and procurement management will be production plan, the value of the given criterion (with a potential deviation diapason of decisions), the value of risk metrics and the volumes of changes in required parts and components taking into account possible deviations from target production volumes (**Figure 7**).

6. Conclusion

The present chapter describes the approaches that thanks to the use of the concepts Industry 4.0 enable the formalization of the processes that are connected with the reasoning and preparation of managerial decisions which are based on real statistical data that take into consideration the interaction of subsystems in production system. Therefore, together with the use of predictive models IIoT helps not only enhance the level of automation and reduce a certain part of personnel production expenses but also consider such factors as increasing power intensity and resources consumption of productions, inertness of integration and management processes in production systems, and the situations that are connected with repair actions, equipment mortality, procurement failures, change in demand and prices etc.

We have investigated the question how to use and apply under existing conditions the approaches that search feasible and optimal solutions in the tasks of efficient management and planning (taking into account time factor). The changes that affect the setting and solution of tasks can be explained by the shift to automated and automatic enterprises, by the shift from mass production to single-part production. In this connection, the current situation requires operational rearrangement of ongoing production processes; we need to increase global economics mobility, i.e. the variability of external environment where production systems operate.

The approach that is described in the chapter is relevant as it tackles management tasks given as optimization tasks; besides, it helps deal with the phenomenon of *NP* is the completeness of obtained tasks.

The obtained results are sensitive to the quality of forecasts and lack time lags; more than that, we can observe a change in production volume that creates additional increased capacities for production system (related to the change in production schedule).

That is why, the shift to the concepts Industry 4.0 gives not only evident momentary advantages, but also outlines new areas for studies, i.e. the solution of tasks that take into consideration the inertness of production system and expenses that arise due to changes in production volume and risk metrics, that appear upon interaction with external systems (for example, delayed delivery, the delivery of faulty parts, return of goods etc.).

The development of mathematical formalization of these areas of studies can lead to additional effects in future and underlie the appearance of industrial concepts of next generations.

Acknowledgements

The author thanks the government of Perm Krai for the support of the project for “Development of software and economic and mathematical models for supporting innovation project management processes in production systems”, which is being implemented in accordance with decree No. 166-п of 06.04.2011.

The reported study was partially supported by the Government of Perm Krai, research project No. C-26/058.

http://dx.doi.org/10.5772/intechopen.73085

Author details

Leonid A. Mylnikov

Address all correspondence to: leonid.mylnikov@pstu.ru

Perm National Research Polytechnic University, Perm, Russia

References

[1] Arnold C, Kiel D, Voigt K-I. How the industrial internet of things changes business model in different manufactoring industries. International Journal of Innovation Management. Dec 2016;**20**(08):1640015-1-1640015-25

[2] Kaiser C, Schlick S, Bodendorf F. Warning system for online market research? Identifying critical situations in online opinion formation. Knowledge-Based Systems. Aug. 2011;**24**(6): 824-836

[3] Saaty TL, Forman EH. The Hierarchon: A Dictionary of Hierarchies. Rev ed. Expert Choice: Pittsburgh, PA; 1996

[4] Walczak D, Rutkowska A. Project rankings for participatory budget based on the fuzzy TOPSIS method. European Journal of Operational Research. Jul. 2017;**260**(2):706-714

[5] Aissaoui N, Haouari M, Hassini E. Supplier selection and order lot sizing modeling: A review. Computers and Operations Research. Dec. 2007;**34**(12):3516-3540

[6] Olson DL. Supply chain information. Technology. 2015

[7] Mylnikov L, Kuetz M. The risk assessment method in prognostic models of production systems management with account of the time factor. European Research Studies. 2017;**20**(3):291-310

[8] Tajbakhsh SD, del Castillo E, Rosenberger JL. A Bayesian approach to sequential optimization based on computer experiments. Quality and Reliability Engineering International. Oct. 2015;**31**(6):1001-1012

[9] Moghaddam KS. Supplier selection and order allocation in closed-loop supply chain systems using hybrid Monte Carlo simulation and goal programming. International Journal of Production Research. Oct. 2015;**53**(20):6320-6338

[10] Fogel L, Owens A, Walsh M. Artificial Intelligence through Simulated Evolution. John Wiley & Sons; 1966

[11] Nilson N. Principles of Artificial Intelligence. San Francisco: Morgan Kaufmann; 1980

[12] Kuetz M. IT-Prozesse mit Kennzahlen steuern. Controlling & Management Review. Mar. 2014;**58**(7):86-93

[13] Faizrakhmanov RA, Mylnikov LA. The foundations of modeling management processes for innovation projects in production-economics systems. Automatic Documentation and Mathematical Linguistics. May 2016;**50**(3):84-90

[14] Mossin J. Equilibrium in a capital asset market. Econometrica. Oct. 1966;**34**(4):768

[15] Suslova A, Mylnikov L, Krause B. Prognostic model for estimation of innovative activity factors of regions by example of the patenting data based on cognitive map modeling. European Respiratory Journal. 2013;**61**(10):2508-2517

[16] Mylnikov L. Particularities of solving the problems of support for managerial decision making in production and economic systems using the statistical data. International Journal of Economics and Financial Issues. 2016;**S8**(6):1-11

[17] Burke EK, Landa SJ, Soubeiga E. Hyperheuristic approaches for multiobjective optimization. In: Proceeding of the MIC 2003; Kyoto, Japan; 2003

[18] Syswerda G. Uniform crossover in genetic algorithms. In: Proceedings of the Third International Conference on Genetic Algorithms. 1989. pp. 2-9

[19] Jaszkiewicz A. Genetic local search for multi-objective combinatorial optimization. European Journal of Operational Research. Feb. 2002;**137**(1):50-71

[20] Gantt HL, Forrer D. Organizing for work/ by Henry Laurence Gantt; edited and introduction by Donald A. Forrer. Florida: Dr, Donald A. Forrer; 2006

[21] Russell SJ, Norvig P. Artificial intelligence: A modern approach. 2nd ed. Upper Saddle River, N.J: Prentice Hall/Pearson Education; 2003

[22] Venttsel ES. Teoriia veroiatnostei. Moskva: Vysshaia shkola; 1999

Influence of Strategic Technology Management on Smart Manufacturing: The Concept of 'Smart Manufacturing Management'

Arif Sikander

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.72184

Abstract

As technology advances, organisations are moving towards adapting the best options so as to enjoy a competitive edge. The performance of firms, besides other factors, relies on effective management of these technologies. Strategic management of these technologies is of interest to firms, but studies on this have been restricted to studies in the West. A study carried out by the author helped to analyse which of the technology strategy (TS) and technology management (TM) factors are related to performance of firms. Additionally, it was explored if any of these factors are related to nature and size of the firm. The research focused on high-technology manufacturing industries; some of which employed advanced manufacturing. This chapter will introduce the concepts of strategic technology management and smart manufacturing, provide a critical analysis of literature on the work done in these areas, discuss results of a study done on the application of STM in a high-technology manufacturing sector and extend the results of research to smart manufacturing. It is concluded that a good STM can guide smart manufacturing in enhancing firm productivity and achieving a competitive advantage.

Keywords: technology management, strategic, smart manufacturing, performance

1. Introduction

Technology management has come to be accepted as a vital activity and considered by many to be the basis of competition amongst organisations. On the other hand, Pandza et al. (2004) posit that 'Advances in technology have moved manufacturing organisations toward a new competitive landscape. Managers in manufacturing organisations are experiencing the emergence of new manufacturing concepts or even a new paradigm' (p. 402). Smart manufacturing is one of these emerging concepts. There has been considerable interest by researchers to peep inside manufacturing firms and explore the elements contributing to their performance. 'Over the last decade there have been many attempts to set out the elements of manufacturing systems and to understand their effects' [1]. Concepts such as virtual organisations, concurrent engineering, advanced manufacturing, flexible manufacturing systems and computer-integrated manufacturing have been applied at the company level. However, Hayes and Jaikumar [2] are of the opinion that 'investment based on these technologies frequently proved disappointing, not because of any fundamental weakness in these technologies, but because the links between these technologies and the needs of business were not well understood'. The repercussion of this has been, according to Womack et al. [3], a move by companies to lay more emphasis on soft issues like operations, quality, financial control, production control, change management and supply chain networks. It would be worthwhile to deduce that advanced manufacturing or smart manufacturing alone might not relate to performance of firms. The application of advanced technologies needs to align with the strategy of the firm, hence the need to consider technology strategy and technology management as the main drivers of smart manufacturing.

It is almost impossible for firms to keep away from technology. Continuous development in various industries has relied heavily on technology. The manufacturing sector has also moved leaps and bounds in technology applications. The concept of smart manufacturing also relies on utilising state-of-the-art technologies to monitor and improve productive effectiveness. 'The primary fact about technology in the twentieth and twenty-first centuries is that it has a momentum of its own. Although the technological stream can to some extent be directed, it is impossible to dam it; the stream flows on endlessly' [4]. The development of the Internet and modern sensor technology has benefited most. These technologies can be 'directed' to able to monitor and control the production processes more effectively than is done by current systems which are a mix of manual and automatic parameters. The trend in the development of fast Internet and control systems has provided unique opportunities to introduce smart manufacturing. However, technology alone cannot provide a competitive advantage. The way these technologies need to be applied (technology strategy) and implemented (technology management) needs to be understood by both the academics and the practitioners. This concept of integrating the areas of engineering and management is a concept which this chapter looks into and is introduced by the author for the first time here as 'smart manufacturing management' and resembles with 'engineering management' and 'technology management'. It provides useful results based on a study undertaken in a high-technology manufacturing sector.

Business strategy can be apprehended through its content or its processes [5]. Content research mainly focuses and investigates strategic typologies. Process research puts more emphasis on how the strategy is formulated and implemented ([6], p. 193). 'Strategic technology management' (STM) encompasses both the 'content' of technology strategy and the 'process' of technology management. Technological advances and the timing of their implementation have a considerable influence on the competitive standing of firms. Technology strategies could thus be regarded as important elements which could provide a competitive edge to organisations and also help in the development of their business strategies. Badawy ([7], p. 359) observed that White and Bruton use a similar definition for the management of technology, that is, 'the linking of engineering, science and management disciplines to plan, develop and implement technological capabilities to shape and accomplish the strategic and operational goals of an organisation'.

2. Technology management

Technology management, according to Corey [8], is an integration between business and technical disciplines to develop technology capabilities in order to achieve operational objectives. He further elaborates that R&D is also an essential ingredient for incorporating technology into the products and processes of a firm. Jones, Green and Coombs [9] have defined technology management as the 'identification, development and application of relevant technical knowledge and expertise to achieve organisational goals'. This definition goes beyond the usual domain of R&D and is more strategic in nature.

The effect of employing such strategies has resulted in enhanced productivity of many firms where technology was once treated as a relatively low priority [10]. The importance of technological competencies is evident from the fact that NEC outperformed GTE simply because 'it conceived itself in terms of core competencies' [11]. Therefore, it can be concluded that for the advanced manufacturing industry, technological competencies are always going to be significant as effective *management* of technology is dependent on them (on this, see also [12–16]).

2.1. Missing links in technology management

In order to determine the missing links in technology management, Gregory [1] conducted a critical literature review on this subject and concluded that 'all authors identify the need for a set of instruments, for a methodology to facilitate technology oriented decision making and none of the current approaches relates to general management concepts i.e. they do not lend themselves to integration in a unified concept of firm management'. Traditional approaches to technology strategy tend to focus on the identification of critical technologies and the allocation of R&D effort to the most important of these. Manufacturing firms tend to become multinationals, and technologies employed in the parent firm are similar to those employed by other countries, but it is unclear as to whether or not R&D is similar in the home and host countries. The firm exists to create value-added products. Wahab [17] reiterates that the 'performance of firms depends very much on innovation and R&D environment'. However, despite their similarities there are striking differences in the ways that different firms and organisations approach their technology management—the university system in the USA, for example, plays a different role from the one in Southeast Asia. Thus, technology management strategies applied in advanced manufacturing firms in the host country might be different than those applied in the home country—this is a missing link (gap), and this chapter in part has tried to address this gap.

2.2. Overemphasis on technologies in smart manufacturing

If as Gregory [1] maintains that 'a strategy is only of value if mechanisms for its implementation and renewal are in place', it is surprising that no comprehensive framework for technology management has emerged. Many authors, including Hayes and Jaikumar [2], have highlighted that an overemphasis on technology, rather than on products and services, has led some companies to develop or acquire inappropriate technologies. 'There is a need, then, for a "language" which can represent and link the important dimensions of a business, including technology, in the context of customer requirements' [1]. However, if such a language of technology is developed, it should be common across all functions in the organisation. It should be noted as an example that 'accounting language tends to be the only common language of the firm while technological language fragments at lower operational levels, that is, in production engineering and R&D' [5]. The failure to *measure* technological capabilities is also a missing link in technology management; though the technology contribution factor (TCF) has been applied in research conducted by various researchers, it does not provide the necessary link between the various dimensions of technology management. Therefore, studies which can provide measures to establish this link should contribute to the existing knowledge. The concept of strategic technology management introduced in this chapter—a combination of technology strategy (TS) and technology management(TM)—attempts to address this issue in the sense that it measures the performance of firms in relation to various technology strategy and management dimensions. Acquiring smart manufacturing capability is a moderator in the performance of the firm, and strategic technology management is the driver.

2.3. The strategic content in technology management

The rapid change in technology over the last two decades has raised concern on two major issues. These have been defined by Mitchell [18] as (1) poor linkage between technology and strategy planning and (2) over-reliance on short-term measures, both of which masks the more strategic plans. Strategic importance of technology has been recognised as helping to provide competitive advantage. However, Mitchell [18] states that strategic management of technology has certain practical problems, which are:

1. There is no generally accepted language for defining the critical technologies.
2. There is no way to manage these technologies.
3. There is no appropriate financial framework for allocating resources for strategic positioning.

Hence, there are opportunities to explore how technology strategies are formulated by firms, how they are subsequently implemented and how they contribute towards the firm's growth, especially those which employ advanced manufacturing.

The need to create and use new technology to provide a competitive advantage has been ever increasing and has been a source of growth for many firms. This requires strategic thinking about technology beyond the simple development of new products and services. Hence, 'the task of managing technology is integral to, and essentially synonymous with, strategic management' [19].

Since 1980, the relationship between technology and business strategy has been considered important by companies, but its implementation has not. As highlighted by Chiarmonte [20], 'technology, although very important, was still often not considered in the process of strategy formulation, the essential reason being the trend that technology development takes longer time compared to other functions of the company like marketing'. Thus, more than recognition of this issue is needed to determine what linkage mechanisms need to be established to provide the technology strategy fit.

Contrary to this argument, Thomas and McGee [21] suggest that the strategy literature treats technology as an implementation issue, that is, the technology to be used is defined by strategy.

Thus, technology does not enter into the strategy formulation process, and there is no clear direction on how to manage it. The authors further suggest that technology should be considered as the central part of a company's thinking. Evan et al. [22] go a step further and suggest that 'technology should be recognised as a strategic resource … to ensure new technologies provide sources of strategic advantage. This has tempted cutting-edge firms [to] increasingly integrate technology management with their management processes'. However, this approach on its own is not sufficient; it may confine firms to an inward-looking approach. There is also a need to explore those technology developments occurring outside the firm so that appropriate technologies can be matched to their management strategy. This emphasis by firms on both internal and external inputs—a key aspect of strategic technology management—is explored in this chapter, and both approaches are included as relevant variables in the survey instrument.

Attaran [23] opines that technology in itself does not guarantee success in increased efficiencies and reduced inventory turnover times. He further states that 'management plays a fundamental role in the implementation of such initiatives which could include flexibility, customer service, employee welfare, quality and training'. Thus, allocation of appropriate resources and provision of capital, both for product (development) and services (welfare, training, etc.), are important for the implementation of technologies—a point which has been borne out by one of the results of the bigger research and does not form part of this chapter.

Wilson [24] analyses the strategic management process of Bank of America and concludes that four major thrusts are included in the technology planning of its strategic management process. They are 'emphasis on focusing on technology to meet customer needs; investing in employees to build a diversity of skills and talent; applying technology to build a competitive advantage; and linking business and technology strategies to build a common value'. These values provide a useful set of strategic technology management strategies for researchers. Wilson's understanding of the subject is supported by Sahlman and Haapasalo [25] who regard strategic technology management as the management of those technology activities which interact with a company's socio-economic and technological environment and help to formulate and implement that company's overall strategy.

According to Thomas and McGee [21], 'the evolutionary theory of the firm also provides an important framework for the strategic management of technology because the strategic capabilities evolved through experience reflect the ability of the organisation to adapt to changing technologies which provides profitability'. Although not exclusively naming the approach as strategic technology management, Corey [4] proposes that 'technology management must accept the responsibility for managing its process with the associated strategic perspective otherwise the results could be catastrophic'.

One of the definitions of technology management which integrates the elements of strategic management comes from the NRC Report (cited in [26]): 'Management of technology is a linking block amongst engineering, science and management disciplines to plan, develop and implement technological capabilities to shape and accomplish the strategic and operational objectives of an organisation'.

One of the key recommendations of the Strategic Management of Technology Conference [27] was that firms needed to create a sustainable competitive position, one which requires strong linkages between the company's business environment and the way that company develops and maintains its technological base. Despite this, the main focus remains on the way of acquiring new technology and how to improve the existing ones to gain competitive advantage. The underlying task remains how to find an answer to match technology to market. This is relevant in the case of smart manufacturing whereby employing only modern technologies in terms of IoT (Internet of Things), and data analytics might not be able to provide the competitive advantage.

3. Smart manufacturing and strategic technology management

Smart manufacturing is nothing new; terminologies like advanced and flexible manufacturing have also been used in the past which focus on utilising modern technologies to improve manufacturing. Smart manufacturing entails availability of data of the entire manufacturing process so that manufacturing organisations can *strategise* the processes to match the market. In this respect smart manufacturing 'influences' and 'aids' technology management decisions. Smart manufacturing provides data and empowers everyone in the organisation including top management, which should help management in developing appropriate technology strategies to maintain a sustainable competitive advantage. It would not be wrong to say that smart manufacturing is in fact a technology management trend.

Ettlie [28] conducted a study of various successful firms in the USA and found that synchronous innovation of both technology and administration made for the best-performing firms. 'If business strategy can be thought of as defining the preferred field of contest and the tactics used in confronting a competitor, a technology strategy defines how these tactics can be created and employed' [29]. Clark et al. [30] use the phrase 'technology management' to refer to 'organizational issues and processes involved in developing and implementing a strategic approach to technology'. *As such in the context of smart manufacturing, only utilisation of advanced technology is one of the aspects of performance of firms; how to employ and administer these technologies (TS/TM) will remain the major driver of performance enhancement.*

According to Dell ([31], smart manufacturing provides immense opportunities for organisations including predictive maintenance, quality control, automated process management and supply chain visibility. To be able to avail these opportunities, organisations will need a robust technology strategy in order to determine what tactics need to be employed to ensure compliance of these.

Andrew Waycott [32] suggests that smart manufacturing is about collecting and crunching data to make more informed decisions. With greater visibility of the real workings, your shift supervisors and operators can make better, more informed decisions, all day long. Thus, smart manufacturing can help in strategic management of technology.

Chand and Davis in a paper written for Rockwell Automation [33] suggest that smart manufacturing is not merely technology rather an integration of information, technology and human ingenuity. This integration could be achieved by application of technology management strategies at the strategic level in the organisation to ensure it aligns with the business strategy and provides a competitive advantage.

4. Strategic technology management in advanced manufacturing: analysis of a research study

A study was carried out to determine the influence of STM on the performance of firms in technology-intensive advanced manufacturing sector of the economy. This was a mixed-mode study and employed a survey instrument comprising both quantitative and qualitative questions. The respondents were the chief executive officers, technology managers and senior management in 101 high-technology firms who were considered to be part of strategies at the firm level. The responses were analysed using statistical tools. The variables included in the questionnaire were reduced by performing factor analysis. The relationship between the variables of interest was determined using regression analysis. The factors were grouped into TS and TM dimensions. These were then used to determine their influence on performance of firms. Sales revenue growth (SRG) was selected as the performance measure. Two of the factors, namely, *key positioning* and *strategic R&D*, were found to relate with performance, while the other five factors, namely, *technology leadership*, *up-to-date plants and facilities*, *technology consciousness*, *formal planning* and *external technology acquisition*, were not correlated with performance. Multinational corporation and joint venture firms were found to have acquired the factors of key positioning and strategic R&D, whereas foreign and locally owned companies were found less likely to acquire these factors. These results have implications both for management within the firm and the policy planners at the national level.

4.1. Influence of R&D on technology strategies

Investment in R&D contributes to technological innovation, and to manage these innovations requires the development of technology strategies. So, why do firms invest in R&D? Shane [34] highlights five reasons for this:

1. To create new technologies that can serve as the basis for new products and services.
2. To develop products to replace those threatened by substitutes.
3. To differentiate products from those of competitors.
4. To create strong intellectual property positions by making fundamental discoveries on which pioneering patents can be obtained.
5. To create absorptive capacity to recognise and use knowledge from elsewhere.

Competition amongst firms lays the foundations of business strategy and is a driving force in the establishment of R&D strategy. 'R&D strategy' is often used interchangeably with 'technology strategy' in the literature. As such R&D management has dominated in technology-intensive and advanced manufacturing industries. This R&D emphasis is quite common in the US industries; this is in contrast to the European model which stresses acquisition, diffusion and transfer of knowledge [20]. R&D strategy needs to be integrated with the other strategies of the firm. And, indeed in recent times, there has been a 'shift from an R&D management focused attitude, towards a wider perspective of the issues facing innovation management, and, more recently, towards a combination of innovation, technology and strategy' [20].

In this study R&D is considered as an integral part of a firm's strategy and is employed as a background variable to determine its relationship with the performance of firms. Technology helps in the formulation of a company's technology strategy, and its implementation provides the success. This is the rationale to define strategic technology management as a combination of technology strategy and technology management.

'R&D has to live in continuous symbiosis with other functions in the company and should be absorbed into the technology function' [27]. This Strategic Management Conference [27] also recommended that firms need to 'measure the technological assets' so as to decide on how to use technology in making strategic choices.

According to Van der Meer et al. [35], 'Companies which operate in technology intensive environments are compelled to invest heavily in R&D in order to maintain a competitive advantage'. This study, besides exploring the effect of technology strategy factors on success of firms, also explored if R&D investments in terms of the number of people employed in the R&D department related to the performance of the firms.

'The promise that R&D holds is not the reality for many firms as competitors often appropriate and commercialise new technologies more nimbly than the firms that paid to develop them' [36]. Firms need to find a fit between their R&D and their company strategy. Evan et al. [22] suggest that technology strategy improves communication between R&D and the rest of the firm and seeks to answer questions like:

1. What is the fit between technology projects and the company strategy?

2. How do technology efforts compare with those of competitors?

3. Are external sources (universities, laboratories) used effectively?

4.2. Methodology

4.2.1. Sample

The definition of a high-technology industry has not been agreed upon. The Department of Commerce (USA) [36] defines a high-technology industry on the basis of the percentage of its investment in R&D relative to its sales revenue. Although MNCs in the manufacturing sector outnumbered other types, this study chose to include all types of firms within this subsector: multinational corporations (MNCs), joint ventures (JVs), foreign-owned (FO) and locally owned (LO). The further classification of firms was inspired by Thomas and McGee [21] who define firms in terms of modes of innovation: 'mode 1 as small high technology firms, mode 2 as large multi-product, multi-market, and multi-divisional corporations and mode 3 as huge multinational enterprises that usually involve public and private sector collaboration on mission-oriented programs' (p. 266).

There were a total of 380 E&E firms listed in the Federation of Manufacturing Directory. However, about 80 of these were incorporated after the date this research was carried out, so they were excluded, leaving about 300 high-technology manufacturing firms for the survey.

This sample was considered as a probable one, and it was thus possible to 'extrapolate beyond the sample to establish findings for the wider population of interest' ([37], p. 184).

Because of their familiarity with technology management and strategy issues in their firm, the CEO, technology managers or senior management of each firm was expected to complete the questionnaire.

4.2.2. Research design

In order to address the research question, a mixed method design was used to collect data. Zahra [38] has indicated a 'need to refine the conceptual and operational definitions of technology strategy and … that field studies and surveys can help to identify additional components of technology strategy' (p. 214). The data-gathering phase had three objectives:

1. To gather data on key technology strategy and management elements from senior executives of firms in the manufacturing sector.
2. To gather data about the level of technology awareness of the respondents and about their understanding of the role of technology and the competitive environment.
3. To gather data about the performance of the firms.

The research was designed in three phases. The first phase involved the development of a survey instrument. The survey instrument was developed in line with the objectives of the research and so as to maximise information extraction from the respondents ([39], p. 29). Advantage was taken of prior surveys in selecting the variables chosen for the study, especially Herman [40]. The response rate was initially 18%; this increased to 26.5% (useful rate being 20.7%) after two follow-up letters were sent. The second phase involved the pilot testing of the survey instrument. The pilot study involved 10 firms and sought to assess the clarity and usefulness of the questionnaire items. Phase three of the study involved the administration of the survey.

4.2.3. Measures

According to Jones et al. [9], 'Successful technology strategy management must go beyond content, implementation is as important' (p. 158). There are 10 elements of strategic technology management that were selected for this study. Each element is measured through inductively developed items in order to develop a richer description of the element and to triangulate on the element value. A four-point modified Likert scale was chosen due to its inherent advantages over the original odd-numbered Likert scale.

4.2.4. Firm's performance dimensions

In this study firm performance was measured using sales revenue growth (SRG), that is, by considering the annual sales revenue at the start and end of the period of this study. SRG reflects the effects of technology strategy decisions. Although SRG is not a perfect measure, various researchers have found it adequate for performance, especially for developing countries [41].

4.3. Data analysis

4.3.1. Factors underlying strategic technology management

Factor analysis was used to reduce the original number of items (32 items, 16 strategy and 16 management) in the survey. The literature review identified several variables which could be used to measure two dimensions which define strategic technology management. These two dimensions are referred to as technology management (TM) and technology strategy (TS). A thorough analysis of the environment in which the survey was carried out revealed that 32 items could be used to measure these dimensions. According to the respondents to the pilot study, these items were deemed suitable for use in the main questionnaire.

Principal component analysis (PCA) was selected for extracting the factors. In order to determine the appropriateness of the factor analytic framework, a number of methods were employed. These included Bartlett's test of sphericity and Kaiser-Meyer-Olsen's (KMO) test. The 16 strategy items were factor analysed using the PCA method.

Kaiser's criterion with an eigenvalue of greater than 1.0 was used to determine the number of factors to be extracted. The extraction using PCA for the 'technology strategy' variables revealed that three components accounted for 71.3% of the total variance. The extraction using PCA for the 'technology management' variables revealed that four components accounted for 83.2% of the total variance. The rotated factor loadings are presented in Appendix A.

Strategic technology management in this research has been understood in terms of the technology strategies formulated by firms and the processes for implementing or managing these strategies. Seven new factors have been identified by this research, and these all apply at the company level (Appendix A). These seven factors can be seen as falling into two dimensions: the technology strategy (TS) dimension and the technology management (TM) dimension.

The TS dimension, which refers to the *content* of strategies, is in this study and can be conceptualised in terms of three factors:

1. The first is *technology positioning*, in which a firm introduces high-risk or breakthrough technologies in order to build a reputation for technical innovation that it can be used as a competitive advantage. A firm that uses *technology positioning* also emphasises the sophistication of the technology they apply, with an emphasis on state-of-the-art tools and equipment and a focus on hiring highly trained R&D personnel. Such a firm strives to not only increase its range of products but also to reduce product development time. Thus, this factor could be summarised as referring to a firm's utilisation of technology to achieve competitive advantage. It does so by using even more sophisticated technology and by increasing the number and rate of development of new products.
2. The second factor developed from the data is that of *leading in the discovery of new technologies and introducing innovative products*. This factor relates to the efforts a firm puts into the *discovery* of new technologies and to introducing new products before other firms. Thus, it is about the willingness to lead in technology discovery and in the introduction of new products.

3. This third factor relates to the extent to which *technology is embedded in plants and processes*. This construct relates to a firm's exploitation of technology to manufacture unique products, to reduce manufacturing costs and to increase the flexibility of production processes. This measure also reflects the maximisation of the inclusion of technology in a firm's plant and processes in order to gain an advantage in relation to competitors.

The TM dimension, which relates to a firm's handling of the process side of technology, can be conceived in terms of four unique factors:

1. The first is *R&D linked to business*. This refers to the degree to which a firm links its R&D activities with its other business operations, that is, the degree to which it elevates R&D to a strategic level. It also relates to the existence of mechanisms—mechanisms for recognising and rewarding R&D and mechanisms for evaluating the costs and benefits of specific R&D projects.

2. The second factor is called *keeping abreast with emerging technologies*. This is about the processes that firms employ to ensure that they are aware of innovative and competing emerging technologies. This basically refers to the processes it has in place for scanning for new technologies employed by firms.

3. The third factor is *formal process for planning*. This reflects the emphasis that firms place on using formal processes for planning and selecting technologies, as compared to *ad hoc* decision-making.

4. The fourth factor is *in-country external acquisition of technology*. This is about the processes that firms use to acquire technology by conducting R&D in collaboration with universities, research labs and other companies within a country, that is, technology acquisition that does not rely on internal R&D at the firm level.

The seven strategic technology management factors highlighted above were evident in firms investigated. However, not all factors were found to contribute to a firm's success. The next section describes in detail the relationship between these factors and SRG.

4.3.2. Factors influencing performance of firms

For this study, sales revenue growth (SRG) was used as a measure of firm performance and was averaged over a 10-year period.

The results revealed that there was a statistically significant correlation between *strategic R&D* and SRG, as well as between *technology positioning* and SRG. These two factors represent technology management and technology strategy dimensions of strategic technology management; thus, it could be stated that application of strategic technology management factors contributed to the positive performance of the advanced manufacturing firms during the 10-year period under review. The summary of the factors that correlated with success is provided in **Table 1**.

Factors	Correlation with SRG	Result
Strategic R&D (TM)	Yes ($r = 0.34$, $p < 0.01$)	The firms that are extremely focused in placing emphasis on R&D and linking it with other business operations have a positive significant correlation with the growth rate
Key positioning (TS)	Yes ($r = 0.33$, $p < 0.01$)	The firms that are extremely focused in using technology as a key positioning factor in their strategy have a positive significant correlation with the growth rate

Table 1. Strategic technology management factors contributing to success.

5. Implications

This study has contributed to the discipline of STM and SM by investigating the nature of technology strategies applied in advanced manufacturing firms in an Eastern environment.

The study has offered an approach to quantify the cumulative effect of STM application in SM and performance.

The results could be extremely useful to provide an insight to the national technology planners of the influence of STM in smart manufacturing and the performance of firms.

This study indicated that not all factors of strategic technology management applied in smart manufacturing would produce sales revenue growth. This has implications for the managers of firms and especially for those who are responsible for technology management.

6. Conclusion

Smart manufacturing alone will not be able to provide success in the performance of firms. It has been demonstrated based on the literature review, and an exclusive study carried to explore if strategic technology management factors rather technology alone (as is smart manufacturing) influence performance of advanced manufacturing firm. Although several factors were drawn up from this study, but only two factors contributed to the performance of such firms, and they were strategic R&D and key positioning. The strategic R&D factor demonstrates that the innovative use of technologies and new product designs can contribute to performance of firms. The key positioning factor accounts for good decision-making in terms of market positioning. The study also supports the viewpoint of Chand and Davis (in Rockwell Automation Report) [33] that smart manufacturing is not merely technology rather an integration of information, technology and human ingenuity. Since two factors in strategic technology management contributed to the growth of firms, it could be concluded that integration of both

http://dx.doi.org/10.5772/intechopen.72184

technology (R&D) and human ingenuity (key positioning/decision-making) can provide success to firms. Thus, smart manufacturing is the engine, and strategic technology management the driver for performance of firms.

A. Appendix A: factor analysis

A.1. Technology strategy

Total variance explained

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings[a]
	Total	Percentage of variance	Cumulative (%)	Total	Percentage of variance	Cumulative (%)	Total
1	8.261	51.632	51.632	8.261	51.632	51.632	7.383
2	1.755	10.968	62.600	1.755	10.968	62.600	3.750
3	1.388	8.677	71.277	1.388	8.677	71.277	4.769
4	.987	6.167	77.444				
5	.784	4.903	82.347				
6	.672	4.203	86.549				
7	.457	2.853	89.403				
8	.428	2.678	92.080				
9	.324	2.025	94.105				
10	.256	1.598	95.703				
11	.192	1.199	96.902				
12	.187	1.167	98.069				
13	.113	.704	98.773				
14	.089	.558	99.332				
15	.071	.446	99.777				
16	.036	.223	100.000				

Extraction method: principal component analysis.

	Component matrix[a]		
	Component		
	1	2	3
Pursuing high technical risk	.757		
Having reputation for technology innovation	.775		
Dominance in key technologies	.774		−.411
Importance of advanced qualifications	.652		
Striving for technology development	.755		
Employing pacing technologies	.795	−.425	
Using state-of-the-art tools	.796	−.420	
Reducing product development time	.769		
Increasing the number of products	.582		
Continuously improving products	.708		
First in discovering technologies	.704	.638	
First in introducing new products	.683	.628	
First in introducing low-cost products	.498	.626	
Unique product manufacturing capabilities	.725		.579
Low manufacturing cost	.661		.606
Improving production flexibility	.790		.478
Extraction method: principal component analysis			

[a]Three components extracted.

A.2. Technology management

Total variance explained							
Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings[a]
	Total	Percentage of variance	Cumulative (%)	Total	Percentage of variance	Cumulative (%)	Total
1	7.804	48.772	48.772	7.804	48.772	48.772	6.961
2	2.927	18.296	67.069	2.927	18.296	67.069	4.941
3	1.387	8.668	75.737	1.387	8.668	75.737	2.117
4	1.190	7.440	83.177	1.190	7.440	83.177	2.548

Total variance explained							
Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings[a]
	Total	Percentage of variance	Cumulative (%)	Total	Percentage of variance	Cumulative (%)	Total
5	.642	4.012	87.189				
6	.505	3.155	90.344				
7	.358	2.237	92.582				
8	.320	1.998	94.580				
9	.259	1.619	96.199				
10	.167	1.046	97.246				
11	.150	.939	98.184				
12	.116	.725	98.909				
13	.060	.374	99.283				
14	.052	.327	99.610				
15	.033	.203	99.814				
16	.030	.186	100.000				

Extraction method: principal component analysis.

Component matrix[a]				
	Component			
	1	2	3	4
Awareness of existing technologies	.665	.658		
Awareness of emerging technologies	.650	.670		
Awareness of innovative technologies	.619	.689		
Awareness of competing technologies	.520	.746		
Technology acquisition within the firm	.786			
Technology acquisition from laboratories & universities	.570			.528
Technology acquisition from outside firms within the country				.738
Market-driven programmes	.692			
Product-driven programmes			.776	
Formal planning processes	.454		.455	
R&D integrated programmes	.867			
R&D researchers empowered	.905			

Component matrix[a]				
	Component			
	1	2	3	4
R&D success rewarded	.895			
High R&D investment	.858			
Ensuring high returns on R&D investment	.894			
External R&D funding	.753			

Extraction method: principal component analysis.
[a]Four components extracted.

B. Appendix B: regression analysis

Variables entered/removed[b]			
Model	Variables entered	Variables removed	Method
1	Capital Investment, employees[a]	.	Enter
2	Strategic R&D[a]	.	Enter
3	Technology positioning[a]	.	Enter

[a]All requested variables entered.
[b]Dependent variable: sales revenue growth.

Model summary				
Model	R	R square	Adjusted R square	Std. error of the estimate
1	.732[a]	.536	.520	342.24750
2	.733[b]	.538	.514	344.47139
3	.740[c]	.547	.516	343.85691

[a]Predictors: (constant), capital investment, employees.
[b]Predictors: (constant), capital investment, employees, strategic R&D.
[c]Predictors: (constant), capital investment, employees, strategic R&D, technology positioning.

ANOVA[d]						
Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	7979285.248	2	3989642.624	34.061	.000[a]
	Residual	6910867.880	59	117133.354		
	Total	1.489E7	61			
2	Regression	8007841.708	3	2669280.569	22.495	.000[b]
	Residual	6882311.420	58	118660.542		
	Total	1.489E7	61			

http://dx.doi.org/10.5772/intechopen.72184

ANOVA[d]

Model		Sum of squares	df	Mean square	F	Sig.
3	Regression	8150611.362	4	2037652.841	17.234	.000[c]
	Residual	6739541.766	57	118237.575		
	Total	1.489E7	61			

[a]Predictors: (constant), capital investment, employees.
[b]Predictors: (constant), capital investment, employees, strategic R&D.
[c]Predictors: (constant), capital investment, employees, strategic R&D, technology positioning.
[d]Dependent variable: sales revenue growth.

Coefficients[a]

	Model	Unstandardised coefficients		Standardised coefficients	t	Sig.
		B	Std. error	Beta		
1	(Constant)	−440.577	125.548		−3.509	.001
	Employees	40.917	53.711	.094	.762	.449
	Capital investment	342.801	63.427	.664	5.405	.000
2	(Constant)	−416.552	135.523		−3.074	.003
	Employees	47.858	55.881	.109	.856	.395
	Capital investment	350.486	65.733	.679	5.332	.000
	Strategic R&D	−27.306	55.663	−.052	−.491	.626
3	(Constant)	−640.907	244.923		−2.617	.011
	Employees	44.717	55.855	.102	.801	.427
	Capital investment	351.309	65.620	.681	5.354	.000
	Strategic R&D	−79.027	72.820	−.151	−1.085	.282
	Technology positioning	123.035	111.967	.141	1.099	.276

[a]Dependent variable: sales revenue growth.

Excluded variables[c]

	Model	Beta In	t	Sig.	Partial correlation	Collinearity statistics tolerance
1	Strategic R&D	−.052[a]	−.491	.626	−.064	.705
	Technology positioning	.051[a]	.520	.605	.068	.826
2	Technology positioning	.141[b]	1.099	.276	.144	.481

[a]Predictors in the model: (constant), capital investment, employees.
[b]Predictors in the model: (constant), capital investment, employees, strategic R&D.
[c]Dependent variable: sales revenue growth.

Author details

Arif Sikander

Address all correspondence to: a.sikander@murdoch.edu.au

School of Business and Governance, Murdoch University, Australia

References

[1] Pandza K, Polajnar A, Buchmeister B. Strategic management of advanced manufacturing technology. Advanced Manufacturing Technology. 2004;**25**:402-408

[2] Hayes RH, Jaikumar R. Manufacturing's crisis—New technologies, obsolete organisations. Harvard Business Review. 1988;**66**(5):77-86

[3] Womack JP, Jones DT, Roos D. The Machine that Changed the World. UK: Maxwell Macmillan International; 1990

[4] Pournelle JE, Possony ST, Kane FX. The Strategy of Technology. 1997. Retrieved from Murdoch Net Library. http://www.jerrypournelle.com/sot/sot_4.htm & http://www.jerrypournelle.com/sot/sot_1.htm#Foundations of the Technological War

[5] Chandler AD. Strategy and Structure: Chapters in the History of the American Industrial Enterprises. Cambridge, USA: MIT Press; 1962

[6] Raymond L, Croteau A-M. Manufacturing strategy and business strategy in medium-sized enterprises: Performance effects of strategic management. IEEE Transactions on Engineering Management. 2009;**56**(2):192-202

[7] Badawy MA. Book review: "The management of technology and innovation: a strategic approach" by White, M.A. & Bruton, G.D, Thomson South Western, 404pgs. Journal of Engineering and Technology Management. 2007;**24**(4):395-399

[8] Corey JP. Strategic planning process and technology management. International Journal of Technology Management. 1989;**4**(6):613-624

[9] Jones O, Green K, Coombs R. Technology management: Developing a critical perspective. International Journal of Technology Management. 1994;**9**(2):156-170

[10] Bone S. Chief Executive's Attitudes to Technological Innovation in UK Manufacturing Industry. Cambridge: PA Technology; 1992

[11] Prlahad CK, Hamel G. The core competencies of corporation. Harvard Business Review. 1990;**68**(3):79-92

[12] Meyer MH, Utterback JM. The product family and the dynamics of core capability. Sloan Management Review, Spring. 1993;**34**(3):29-47

[13] Roussel PA, Saad KN, Erickson TJ. Third Generation R&D. Boston: Harvard Business School Press; 1991

[14] Barton PA. Keys to productivity and profitability in the 90's. ACA News. 1992;**35**(10):1

[15] Teece DJ, Pisano G, Shuen A. Dynamic Capabilities and Strategic Management. Working Paper. 1992;**18**(8):509-533

[16] Carter DE, Baker BS. Concurrent Engineering—The Product Development Environment for the 1990s. Massachusettes: Addison Wesley; 1992

[17] Wahab AA. A complexity approach to national IT policy making: The case of Malaysia's Multimedia Super Corridor [PhD Thesis]. University of Queensland; 2003

[18] Mitchell GR. Options for the strategic management of technology. International Journal of Technology Management. 1988;**3**(3):253-262

[19] Price RM. Technology and strategic advantage. California Management Review. 1996;**38**(3):38-56

[20] Chiarmonte F. From R&D management to strategic technology management: Evolution and perspectives. International Journal of Technology Management. 2003;**25**:538-548

[21] Thomas H, McGee J. Technology and strategic management progress and future directions. R&D Management. 1989;**19**(3):205-213

[22] Evan B, Vasconcellos E, Werther WB. Executive levers for the strategic management of technology: Leaders must have the tools to move their firms towards the use of technology as a strategic resource. Business Horizons. 1994;**53**(9):53-61

[23] Attaran M. Strategic management of technology at Frito-Lay's Kern manufacturing facility. Industrial Management. 2001;**101**(5/6):264-272

[24] Wilson I. The strategic management of technology: Corporate fad or strategic necessity? Long Range Planning. 1986;**19**(2):21-30

[25] Sahlman K, Haapasalo H. Elements of strategic management of technology: A conceptual framework of enterprise practice. International Journal of Management and Enterprise Development. 2009;**7**(3):319-337

[26] White MA, Bruton GD. The Management of Technology and Innovation: A Strategic Approach. USA: Thomson Publishers; 2007

[27] Strategic Management of Technology Conference. Conference Proceedings, INSTEAD, Fontainebleau. 7-9 July; 1987

[28] Ettlie J. Taking Charge of Manufacturing. San Francisco: Jossey-Bass Publishers; 1988

[29] Messina A. Technology management for the 1990s. Journal of Manufacturing Engineering. 1989;**6**:49-51

[30] Clarke K, Ford D, Saren M. Company technology strategy. R&D and Management. 1989; **19**:215-229

[31] Internet of Things—Smart Manufacturing. 2017. Available from: http://www.dell.com/en-au/work/learn/internet-of-things-smart-manufacturing. [Accessed: 10th Sept 2017]

[32] What is Smart Manufacturing. 2016. Available from: http://www.industryweek.com/systems-integration/what-smart-manufacturing. [Accessed: 8th Sept 2017]

[33] What is Smart Manufacturing. 2017. Available from: https://www.rockwellautomation.com/resources/downloads/rockwellautomation/pdf/about-us/company-overview/TIMEMagazineSPMcoverstory.pdf . [Accessed: 12th Sept 2017]

[34] Shane S. Technology Strategy for Managers and Entrepreneurs. New Jersey: Pearson Education; 2009

[35] Van der Meer, Jacques BH, Calori R. Strategic management in technology intensive industries. International Journal of Technology Management. 1989;**4**(2):127-140

[36] The Department of Commerce USA. Technology Reports, U.S. Department of Commerce (1984, 1996)

[37] Ahmed ZU, Tsu T. Managing market intelligence: An Asian marketing research perspective. In Ibrahim et al. Reinventing Asian Management for Global Challenges: Proceedings of the Asian Academy of Management Conference; Kuala Terengganu, Malaysia; 16-17 July 1999. Penang: University Science Malaysia; 1999. pp. 183-192

[38] Zahra SA. Technology strategy and financial performance: Examining the moderating role of the firm's competitive environment. Journal of Business Venturing. 1996;**11**(3): 189-219

[39] Kinnear JW. Clean air at a reasonable price. Issues in Science and Technology. 1991;**8**(2): 28-37

[40] Herman EL. Technology strategies in the US electronics industry [PhD Thesis]. Dissertation Abstract International (UMI No. 9834862). Portland State University; 1998

[41] Buzzel R, Gale B, Sultan RM. Market share: A key to profitability. Harvard Business Review. 1975;**53**:97-106

Chapter 7

Digital Smart Jewelry: Next Revolution of Jewelry Industry?

Erno Salmela and Ivary Vimm

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.71705

Abstract

The purpose of this article is to examine business potential of digital smart jewelry. When jewelry has tens of thousands of years of history, it is interesting to find out what people think of jewelry that contains technology. The study was conducted as an action research, in which researchers acted as main innovators of smart jewelry. The smart jewelry can be divided into two main product groups: the esthetic light jewelry and the functional jewelry. Six different jewelry prototypes were manufactured–three pieces for both product groups, after which they were tested by potential and nonpotential users. According to study, the smart jewelry seems to have business potential, but as often with radical products and new markets, it will take time. Forty percent of potential users saw the smart jewelry as fun, cool, fantastic, and an inevitable future. On the other hand, 25% kept them as obnoxious. The functional jewelry seems to have much more potential target groups and users than the light jewelry. As wearable technology and the Internet of things become more common, the smart jewelry market will probably grow as well. The healthcare and wellness industry is a particular force for growth.

Keywords: smart jewelry, digital jewelry, wearable technology, prototype, revolution, radical innovation, user-centered innovation, user experience, user-study method, user data

1. Introduction

Wearable technology is one of the megatrends. One of its branches is the digital smart jewelry (later in text ‘smart jewelry’) that are esthetic and jewel-like smart electronic devices, which provide different kinds of value for their user. The smart jewelry is a new product group without an established market. Therefore, the uncertainty in demand is very high. Smart jewels are already on the market, but the sales volume is still modest. Why do not people buy smart jewelry? What people think the jewelry that contains technology? On the other hand, because of the current movement toward digitalization is everywhere, it may be only a matter of time before digital technology will emerge in jewelry. The aim of this study is to find out whether the smart jewelry has the potential to break through widely and even revolutionize the jewelry industry. In order to reach a holistic view to research problem, the study seeks answers to the following questions:

- What kind of smart jewelry has the most business potential?
- What value people expect to experience from the smart jewelry?
- Who are the most potential users of the smart jewelry?
- How and in what circumstances the smart jewelry would be used?
- What can prevent people from buying and using the smart jewelry?

Therefore, the objective was to create new information on demand and thus reduce uncertainty in demand. It was important to understand what potential and nonpotential users think of smart jewelry. Nonpotential users were defined as a group that does not use even traditional jewelry. Uncertainty of innovation, user-centered innovation, and user-study methods were utilized as theoretical themes. Users were participated in innovation in different ways, and user data was collected with various user-study methods. The smart jewelry was divided into two product groups: the LED technology-based light jewelry and the functional jewelry that can contain different kinds of technologies. Jewels in the light jewelry group do not create functional value for their users, but esthetic, status, emotional, and symbolic value. Three different kinds of smart jewel prototypes were manufactured for both the product groups to obtain user feedback concerning five questions presented above. The light jewelry prototypes included light jewelry for consumers, light jewelry for pets, and effect jewelry for a movie and its fans. The functional jewelry prototypes included bola jewelry, lifesaving jewelry, and access control key jewelry.

Next section presents the methodology of the study, after which Section 3 focuses theoretically on uncertainty of innovation, user-centered innovation, and user-study methods. Section 4 presents the action research and its results, and the article ends with conclusions.

2. Research methodology

The purpose of an action research is to develop new skills or a new approach to a specific matter and to solve problems that have connection to some practical activity. Action researchers have an active role in this. Action research helps to examine reality in order to change it, but also to change reality in order to examine it. Action research is suitable for situations where action is taken to change something and at the same time increase both understanding and knowledge about change. The action study proceeds cyclically. During the new rounds, new efforts are made to increase knowledge or improve something.

http://dx.doi.org/10.5772/intechopen.71705

The objectives and problems of an action research are formulated together with researchers and practitioners. Often, it is somewhat difficult to determine what a customer needs for results. The customer may also be unknown when the research is executed. The purpose of this research was not to influence a specific company but rather to provide with information on the potential of smart jewelry to inspire and prompt some companies to develop smart jewelry in the future. The research was positioned in the first phase of market design, the mental model design such as market definitions for smart jewelry. The action researchers were in the role of an activist by encouraging companies to move forward.

Reflection is an essential part of action research. It is defined as a conscious, systematic, and critical assessment of events, with the aim to learn something new. It is a matter of distancing oneself from the phenomenon under consideration–by watching it from the outside. Action research proceeds as follows:

1. Definition of problem or setting of goals
2. State of art: what is already known about the problem or solutions
3. Planning of study and interventions
4. Action: Doing interventions
5. Gathering data from interventions; for example by observing
6. Reflection: Assessment of interventions; what was learned [1–4]

The study was conducted as an action research of two researchers. Adapting the above process, this study proceeded as follows:

1. Definition of problem: What is the business potential of the smart jewelry. Research questions were set based on uncertainties – in other words, what information is needed to understand the business potential.
2. State of art: Preliminary understanding about the uncertainty of innovation, user-centered innovation, user-study methods, and smart jewelry was created.
3. Planning: Interventions were recognized and planned to create new knowledge on research questions.
4. Action. Part 1: Hundreds of different smart jewels were brainstormed by potential and nonpotential users, after which the best 30 ideas were conceptualized. Prototypes were designed and manufactured for six different smart jewelry groups. Part 2: Implementation of interventions to get feedback from potential and nonpotential smart jewelry users.
5. Gathering data: Prototypes, surveys, trial runs, design probes, observation, interviews, conceptualizing workshops, and storytelling were used as methods to gather user data.
6. Reflection: The action researchers conducted a critical reflection of the user data and created understanding how people relate to smart jewelry.

3. Preliminary theoretical understanding through literature review

Theoretical themes included uncertainty of innovation, user-centered innovation, and user-study methods. In addition, it was examined what kind of smart jewelry is already on the market. In 2013, there were still very few jewelry for sale, but innovation and development work seemed to be in quite a many places in progress.

3.1. Uncertainty of innovation

Innovations can be parsed with the product-market matrix (**Figure 1**). Uncertainty is greatest when creating a new product for new markets. This is called a suicide quadrant of innovation. In fact, entrepreneurs or innovators do not see this as a suicide quadrant, but as a vital possibility to create new business [5, 6].

Uncertainty can be divided into uncertainty in demand (whether customers buy a solution) and supply/technology (can we build the desired solution). Uncertainty is related to a lack of knowledge. The more unknown things are in customer preferences and behaviors, the greater is the uncertainty in demand. If there are already existing products and market, then forecasting is easier, for example by analyzing competitors' sales and actions. Technological uncertainty is associated with, what new technologies emerge, and when or what kind of new technology the company can itself develop. Experimental innovation with users has been seen as a key tool to reduce uncertainty [7–9].

3.2. User-centered innovation

User-centered innovation means that persons in the company and its value network are included in the innovation. Especially the end users of products and services play an important part in this. Users can also come from outside the current value system, in which case the issue deals with extreme type of open innovation [10, 11].

Users may have different roles during the innovation process, such as idea creator, evaluator, idea refiner, designer, and manufacturer of prototypes. At most, they may participate in

	Current market	New market
Current product		
New product		**Suicide quadrant**

Figure 1. Product-market matrix [5, 6].

http://dx.doi.org/10.5772/intechopen.71705

innovation throughout the innovation process. On the other hand, users can be grouped to three groups according to how active they are:

- for the user: company creates a solution based on knowledge about users' needs,
- with the user: company and users co-design a solution, and
- by the user: users innovate a solution on their own initiative [12–16].

Innovation is born when a company meets the conscious or unconscious needs of the customers. Majority of the customers cannot say what they need before seeing and even experiencing a solution. Unconscious needs often come up only through product or service experiences. This may take place, for example, by providing a prototype for the customers to test use. Customers can be divided into innovators, early adopters, early majority, late majority, and skeptics. Innovators and early adopters are called lead users. Compared to the designers who are good at solving defined problems, the lead users or fans are need experts who have insider knowledge. They can identify previously unknown customer needs. When they bring their need expertise in order to connect it with a designer's solution expertise, new solutions can become blockbusters. Lead users often help designers further customize and fit a product into users' everyday life. The innovators are the kind of lead users who innovate on their own initiative. The early adopters, on the other hand, are more like codesigners. Critical point is between the early adopters and the early majority. Most innovations die in this chasm [9, 12, 15–20].

3.3. User-study methods

The essential thing in creating new products for new markets is to challenge the current market definition and create a new one; in this case, challenge the definition of traditional jewelry and create a new one for smart jewelry. Creating a new market definition is based on an in-depth understanding of the users. For this reason, it is necessary to consider what designers know in advance, and which questions can only be answered through collaboration with customers and other partners. For this, variety of user-study methods can be utilized such as user participation, prototypes, experiments, observation, and interviews (**Figure 2**). On the basis of the user research problem, the most suitable method classes and single methods within them are utilized. The use of different methods may take place simultaneously (e.g. observation and interview) or sequentially, such as making first prototypes and then testing them. Choosing the method and knowing how to use it are essential skills when carrying out user research [17, 21–23].

In the user-centered innovation, qualitative research methods are utilized instead of or in addition to traditional market surveys. The aim is to get caught up on the users' experiential relationship to a product. This approach is a key to getting an idea of a variety of product use cases and finding the core value of product. It is critical to understand user goals and motives through the meanings. User understanding can be structured through user profiles that refer to a variety of ways to use the product, as well as attitudes toward the product. Users can be placed in different categories, such as doubtful, familiar, seeker, etc. Creation of a user profile can start from only one customer by understanding his life profoundly. After this, the profile may reflect a larger crowd [9, 17, 24].

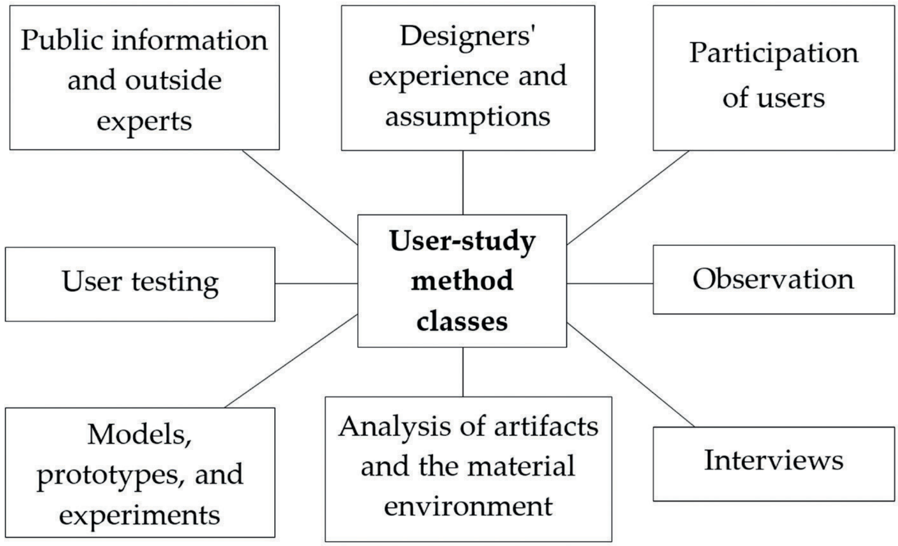

Figure 2. User-study method classes [21].

4. Action research

Smart jewelry is a new product group without an established market. An initial market definition was named concisely "smart and digitalization comes to jewelry." Smart jewelry is a category of wearable technology, and therefore the market definition of wearable technology [25] was applied to the second market definition: *Smart jewelries are esthetic electronic devices (electronic devices with microcontrollers), which provide value for their user through esthetic and different functions and features.*

4.1. Background of smart jewelry innovation

The idea of smart jewelry was conceived in 2012, in a technology company's innovation workshop, where different applications for the company's display technologies were created. One of the ideas related to the smart jewelry. One of the researchers was involved in the workshop, and through this, innovation of smart jewelry started. Initially, seven smart jewelry brainstorming and conceptualizing workshops were held, which produced hundreds of ideas of 30 concepts. The best 100 ideas were described briefly in text format, through which a common understanding of smart jewelry was formed. For example, a reminder necklace was described as follows: *The necklace reminds a person when to take the medicine*. In the brainstorming stage, the smart jewelries were divided into two product groups: the esthetic light jewelry and the functional jewelry.

> Smart light jewelry was defined as follows: *Light jewelry provides users esthetic, symbolic, social, and emotional value, and differs from traditional jewelry by using internal light as additive design element.*

http://dx.doi.org/10.5772/intechopen.71705

> Smart functional jewelry was defined as follows: *Functional jewelry provides users just only aesthetic, social, symbolic and emotional value but also functional value, in other words concrete benefits.*

The best 30 smart jewelry ideas were conceptualized. **Figure 3** shows pictures from conceptualizing workshop and the first rapid prototypes of smart jewelry. Rapid prototypes were important in making the ideas more concrete as well as in forming a common understanding what smart jewelry means. They also inspired to innovate more.

The best smart jewelry ideas were conceptualized, after which prototypes were manufactured from the best concepts. By utilizing readily available electronics, some of the prototypes became bulky and heavy compared to many traditional jewelries. Solar cells were utilized in some prototypes as renewable energy source.

Action researchers were the main innovators of smart jewelry and potential jewelry users themselves. Numerous other potential and nonpotential users participated in innovation work as innovators, early adopters, and other users of smart jewelry. Less than 5% of them had previous knowledge of smart jewelry and no one had any previous user experience. Sixty-eight percent of users were Finnish and the remaining 32% came from other nationalities, emphasizing on Europeans. Totally 14 different nationalities were presented. The proportion of women to men was 61 vs. 39%, and the age varied from 16 to 62 years, the average age being 25 years. One-fourth of the test group people did not use even traditional jewelry at all. They were chosen to study as the laggards or the late majority groups. It was immediately obvious that the smart jewelry was "high concept," which attracted people's attention and pulled free resources to participate in innovation. To get answers to the five research questions, different kinds of user-study methods were used (**Table 1**). The manufactured prototypes were utilized with all the methods.

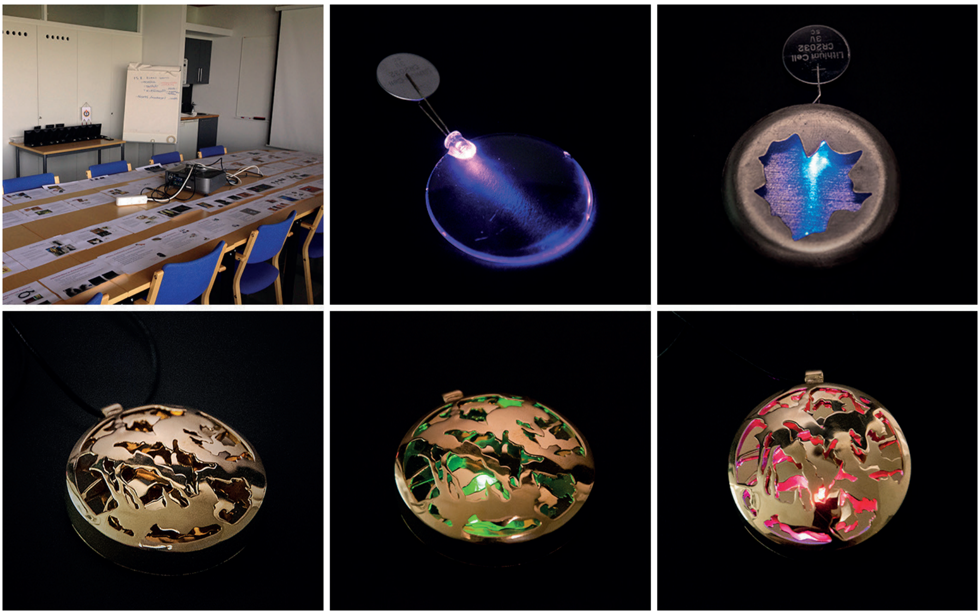

Figure 3. The concepts and first rapid prototypes of smart jewelry.

Research method	Objective
Public information and outside expert	Examine, what kind of smart jewelry is on the market and how much they sell.
Designers´ experience and assumptions and user participation	To create smart jewelry ideas and concepts. Eight designers created hundreds of ideas and 30 concepts in seven brainstorming and conceptualization workshops with Finnish people.
Rapid prototypes and prototypes	To recognize technological challenges, to inspire, and to help obtaining user feedback, two designers (action researchers) designed and manufactured 15 rapid prototypes and after this prototypes for six different kinds of smart jewelry.
Survey	To obtain views from a wide range of people from different nationalities about smart jewelry value, use cases, main target groups, and jewelry design. The surveys were carried out in Finland and Germany in international events. N = 186.
User testing and interviews	To find the emerging experiences and meanings from smart jewelry use in real-life situations. Information was collected through design probes and interviews. The trial use was carried out by Finnish users. N = 21.
Passive observation	To get information about smart jewelry users' preliminary reactions and how other people react the users with jewelry. This observation was carried out in Finland and Germany in international events. N = 85.
Participatory observation and interviews	To get information about smart jewelry user's preliminary reactions and how other people react the users with jewelry. Action researchers put the smart jewelry on themselves. Third of the people were also interviewed. The observation was carried out in Finland in international and domestic events. N = 57.
User stories	To obtain feelings toward smart jewelry. User stories were written by Finnish users. N = 12.

Table 1. User-study methods used in mental model design.

In the following, six different smart jewelry prototypes are presented and how users experienced them. The light jewelry prototypes included jewelry for consumers, jewelry for pets, and effect jewelry for a movie and its fans. The functional jewelry prototypes included life-saving jewelry, access control key jewelry, and bola jewelry.

Taking into account all prototypes, almost all people interested also in traditional jewelry reacted to smart jewelry with a strong or fairly strong emotion – positively or negatively. Forty percent of these people saw smart jewelry as fun, 'cool,' fantastic, and an inevitable future. About half of them loved the smart jewelry. On the other hand, 25% of "traditional jewelry people" could not tolerate the smart jewelry. The remaining 35% were unable to form a clear opinion. One fourth of the participating test users were not "jewelry people." Eighty-five percent of them were not either interested in the smart jewelry. With the functional jewelry, the potential user base is remarkably larger than the light jewelry.

4.2. Prototypes and user tests of light jewelry

4.2.1. Light jewelry for consumers

Three different light jewelry prototypes were manufactured (**Figure 4**) to help people to find the most preferred design for themselves. The jewelry on the left was a favorite for test users

Figure 4. Light jewelry prototypes for consumers.

because of its pleasant design. The light effect worked best in it as an additional design element. For the test users, the light jewelry produced esthetic, emotional, symbolic, and social value. Middle jewelry in the figure was able to charge with solar energy while the other two were charged electrically. From test users´ point of view, this was a good feature that produces ecological value.

The light jewelry was considered most likely to be used in evening parties, parties for young people, and at Christmas or pre-Christmas, but also in everyday use (**Figure 5**). As user studies progressed, it was realized that the original assessment of young adults as the main target group of light jewelry was wrong. Young people quickly began to ask whether the light jewelry incorporated additional features, such as a music player and sensors—in other words, functional value. They wished to challenge jewelry more holistically with regard to design. On the contrary, many 35–50-year-old women born in 1960s and 1970s fell in love with the light jewelry. More precisely defined, they have a positive attitude to life and were extrovert, courage, tolerant, being trendsetters, and 'nutty.' Also men who have same kinds of characteristics were seen as potential target group. Other potential target groups were communities, guides, and tourists. Also, pets were found to be one new potential user group–*"I could also buy a collar with light jewelry for my dog."*

Light jewelry was seen more as a work of art than an electronic device. Silver or other high-quality material was seen as a clear added value. Jewelry design had a significant impact. Test users wanted to find their preferred model from the model options. None of the test users expected personal customization, but the personal product relationship appeared strong.

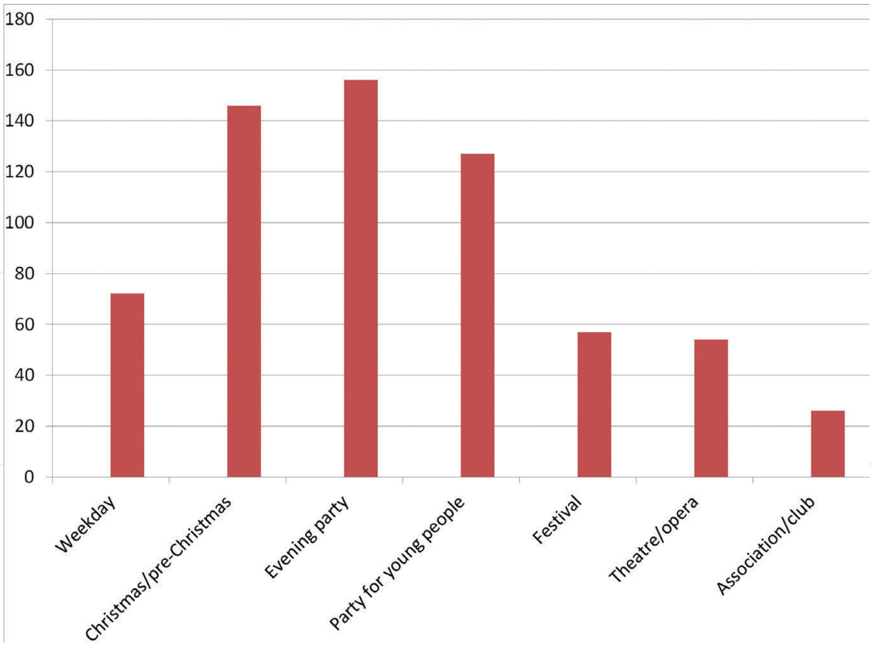

Figure 5. Use cases of light jewelry.

Color options for lights in the same piece of jewelry were important. Most quickly found their favorite color and said they could also change the color depending on the situation and their clothes. Light jewelry aroused curiosity and interest in people. Strangers watched the jewelry cautiously and whispered, *"Is there a light?"*. Users felt it was important that the jewelry was impressive even without light. Jewelry with light is not suitable for all situations; for example, a funeral or when someone else is the center of attention. In everyday use, jewelry also received some disapproving views, such as *"Why are you trying to show off."*

During the test use, it obtained usable bits of story such as *"Light jewelry brings joy to my and others' lives,", "I would proudly wear light jewelry," "Light jewelry looks impressively grand," "I would want one right away,"* and *"I would buy is as a Christmas present for my wife."* People also wanted to give their own names such as *"Twinkle," "Aurora borealis," and "Fairy of Light"* for the jewelry.

Battery life, the need for maintenance, price, and market position raised questions. Most of the respondents estimated the price range as or would be willing to pay 200€ for designed light jewelry. On the other hand, if light jewelry is perceived as bauble, the price should be max 20€. Some did not like the large size of the jewelry, while others appreciated it for that same reason. Quite many, however, thought the jewelry prototypes were too heavy. People wished for more compact and lighter models as well as more details. **Table 2** summarizes contents from stories that test users wrote about the light jewelry.

http://dx.doi.org/10.5772/intechopen.71705

Why would I buy them?	- They stand out from the crowd, they are different - They are modern and innovative, they have a novelty value - They are wonderful, esthetically pleasing/attractive, fun, interesting, youthful, impressive, playful, intriguing, surprising, and personal - They are striking - They are versatile–they adapt to different situations and clothes
Whom I would buy light jewelry?	- For myself - For family members – for a spouse and/or children - For friends or acquaintances - As gifts or business gifts - My pet
What would I tell about light jewelry to others?	- They are great gifts - They are fun, beautiful, and unique - The color of the jewelry can be changed - They have received recognition on television news and other media - They are jewelry containing electronics/new technology - They make for good costume jewelry and also work for bar nights - They are a different and a thing for pioneers - The jewelry comes in various models that can be adapted - They are unique and handcrafted
What may be troublesome?	- Adequacy of power - Changing the battery–could energy be produced ecologically? - Frost durability - Lifetime/duration of technology - Big size, palette is too colorful - Price

Table 2. Summary of results from user stories.

4.2.2. Light jewelry for pets

When it comes to pets, the reactions of the animals to light jewelry were observed. The prototype was tried on cats and dogs (**Figure 6**). When the cord was adjusted appropriately, so that it did not meddle with walking, it did not bother dog at all, seeing as dogs are used to collars to begin with. It was more challenging with cat, but it also got used to the collar in ca. 5 minutes. The cat got used to collar more quickly the next time it used jewelry. A solution that would be lighter than the prototype would be more suitable to smaller animals. The test pets weighted 7 and 4.5 kg. The potential purchasers are naturally pet owners and their animal friendly friends. The pets themselves do not obviously be esthetically pleased with the jewelry. Pet owners saw two crucial values of the pet jewelry: they decorate the pet and act as a substitute to a traditional reflector for safety, later of which is a functional feature. Ca. 30% thought that the idea of jewelry for pets was good, but an equal amount was of a different opinion. Mostly the pet jewelry was interesting to those pet owners, who themselves wanted to own a light jewelry. The idea for further design work was that more user friendly solution would be a design collar with integrated jewelry. The collar would be more practical because it lets the pet move freely, and poses no imminent threat of choking. As an additional functional feature, a locating or tracking system was wished for, in case the pet goes astray.

Figure 6. Light jewelry prototype for pets.

Too high a price can be a hindrance when buying light jewelry for your pet. On the other hand, the jewels are possible to be made more cheaply for pets because of more affordable materials, for example, plastic, rubber/latex, etc. The need for maintenance was also seen as a possible hindrance. However, nowadays there are LED collars, where the change of batteries is made easy. Furthermore, there was a speculation about the jewelry's durability and safety in wet conditions, but the solutions are possible to be made waterproof. The whole idea of pet jewelry is part of the trend of people using more their time and money on their pets.

4.2.3. Effect jewelry for a movie and its fans

A prototype with highlighting the logo of the movie was made, which then could be used as a so-called effect jewelry in the movie—even a central part of the plot. Effect jewelry would then bring esthetic value and possibly functional value (cf. the light sabers in Star Wars). For better visibility, the piece of jewelry was made big, ca. 6 inches in diameter. In **Figure 7**, we can see the effect jewelry prototype in action, while in the lower part of the figure shows the blueprint and electronics of the jewelry. The more pivotal role the jewelry would be in the movie, the more likely also the fans would buy the consumer version of the jewelry. The size of the fan jewelry is about half of the original and it would be available also without the effect feature, that is, a regular piece of jewelry. With alternative versions, fans could have a choice of design and price. The jewelry could be numbered and thus unique.

Fan jewelry could be a subject of crowdfunding along with more traditional ones, like signed Blu-ray or DVD discs or posters. It would be a symbolic icon for fans to have been a part of a

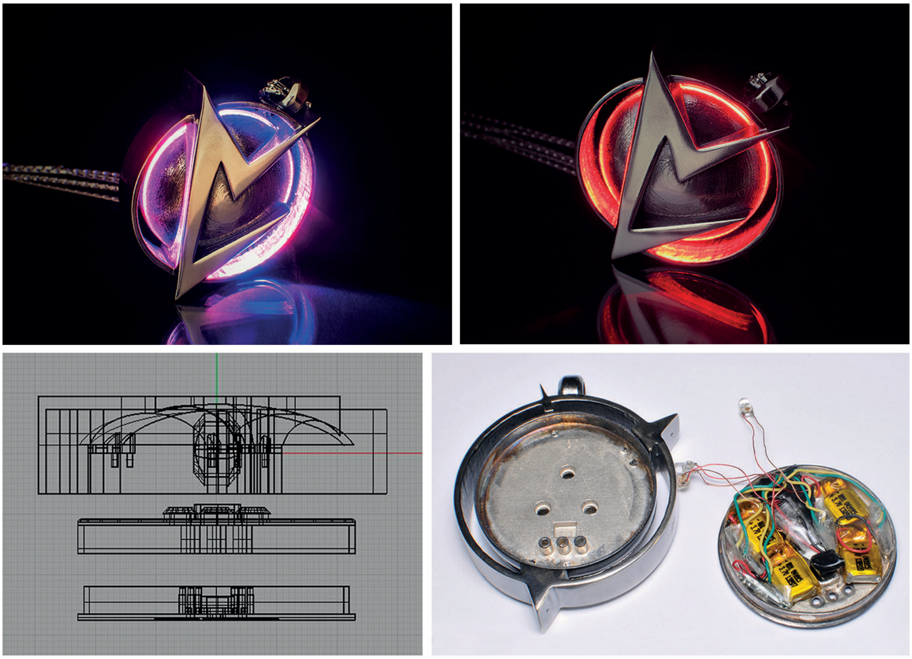

Figure 7. Effect jewelry prototype for a movie and its fans.

group making the movie possible. The jewelry would thus have a clear meaning. Furthermore, it could be a utility article for everyday and party use. Party use could be wearing the jewelry for a premiere or a fan meeting. People could be interested in jewelry of this kind even when they are not usually jewelry oriented. Effect jewelry could be an object in a showcase. The value for the moviemakers would be economical and related to getting the fans hooked; furthermore, the jewelry would have image value and marketing value. This already realized when the media got interested in the effect jewelry.

The insufficient visibility could be a hindrance in using the item in a movie. This already happened when filming the trailer for the movie. As the lights were so strong, the effect jewelry did not shine enough. On the other hand, if jewelry is not an integral part of the plot, it is a mere decoration with no larger significance. The purchase or use of the jewelry can be prevented by the fact that it does not please the fans despite the different choices, the price is too high or the fan is simply not interested.

4.3. Prototypes and user tests of functional jewelry

4.3.1. Lifesaving jewelry

Lifesaving jewelry (**Figure 8**) contains the crucial identity and health data of the person who is wearing it, readily readable in the case of a sudden seizure, which means when the person is not being able to show data or tell about it. Smart jewelry had a near field communication (NFC) tag into which the data had been recorded. In the prototype, the health information

Figure 8. Lifesaving jewelry and its field test.

was readable with mobile phone by putting it close to the jewelry. A field experiment of this was carried out with paramedics. A situation with the person having a seizure was simulated. She acted unconscious and could not communicate at all. Paramedics had ca. 20 seconds to get the health information they needed and began taking measures according to that. The paramedics saw this solution as easy and good. The piece of jewelry was easy to be found so that the information was reachable by turning the actor. The situation could be made easier if the piece of jewelry or a similar gadget could be read from afar, let us say from a five-foot distance, and then the lifesaving jewelry or gadget wouldn't even have to be found. On the other hand, this poses problems to one's privacy. The problem could be solved with a special scanner and special tag.

Lifesaving jewelry is suitable for everyone who likes jewelry, but first and foremost for risk groups, such as diabetics, those with allergies and chronic illness, those who use prescription medication, and those with a heart condition. On the other hand, the solution is suitable for amnesiacs, children, or animals that may go astray or missing. For those groups, the jewelry may contain contact information of home and people near to them. Jewelry is to be worn daily—at least when the user leaves home, but depending on the user it would be good to wear at home.

As seen in the picture, the jewelry can be made with style utilizing NFC tag in the design (black element in the middle). Furthermore, there is a topaz and a jewel that was made of silver. Most of the test users liked the design very much indeed. Some were almost revolted by traditional wristbands that gave the user the stigma of being ill. Part thought that the prototype jewelry was too large (diameter of 31.50 mm), and would not wear it because of that. The design of the piece of jewelry in the picture is for females, but with different design, it could be worn by men alike.

Negative reaction on the authorities' side and bureaucracy might be hindrances to lifesaving jewelry's success. The danger of the client's health information getting abused may be seen stronger than the danger of wrong medication or medical procedure or getting them too slowly. The crucial hindrances are thus related to information security and the safety of privacy. Also, the durability and the reliability were questioned, what if the battery runs out, or the piece of jewelry gets wet? How do you update the health data? The last one is easily done with a mobile phone. Lifesaving jewelry has a passive tag, that is, it does not need a battery. Also, the tag has a waterproof coating. The version made of precious metal might be too expensive, so more affordable versions should be available. On the other hand, the data can be in a wristband or a ring along with the pendant, but we must bear in mind the size of the tag. One obstacle is that everyone does not like jewelry, so other alternatives, such as a tag in one´s wallet or watch, or even a microchip under the skin, must be available. 'Selling' the jewelry to the elderly, especially for men, can be challenging. One has to also bear in mind the limited amount of data that is possible to put in a NFC tag in the jewelry. Perhaps, the best solution would be a system based on fingerprints, which enables access to personal info in a database by scanning the fingerprint.

4.3.2. Access control key jewelry

Access control key jewelry (**Figure 9**) is designed for the opening of electric locks and for monitoring working hours. Three different prototypes were made: a ring, a tie tack, and a bracelet. An access control key is inside the jewelry. It is as easy to realize as the lifesaving jewelry, it does not need a power source. The target group is enormous: production facilities, hotels, hospitals, schools, offices etc., and also homes as the electric locks become more popular. The

Figure 9. Access control key jewelry and its field test.

traditional unappealing access control key may be modified to match with the organization's brand and visual look, as well as create personal designs.

Prototypes were easy to make by taking apart traditional access control keys and changing the RFID tags to the designed ring, bracelet and tie tack. The access control system with scanner was left unaltered. In the user test ca. 25% thought that the access control key jewelry was a good idea. The ring was better than the tie tack or the bracelet in usability. The prototype of the ring was experienced as it was too large. The bracelet was deemed fit for only females. The tie tack positioning in the scanner was experienced as too difficult, unless it was detached from the tie. The people not attracted by jewelry wanted to integrate the chip with a watch, mobile phone, or wallet. On the other hand, it would have been taken to use from the pocket as does the traditional access control key. One approach was that the tag could be integrated as an already existing piece of jewelry with user, for example, wedding ring. One possible solution could be if nanotechnology "greased" into the ring surface and printed electronics, but this was seen as a possible future solution.

The price is the bad side of the idea. Access control keys that are 'jewelified' are 10–100 times as expensive as the current ones. In home usage, this could work better, as the quantities are more small, and individuals may decide on the budget themselves. On the other hand, the material choices are at least partly limited because of the weak penetration of standard signals, which in turn limits design.

4.3.3. Bola jewelry

Bola jewelry is a communication device for the pregnant lady and the unborn child, possibly also after birth. A piece of traditional Bola jewelry makes a noise of mechanical jingling, when in the smart version (**Figure 10**) you can create or upload many a voice – mother, father, and grandparents talking, music, and different kinds of voice recordings. A personal connection is made to an unborn child. Music and recordings of those nearest soothe strengthen the bond with the baby and the outside world. When the child is being born, she remembers and reacts to the sounds she has heard in the uterus, and that creates feelings of safety and calms the baby. Smart Bola jewelry could be worn elsewhere than the neck, for example, the wrist.

A designed and even tailor-made piece of Bola jewelry becomes an object for everyday use and a memento for the kid and the mother, or both. Why not for the whole family. After the birth, even the father can use the jewelry with the child. The prototype was built by creating

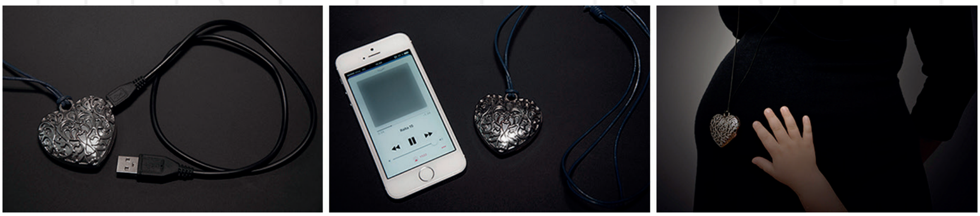

Figure 10. Smart bola jewelry.

http://dx.doi.org/10.5772/intechopen.71705

a streaming from mobile phone to the Bola jewelry via Bluetooth. A hands-free receiver and a loudspeaker were installed to the jewelry. The source of the sound of Bola jewelry was a mobile phone. Optionally, the contents could be downloaded inside the jewelry. Ideas for further development: could the fetus or the baby communicate back to the parents—possibly including heart sounds. Vibration and light could be added to Bola jewelry, as well as auto-timer so it would not be on all the time.

The fear for electronics can be a hindrance when acquiring Smart Bola jewelry. As the product is meant during pregnancy and newborn, the authorities might limit its use by legislation or the security demands are lifted so high that the price would too high for the consumer. Quality jewelry, well made, is always expensive. Furthermore, tradition is in the way of use of Smart Bola jewelry. Traditional Bola jewelry is interesting because of its design and history. Smart Bola jewelry got the least enthusiastic reception of all the smart jewelry in this study. For a certain part of the women, Smart Bola jewelry made their blood boil because they were disgusted by the idea. It might be noted though that no young mothers were a part of this user test, but mothers who have given birth 10–20 years ago.

5. Conclusions

The smart jewelry is positioned in the so-called suicide quadrant of innovation when creating new products and new markets. According to this study, the smart jewelry seems to be a so-called high concept, which arouses people’s interest. On the other hand, the smart jewelry sellers are already on the market but have not yet broken through the big scale. The markets and products are still in the introduction phase of their lifecycle. In other words, the market development degree of smart jewelry is low. The technology already exists and trends also seem to be moving toward smart jewelry, but the demand is not there yet, with the exception of low cost bauble and toy jewelry.

People are especially concerned about the duration, safety, security, and maintenance of technology. The marketing message should focus on alleviating these doubts. Of course, the tradition also has great impact. Jewelry has a long history. It is a big jump to suddenly switch to jewelry with technology inside. Some people will never accept this. It would be useful if a couple of big and credible companies started to focus on smart jewelry more prominently. This would also pave the way for other entrepreneurs in the industry. So far, mainly startups and researchers have made the work of activists ("Believe me, let’s move forward together") in the creation of markets, but now more powerful market builders are also needed ("You have the need and we have the solution") to develop market to the next level.

Prototypes, surveys, trial runs, design probes, participatory and passive observation, interviews, workshops, and storytelling were used as methods to increase user understanding and explore business potential of smart jewelry. Almost all people interested in traditional jewelry reacted to smart jewelry with a strong or fairly strong emotion, positively or negatively. About 40% of these people saw smart jewelry as fun, cool, fantastic, and an inevitable future. About half of them loved the smart jewelry. On the other hand, 25% of people could not tolerate the idea of smart jewelry. The remaining 35% were unable to form a clear opinion. One-fourth of the test users were not "jewelry people." They did not use even traditional jewelry. This group was studied to find out if smart jewelry could attract new customers as jewelry users. According to the study, however, potential buyers of smart jewelry nowadays use traditional jewelry.

People expect from the smart jewelry to experience esthetic, functional, emotional, ecological, symbolic, social, and cultural value. The weighting of these values varies among different kinds of smart jewelry. The esthetic value, however, is common and the most important to potential users. Next comes emotional and symbolic values. These three values are causes why people could use jewelry instead of other products that do functionally the same thing. That is why the smart jewelry users will mainly come from subgroup of traditional jewelry users.

As wearable technology and the Internet of things become more common on the consumer market, the smart jewelry market will also probably grow. The healthcare and wellness industry seems to be a particular force for growth. A different sensor technology has increased and become considerably cheaper. Besides functional value, people appreciate jewel-like devices rather than an engineered appearance that may also be connected to some illness and thus create sense of shame. This seems to be the only cause to tempt nonjewelry people to smart jewelry users. According to the study, there are many target groups for functional smart jewelry. Therefore, the business potential is big.

Designed light jewelry has the potential as well, but for considerably smaller target group than functional jewelry. They could be directed at five target groups: (1) for women and their spouses born in 1960s and 1970s that have a positive outlook on life, (2) for tourists as a souvenir, (3) for different kinds of communities, (4) for entertainment business, and (5) for pets. Young people were not interested in light jewelry. However, some young test users said that jewelry should be challenged more comprehensively and forget the traditional shape of jewelry.

When the market is immature, there is no even common language among people—so-called market definition. If there is no common definition of the market and a subsequent shared language, it becomes difficult to create new demand and supply. As a result, the market will grow slowly or may die completely. In this study, an initial market definition was named concisely" smart and digitalization comes to jewelry." Later it created more specific definitions and own definitions for the light jewelry and functional jewelry. A value proposition can be considered to be a focused market definition. It connects supplier's offering with the customers´ expectations, needs, and benefits. For example, the value proposition of light jewelry for positive women born in the 1960s and 1970s was defined as follows:

> *Light jewelry produces moments of joy for you, your family, and friends. It emphasizes your self-confident and bold trendsetter image—including your playful personality. Light jewelry is a vibrant mystical object. Just when you think you see something, the jewelry shapes into something else entirely. Light jewelry has adjustable color options and allows flexibility in various costumes and uses. In addition, light jewelry is distinct from traditional jewelry by being stunning also in low light. On the other hand, the jewelry is stylish in the absence of light, so that it also suits peaceful moments.*

http://dx.doi.org/10.5772/intechopen.71705

Every piece of light jewelry is unique. The jewelry combines the blacksmith's craft and technology. The jewelry is made of silver. Light jewelry has no need to be charged and is ecological because it derives its energy from body heat and solar energy. Inside a piece of jewelry containing LEDs and other electronics is a 6000-hour warranty, which means the use of over 3 hours a day through the course of 5 years. The jewelry is recommended to be serviced every five years, with regard to electronics and to replace the necessary components. You only need to send it to service center.

As a summary, the smart jewelry seems to have a business potential, but as often with radical products and new markets, there is much of uncertainty. First early adopters have been caught but there is yet miles to go. A good sign is that some people are genuinely enthusiastic about the smart jewelry. On the other hand, the smart watches can somehow equate with the smart jewelry. After the initial interest, the eagerness toward them has faded. It is uncertain; can the smart jewelry revolutionize the jewelry industry—and if it is able to do that, when will this happen? At least nowadays, the business is still quiet. Maybe, the killer application is still missing.

Author details

Erno Salmela* and Ivary Vimm

*Address all correspondence to: erno.salmela@lut.fi

School of Business and Management, Lappeenranta University of Technology, Lappeenranta, Finland

References

[1] Eriksson P, Kovalainen A. Qualitative Methods in Business Research. SAGE Publications; 2008 DOI: http://dx.doi.org/10.4135/9780857028044

[2] Kemmis S, Wilkinson M. Participatory action research and the study of practice. In: Atweh B, Kemmis S, Weeks P, editors. Action Research in Practice. Partnerships for Social Justice in Education. Routledge; 1998. p. 21-36. ISBN: 0203024478

[3] Gummesson E. Qualitative Methods in Management Research. SAGE Publications; 2000 DOI: 10.1002/jsc.512

[4] Heikkinen HLT, Rovio E, Syrjälä L. Toiminnasta tietoon. Toimintatutkimuksen menetelmät ja lähestymistavat. Hansaprint Oy; 2010. ISBN: 9789519140360

[5] Ansoff I. Strategies for diversification. Harvard Business Review. 1957;**35**(5):113-124

[6] Sarasvathy SD. Effectuation: Elements of Entrepreneurial Expertise. Edward Elgar Publishing; 2009. ISBN-10: 1848445725

[7] Furr N, Dyer J. The Innovator's Method. Bringing the Lean Startup into Your Organization. Harvard Business Review Press; 2014. ISBN-10: 1625271468

[8] Galenson D. Old Masters and Young Geniuses: The Two Life Cycles of Artistic Creativity. Princeton University Press; 2007. ISBN-10: 0691133808

[9] Sims P. Little Bets: How Breakthrough Ideas Emerge from Small Discoveries. Free Press; 2011. ISBN: 9781439170427

[10] Chesbrough H. Open Business Models: How to Thrive in the New Innovation Landscape. HBS Press; 2006. ISBN-10: 1422104273

[11] McQuivey J. Digital Disruption: Unleashing the Next Wave of Innovation. Amazon Publishing; 2013. ISBN-10: 1477800123

[12] Antorini YM, Muñiz AM. The benefits and challenges of collaboration with user communities. Research-Technology Management. 2013;**56**(3):21-28

[13] Buur J, Matthews B. Participatory innovation. International Journal of Innovation Manage ment. 2008;**12**(12):255-273

[14] Plé L, Lecocq X, Angot J. Customer-integrated business models: A theoretical framework. Management. 2010;**13**(4):226-265

[15] Sun H. Innovating with fans: Social games and technology design. User Experience Magazine. 2016;**16**:4. Available from: http://www.uxpamagazine.org/innovating-with-fans/ [Accessed: April 3, 2017]

[16] Von Hippel E. Lead users: A source of novel product concepts. Management Science. 1986;**32**(7):791-805

[17] Miettinen S. Palvelumuotoilu: Uusia menetelmiä käyttäjätiedon hankintaan ja hyödyntämiseen. Teknologiainfo Teknova; 2011. ISBN: 9789522380777

[18] Sun H. Cross-Cultural Technology Design: Creating Culture-Sensitive Technology for Local Users. Oxford University Press; 2012. ISBN: 9780199744763

[19] Trott P. Innovation Management and New Product Development. Pearson Education; 2008 ISBN-10: 0273713159

[20] Moore G. Crossing the Chasm. Marketing and Selling High-Tech Products to Mainstream Customers. Harper Business; 1991. ISBN: 0060517123

[21] Hyysalo S. Käyttäjätieto ja käyttäjätutkimuksen menetelmät, Edita; 2006. ISBN: 95137 46402

[22] Storbacka K, Nenonen S. Learning with the market: Facilitating market innovation. Industrial Marketing Management. 2015;**44**(January):73-82

[23] Tikka V, Gävert N. Arvonluonnin uusi aalto. Näin rakennetaan tämän vuosisadan arvokkaimmat yritykset, Tekes-katsaus 309; 2014. ISBN: 9789524575805

[24] Vilkka H. Tutki ja kehitä. Otava; 2005. ISBN: 9789524516624

[25] Wikipedia Wearable Technology. Available from: https://en.wikipedia.org/wiki/Wearable_technology [Accessed: August 28, 2017]

Chapter 8

Renewing a University to Support Smart Manufacturing Within a Region

Heikki Ruohomaa, Mikko Mäntyneva and Vesa Salminen

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.72115

Abstract

This chapter focuses on the topic of renewing a university in order to be able to support the adaptation of smart manufacturing and Industry 4.0 within a region. The chapter introduces Industry 4.0 as a framework for regional development. Factors related to Industry 4.0 related renewal in the region are identified and discussed further. An idea of how to apply Industry 4.0 as a framework for renewal of a multidisciplinary university's structure and curricula is introduced. Also, a case study for applying Industry 4.0 as a framework for increasing competitiveness in the region is introduced.

Keywords: Industry 4.0, smart manufacturing, regional development, university

1. Introduction

The chapter is closely linked to Industry 4.0 framework. The geographic focus, while developing this chapter further, is the region of Häme in the southern part of Finland. The various activities within the region are evaluated from the perspective of smartness and their ability to support Industry 4.0 framework, as well as the renewal of operations in the region.

The development of competitiveness of the region, while maintaining and developing it as an attractive location for companies requires, co-operation between various stakeholders. Industry 4.0 can be applied as a framework for regional development. Universities have a major task to support competence development of relevant topics in various fields. In the field of manufacturing industry, the Industry 4.0 is increasingly relevant topic and the universities should identify their role to support local industry in its adaptation.

2. Industry 4.0 as a framework for regional development

The term "Industrie 4.0" was initially originated in Germany [1]. Industry 4.0 is a policy framework that defines and describes how new technologies should be adopted to renew manufacturing. The renewal is expected to bring major boost in competitiveness. It provides the framework for different kinds of policy initiatives. From the regional development perspective it can also be used as a guideline for steering research and development activities [2].

Industry 4.0 describes how machines, and other technologies adapted in manufacturing communicate with each other. The major importance is on a networked perspective, i.e., how different companies within a value chain communicate each other. The intention is such that computerized systems control and monitor physical processes. Industry 4.0 takes manufacturing-related industries to the next level in adapting and utilizing digitization. In networked environment machines and physical objects are linked with each other. This allows decentralized production and real-time adaptation to the changes on the level of demand in the future [2].

The characteristics of Industry 4.0 is that it promotes computerization of manufacturing. Industry 4.0 is closely linked to Cyber-Physical Systems (CPS) [3]. They can be defined as transformative technologies which manage interconnected systems between its physical assets and computational capabilities [4]. We are increasingly using the concepts of the Internet of Things, the Internet of Everything and the Industrial Internet. The widespread adoption of information and communication technology (ICT) is increasingly accelerating and blurring the boundaries between the real physical world and the virtual one. The linkage is becoming increasingly smart [5].

Industry 4.0 is made possible through the development of the industrial Internet of Things [4]. New ICT-related technologies make Industry 4.0 development possible and give opportunities to re-engineer value chains and create new business models. Internet of Things (IoT) is one of the core technologies for Industry 4.0. The growth of connections brings the new possibilities and solutions for business. On the other hand, exponential growth brings also new challenges for education, R&D&I, and regional development activities. The exponential growth of IoT connections indicates the birth of new business models and new kind of business environments. This "smartness" requires greater connection and collaborations. This is where the "explosion" of platforms and ecosystems is occurring. An attempt to connect the Internet of Things, services, data, and people need radical redesigns within industries and the participants to connect up this all. Presently, Industry 4.0 is more industrial driven, but this will change and broaden out [6].

Industry 4.0 is about increasing productivity and competitiveness. One perspective how this increase in productivity takes place is increase in the efficiency and speed of processes within a company or a value network. Basically, utilization of Industrial Internet makes it possible to optimize the activities and resource utilization in entire value network. Also, material and energy efficiency can be improved, which is important from the perspective of sustainable operations. Large sets of accumulated and real-time data can be applied to forecast or process development purposes. In addition, digitization provides opportunities for new start-ups and may create further prosperity [1].

http://dx.doi.org/10.5772/intechopen.72115

Digitalization will bring new business opportunities and increasing competition. Companies are forced to renew their processes and activities, and at the same time restructure their business processes and models. Regions and areas are forced to plan and redesign services in their business environments as well. In order to see the development needs for attractiveness and welfare, but also to use the development resources in the best possible way, the key research questions related to this paper are:

1. How Industry 4.0 could be used as a framework for regional development?
2. What are issues affecting competitiveness of regions?
3. How structure and curricula of university could be renewed in order to support adaptation of Industry 4.0 in the region?
4. What issues to consider while applying Industry 4.0 to increase competitiveness of a region?

The changes created by Industry 4.0 are not only technological but also organizational [7]. More network-oriented operations are emphasized instead of a perspective of one single economic unit like one factory. The competence development activity, that is required to fully internalize Industry 4.0, is a major task. It should be implemented both on the societal level implemented for example by higher education institutions as well as on private enterprises. It is possible that productivity improvement perspective, which on the short to medium term, may lead to layoffs of workers regarding their current work positions is not necessarily welcomed by representatives of trade unions. However, on longer time frame, the competiveness of European manufacturing-related industries is beneficial for all members of the society [1].

3. Adaption of new technologies supporting Industry 4.0

It is assumed that European manufacturing industry has to radically renew itself. Industry 4.0 provides guidelines on how to make this renewal ambition a reality. The adaptation of new technologies that can be interconnected provides major opportunities. While large-scale utilization of sensors that are connected by wireless networks as well as further adapting robotics provide potential to gain major leaps in productivity. Analytical methods that can be utilized on big data provide further insights on managing a network of producers and suppliers. Mass customization becomes a reality. The overall productivity increase is due to increased speed, improved quality, better utilization of existing resources, and so on. However, the manufacturing firms should be prepared to make required investment on both hardware (equipment and computers) as well as on software (competence development and applications) [8].

Digitization is an increasingly relevant option while companies are trying to renew themselves and their operations to remain competitive. However, digitization is not only a short-term project; it is a long term transformation that should be lead. The leadership perspective is very important in this change management initiative. Such technologies like cloud computing, wireless networks, and big data can be adapted. However, the main question remains,

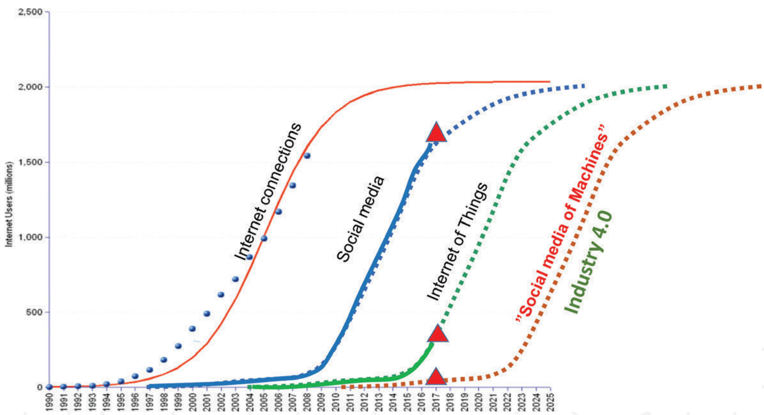

Figure 1. Rapid adaptation of new internet-related technologies.

what changes are about to happen in our industry or value network and how applying digitization makes it possible to remain competitive and even further increase competitiveness.

The development of new technologies not only causes major changes and transformations, but also provides plenty of opportunities for exploitation of sustainable, residential, and residential-oriented urban centers and environments. The subscriptions to the Internet (IoT) alone will rapidly multiply in the years to come. This development affects traffic, travel chains, housing for commerce, welfare, healthcare, tourism, services, industry, etc. This development of new Internet-related technologies described in **Figure 1** places urban development and development principles into a new perspective.

Training, development, innovation, and testing can no longer take place in a separate and closed laboratory environment, but to be able to create sustainable innovations education and development activities must be brought into an operating environment where residents, non-governmental organizations, political decision-making, civil servants, and students meet with regional development and different disciplines. The urban infrastructure is a part of the innovation-based ecosystems of different actors that produce new innovations at their interface.

4. Competitiveness of regions

Private organizations are doing their best to be more profitable and they are open to new ideas. That is why companies are actively starting to use new technologies and trying to find the most suitable business environment for their locations. At the government, region, and town level, the situation is quite different. Their task is not to make business, but to develop good and fruitful business environments for companies. Building infrastructure, providing a skilled labor force, etc., have been their main tasks.

By identifying the key factors for the Industry 4.0 related renewal, we will find different factors, i.e., "levels." These are described in **Figure 2**.

http://dx.doi.org/10.5772/intechopen.72115

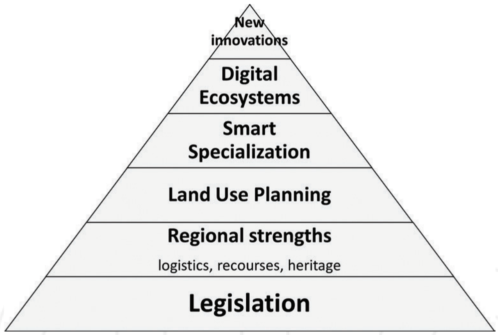

Figure 2. Factors affecting Industry 4.0 related renewal.

4.1. Legislation

Legislation is the very first level that we can see as the driver of development. At this level, we should understand that legislation should not be considered as an actor, which regulates/ limits (actions), but legislation makes new kinds of business possible and supports business development. Generally, we can understand that legislation gives "the rules of the game" and this way makes business environments more predictable with less business risks. Legislation also gives the framework for operations like recycling, land use, and new business models, but also taxation decisions might encourage new businesses. EU legislation gives the framework for legislation but still there is national legislation, which steers local business and industry.

4.2. Land use

We have industrial/logistics areas where companies are located. Usually, the industrial areas have developed and profiled themselves based on the strengths in the local region like logistic connections, population, energy, raw materials, knowhow at universities, skilled labor force, and so on. The question will be: how should we plan land use (business/logistic areas) so that companies would be able to create a fruitful business ecosystem, efficient material use (circular economy), and minimize logistic expenses. This is usually a long process and the steps are not known accurately.

4.3. Regional strengths

We have industrial/logistics areas where companies are located. Usually, the industrial areas have developed and profiled themselves based on the strengths in the local region (like logistic connections, population, energy, raw materials, knowhow at universities, and skilled labor force).

4.4. Enterprise ecosystem

There are clear indicators that short distances will improve co-operation between companies. In the case of material and economic efficiency, short distances give savings in logistic expenses.

4.5. History

Every region and business has its own history and traditions, which makes it challenging to introduce new ideas makes it more difficult to manage change.

5. Renewal of university structure and curricula to support adaptation of Industry 4.0 in the region

One important role for universities is to support enterprises by applied research and creation of research and learning environments for continuous piloting of new technologies and preparation of new business models on Industry 4.0. It is not self-evident that representatives of government, enterprise, and universities collaborate with each other. It would be beneficial to support regional development while building up competence through shared projects and development activities. Digitization provides a large variety of opportunities. The question remains are we competent enough to utilize these opportunities. A close co-operation makes it possible to build a shared vision, which guides the further development work. This is important so that all the existing and available development resources could be aligned.

Quite often, it is expected that public sector organizations take care of the development of infrastructure and business environments. However, it is possible that the public sector organizations are not aligned with each other. Some of them may represent national perspective, while some are have a more local orientation. Also, there may still be other organizations, whose duty is to develop business environment. All the layers and activities should be along the same line, support each other, and be sustainable in order to get the co-operative environment to function efficiently. In a rapidly changing operational environment, a clear and commonly understood vision is required.

Industry 4.0 and Internet of Things are new topics; and both enterprises as well as universities have a little experience on what kind of real benefits they may bring. Co-operation between private enterprises and universities has potential, but still many universities as well as companies are just taking their initial steps on this arena. Various areas of collaboration do exist both on a national as well as on an international level. User-driven innovations show lots of promise, and therefore universities should try to identify the real market or real users for the potential innovations. Companies themselves could serve as field labs. One challenge is the confidentiality of information. This should be respected while promoting co-operational learning on various aspects related to Industry 4.0. To be able to reveal the full potential of enterprise-university partnerships, the interaction should take place on all levels. Being able to help the other partner to achieve their goals is beneficial for all. Longer-term development projects require high quality and in-depth roadmaps that should be developed collaboratively. This increases trust and commitment for long-term co-operation. Concrete co-operation project could emerge on various research projects, thesis work on both undergraduate and graduate studies and so on. Different kinds of experiments and measurements related to them could be started. It is important to succeed in benefiting multidisciplinary competence and sharing information sharing openly.

The vision and approach are based on the need of regional clusters and the strengths of a region (e.g., logistic, university, natural resources, etc.). Industry 4.0 development can be seen as a smart utilization of digitization, which has European level comparability to European development in all key clusters.

Contents of education and training will be designed so that content will respond the future needs. Learning will take place in "real world" environments (field labs), which gives faster cycle time for development activities and implementation. This is the way, how to ensure the birth of new innovations and the renewing the businesses and organizations. In universities, engineering students among others should be prepared to meet the demands of Industry 4.0 in order to be able to operate in future employment domains [9]. However, Industry 4.0 should not be linked to the competence requirements of only engineering students and thus future engineers. It is probable that Industry 4.0 affects largely the whole society, and therefore all the university students should be somehow involved with various perspectives of Industry 4.0.

Most regions do not have a strategy or analysis on aligning regional development and digitization. Häme region of Finland is designing its new strategy "Smart Häme" to respond the challenges of digitization and to be the part of Digital Single Market (DSM). Based on that, the focus is to increase the know-how on how to successfully apply digitization on Häme region. After a Smart Specialization analysis, five key ecosystems (clusters) were identified. These were expected to be the most critical for the development and attractiveness of Häme region (see **Figure 3**). These are the ecosystems, which also should have special attention and resource allocation, in development: "Smart Agriculture," "Smart City," "Smart Factory," "Smart Wellbeing," and "Smart Defense." The evaluation criteria, which were used to select the ecosystems

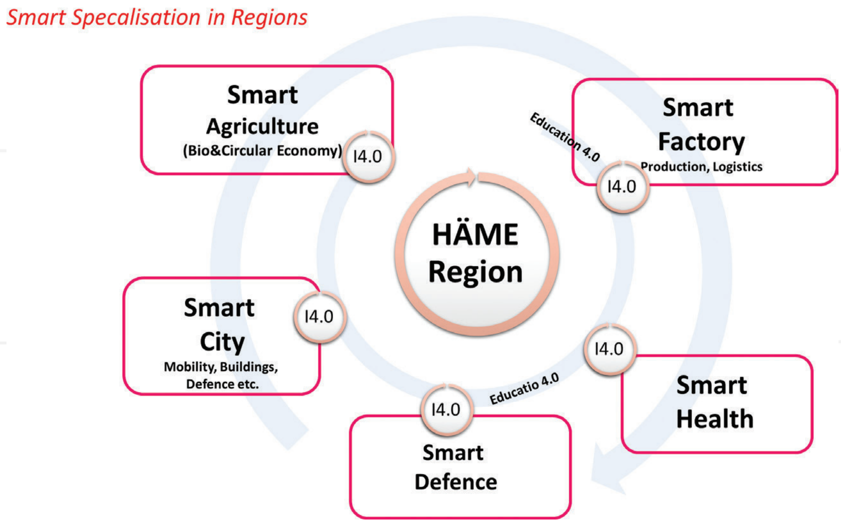

Figure 3. Häme region clusters/"Smarts."

in order to prioritize the development activities and resource allocation, were: size, know-how, importance, and versatility of the identified ecosystems.

“Smart Agriculture” was considered to be the strongest and most advanced, because of food processing industry, agribusiness, large education, and strong R&D activities in the region “Smart Agriculture” includes both BioEconomy and Circular Economy (bio) activities in the region.

“Smart Health” is the biggest expense in the cost structure of public services. Also, the amount of increasing elderly people and demand for better services emphasize a strong need to utilize the various opportunities of digital services. There are also many equipment and service providers in the region.

“Smart City” was also considered to be one of the key elements to improve the competitiveness of the region. There has been a clear understanding that digitization will change the planning of cities and the services in a city. The majority of services are probably in the densely populated urban areas in city centers. In Häme region “Smart City” includes also issues related to tourism, “Smart Mobility,” “Smart Buildings,” and “Smart Security.”

“Smart Factory” has not been traditionally linked with services at all; but when we take a closer look at manufacturing industry, we will notice that lifecycle services might even play a bigger role than the production itself. Also, modern supply chains in the manufacturing industry have a strong and large service component. Regional development point of view is important to see that manufacturing itself creates new innovations and services.

The Smarts in the region and the ecosystemic choice to develop them are based on the region’s own choices and intent. When defining the smarts, at least the following things should be taken into consideration: the strengths of the region, the competence (students and universities), the size, the intent, the development prospects, the history, the inheritance, the logistical position of skilled labor, prospects, and trends.

It is also important to understand the supporting nature of knowledge-intensive services in an increasingly digital world. This would better able the regional authorities and developers in co-operation with other actors to support the emergence of innovative ecosystems. Each smart must create its own “I4.0” renewal program, which creates a common vision, strategic steps forward and integration with the existing network organizations. **Figure 4** illustrates how the selected smarts are linked to university’s faculties (schools) and research units.

Industry 4.0 focuses on the fourth major transition phase in an industrial partnership covering all industries and areas of life. The fourth stage of the transition is digitality and the development of information technology. Industry 4.0 provides a framework for development, development of architecture, and standardization, and hence functional compatibility. The development of Smarts (clusters) is based on a multi-disciplinary know-how, therefore universities must support development work in all the sectors they are implementing academic degree programs. The following topics ought to be taken into account while renewing university’s structure and curricula.

5.1. Transdisciplinary approach

A transdisciplinary approach to research enables multidisciplinary outlook and understanding phenomena from various perspectives. This makes it possible to study complex systems and their interactions.

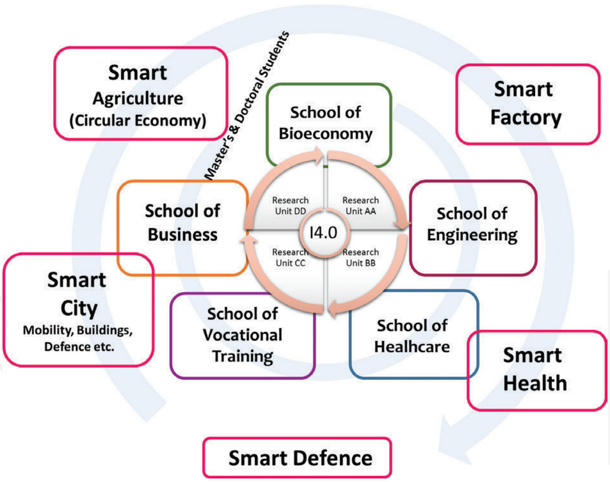

Figure 4. Integrating regional Smarts and university structure.

5.2. System design management

Digitality, multidisciplinarity, and the growing speed of change will result in increasing complexity, which is why the need for knowledge associated with managing complexity needs to be taken into account in education and development.

5.3. Smart specialization

Digitization provides the ability for data collection, rapid transfer, and processing. Various activities create new kinds of networks around them. For this reason, entities should be considered as digital ecosystems, which form efficient value chains and thus support creating new customer-focused products and services.

5.4. Field labs

The real-life learning environment is based on training, research, testing, and piloting environments. Multidisciplinary, complex, and fast changing things need "real-life" environments, where new things can be learned, adapt rapid methods for developing new products and services, and thus enable innovation to emerge.

5.5. Innovations

There are opportunities for new innovations that arise from different disciplines, customer interfaces, digital ecosystems, etc.

5.6. Organizational culture

The introduction of new approaches will also require the systematic development of a new organizational culture and a strong vision of the goals regarding the renewal.

6. Applying Industry 4.0 as a framework for increasing competitiveness in the region

Attractiveness from various perspectives is important so that region would be seen as an interesting and innovative environment. On the other hand, cities and public organizations (for example, hospitals, military bases, elderly houses, schools, parks, etc.) are using tax money for maintaining the welfare and provide services for people and organizations in the region. Based on that background, it would be justified that public organizations would be acting as "platforms" for different actors. This would allow testing their activities and products in "field labs" where education, research, and testing would take place in the same multidisciplinary environment.

We recommend that Industry 4.0 would be used as a transdisciplinary framework supporting a development of local service ecosystem. Since Industry 4.0 is a European concept and part of European platform, it is proposed that best practices will be benchmarked into European approach and experiences.

The key elements to designing the Local Service Ecosystem for Industry 4.0, are:

- "Smart development areas": to recognize the potential "smart" clusters on the region/area
- Vision: create the goal and vision for regional development based on "Smart" clusters
- "Field labs": make public sector organizations, cities, companies and universities to work together and create "real life learning" environment (field labs) in clusters.

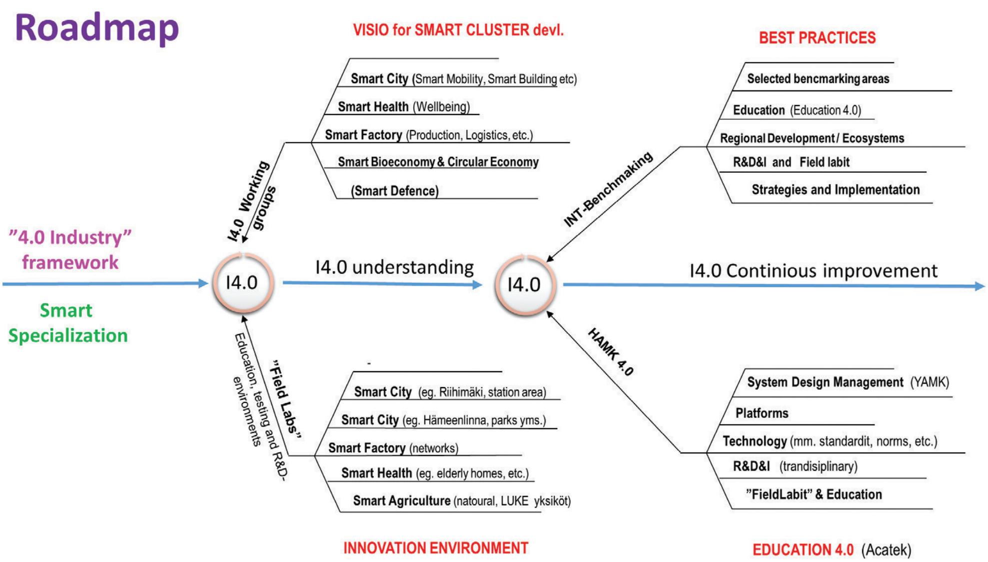

Figure 5. Steps to develop Industry 4.0 related services.

- Education: renew education content so that it response the new ICT-based technologies that are needed in Industry 4.0 and transdisciplinary approach.
- Benchmarking: make benchmarking for the regions, which are like "Häme" and have already taken the steps to adapt Industry 4.0 and to ensure compatibility.

These elements are further covered in **Figure 5**. The core idea of the figure is that Industry 4.0 framework should be understood in the existing innovation environment so that smart clusters could be established. International benchmarking could be applied to identify best practices, which could be adapted to educational programs and field labs. In order to be able to adapt Industry 4.0 framework to education so that it could be called Education 4.0 the following issues should be considered: system design management course should be introduced as a part of graduate studies. Technology platforms and implementation of transdisciplinary field labs should be introduced.

7. Discussion and conclusions

The principal idea behind this article has been to combine the principles of Industry 4.0 to value network thinking and digitization. Industry 4.0 is about creating significant impact and opportunities where business, technology, services, and innovation intersect. The aim has been to find a transdisciplinary concept supporting higher education, regional development, and business renewal in testing laboratories, while supporting and enabling new growth opportunities in the region.

That requires combining of various approaches. The main challenge is in the utilization of transdisciplinary knowledge and implementation work. The use of new technologies; including digitization and big data can capitalize on new opportunities. According to the experiences of conceptual development work, successful activity in Industry 4.0 is dependent on systematic long-term development on the public sector. The essential topic is preparing of up to date platforms, which enables, controls, and support the operations and creates a business environment to apply approaches. There are several contributing technologies related to Industry 4.0 framework. This implies that there is a major emphasis on competence development, and shared learning to apply these technologies to support transdisciplinary regional development.

The practical implications for renewing a university so that it could better support the adaptation of Industry 4.0 are as follows:

1. Higher education institutions should provide education and support for the adaptation of Industry 4.0

It is important to give a relevant role for the higher education institutions to provide and support a transdisciplinary approach to study services in a proper operating environment.

2. Research and learning environments in universities should be used to pilot new Industry 4.0 related technologies

One of the core roles for universities is to support enterprises by applied research and by creating of research and learning environments for continuous piloting of new technologies and preparation of new business models on Industry 4.0. At the same time, a local higher education institution's future areas of focus, challenges related to digitization, as well as profiling among other higher education institutions are taken into account.

3. Enterprise-university partnerships should be established

To be successful on new challenges of Industry 4.0 development, enterprise-university partnerships have to be intense and main objective should be a shared learning. Long-term co-operation creates a background for new co-innovation and co-evolution.

Adapting Industry 4.0 framework as a basis for development activities is expected to provide not only an opportunity for remarkable competitive advantage for businesses, but also for regions.

Author details

Heikki Ruohomaa, Mikko Mäntyneva* and Vesa Salminen

*Address all correspondence to: mikko.mantyneva@hamk.fi

Häme University of Applied Sciences, Hämeenlinna, Finland

References

[1] Drath R, Horch A. Industrie 4.0: Hit or hype? [Industry forum]. IEEE Industrial Electronics Magazine. 2014;**8**(2):56-58

[2] European Parliament. Directorate-General for Internal Policies. Industry 4.0. 2016. Available from: http://www.europarl.europa.eu/RegData/etudes/STUD/2016/570007/IPOL_STU(2016)570007_EN.pdf

[3] Haverkort BR, Zimmermann A. Smart industry: How ICT will change the game! IEEE Internet Computing. 2017;**21**(1):8-10

[4] Lee J, Bagheri B, Kao HA. A cyber-physical systems architecture for Industry 4.0-based manufacturing systems. Manufacturing Letters. 2015;**31**(3):18-23

[5] Deloitte. Industry 4.0 Challenges and Solutions for the Digital Transformation and Use of Exponential Technologies. 2014. Available from: https://www2.deloitte.com/content/dam/Deloitte/ch/Documents/manufacturing/ch-en-manufacturing-industry-4-0-24102014.pdf

[6] PWC. 4.0 Industry: Building the Digital Enterprise. Global Industry Survey. 2016. Available from: https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf

[7] Lasi H, Fettke P, Kemper HG, Feld T, Hoffmann M. Industry 4.0. Business and Information Systems Engineering. 2014;**6**(4):239-242

[8] European Parliament. Briefing 4.0 Industry Digitalization for Productivity and Growth. 2015. Available from: http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/568337/EPRS_BRI(2015)568337_EN.pdf

[9] Schuster K, Groß K, Vossen R, Richert A, Jeschke S. Preparing for Industry 4.0—Collaborative virtual learning environments in engineering education. In: Automation, Communication and Cybernetics in Science and Engineering 2015/2016. Cham: Springer International; 2016. pp. 417-427

INTECH

INTECH