Quality Management in Industry 4.0 Era

Nur Hanifa Mohd Zaidin, Muhammad Nurazri Md Diah, Po Hui Yee, Shahryar Sorooshian

Universiti Malaysia Pahang, Pahang, Malaysia

ABSTRACT: In this era of technology advancement and industrial modernization, the concepts introduced by the German promised a great benefits and widely unexplored opportunities for application in industries. Industry 4.0 concept is one of the heavily discussed topics for academic researcher and practitioners. In this era of consumerism, manufacturing industries are required to manufactured products and services of the highest quality in order to retain competitiveness in the consumers market. The concepts of Smart Factory, Cyber-Physical System as well as Internet of Things and Services offers very capable opportunities and also downside challenges for quality management in manufacturing sectors. Thus, this paper present and discussed the opportunities and challenges in implementation of Industry 4.0 for quality management which triggered by a practical insight of an electronic production and service company in Austria. The findings of the recent study challenges are formed by the three key characteristics of Industry 4.0 which are horizontal, vertical and end-to-end manufacturing integration.

Keywords: Industry 4.0, Opportunities, Challenges, Quality Management;

1. INTRODUCTION

Industrial productivity growth have always been dominantly influenced by the ever growing of technologies. This can be shown based on the chronological based industrial revolution that was 1st started with the usage of steam engine in production plant at the end of 1700s [1]. The 2nd industrial revolution was led by introduction of electricity machinery in mass manufacturing and labor division system at the end of 1800s[1], followed by the beginning of automation processes (powered by computers) in the late 1900s that led to the next step of industrial revolution (3rd) [1]. Now, the 4th industry revolution came into the picture even before it fully implemented [2] and many practitioners and organizations are aggressively trying to implement the revolutionary concept [3-5].

1.1 Industry 4.0

First originated as a German government's industry key strategic initiative in 2011 [1], Industry 4.0 or 4th industrial revolution has emerged as a hot topic of discussions for companies, researchers as well as the international governments [6]. Industry 4.0 is a digital transformation of the industry by assimilating Internet of Things (IoT), information integration and other high-tech developments which begins with focusing on production/manufacturing sector and expands to many sectors beyond the industry. This industry revolution have no perfect single definition for this term as there are numerous definitions for it [7]. However, based on a literature review by Herman et al., the study provide the definition of this next generation industry revolution comprises of four basic concepts that are Smart Factory, CPS, IoT and IoS [6].

Smart Factory concept is when factory adopts the Cyber-Physical Systems or CPS (combination of physical technology and cyber technology) and intensely assimilates previously independent separate systems making the automation technologies more complex and precise [8]. IoT or in full Industry 4.0 term, Industrial Internet of Things (IIoT) in general is a way of that industry uses smart electronics in their production system of a product in order to dynamically build a global or an

internal network of information [9] and is supported by Internet of services (IoS) for example cloud computing.

The goal of the 4th industry revolution is to advance the production model that is flexible in term of the products and services that are digitally produce and combining with real-time communications between all the related parties and facilities during the manufacturing process [10]. For an instance, production company that receives custom purchases or instructions through cloud services and immediately make changes in the production line in a very cost effective method to cater for the different customers need and quality requirements. This will largely effect the traditional production sales model.

1.2 Quality Management

To ensure competitiveness and economic sustainability, the manufactures or company products, services and processes quality are vital in today's industry [11]. The definition of quality is dependent on the people defining it and based on American Society of Quality, it is define as, "the totality of features and characteristics of a product or service that bears on its ability to satisfy stated implied needs." [12]. However there are different concepts of quality management that have been cited and research as mentioned by Garvin [13] and ISO [14]. For example, a clear concept of quality management are as shown in Figure 1 and not limited as there are other approaches such as Total Quality Management (TQM) [15] and Zero Defects Concepts [16].

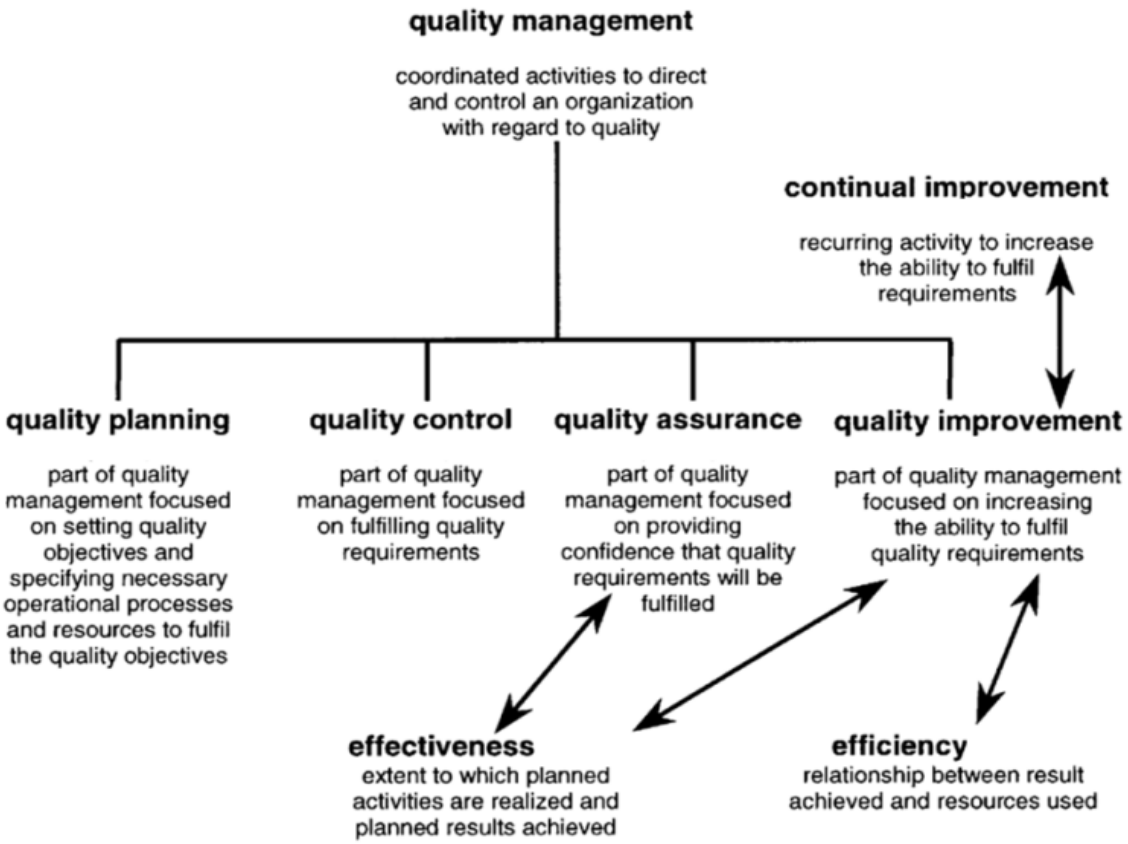

Figure 1. Quality management concepts based on ISO [14].

With the emerging of 4th industrial revolution, quality management have advances through the usage of smart electronics that are linked together in a internal or external networks of data (IIoT) that can be automatically controlled without the introduction of human intervention (IoS). This in a way impacted the quality management approaches positively and negatively [17].

1.3 Quality Management and Industry 4.0 in context of Malaysia

Astro Awani news dated 12 December 2017 reported that Malaysia Ministry of International Trade and Industry (MITI) will present the blueprint for the National Industry 4.0 policy framework by the first quarter of 2018. The draft of the National 4.0 Policy Framework is already available for viewing in online. In summary of the draft there are challenges that will be faced by Malaysia industries in adaptation of Industry 4.0 and in general will impact quality management of those industries if it is not clearly identified.

Thus, this shows that Malaysia is bound for fully adopting Industry 4.0 in direction of its nation's objectives and aspiration in realizing the rank of the fourth national industrial revolution. With the adaptation of Industry 4.0 in Malaysia, indirectly it will influence the quality management of the industry in Malaysia. With this being said and done by the nation, there are a lot of questions that will eventually come into picture once the blueprint have been fully executed and one of it is: What are the opportunities and challenges of quality management in Industry 4.0?

The aim of this paper is to describe and address where acceptable on the opportunities and challenges of quality management during and after transformation of industry 4.0 in manufacturing sectors in guiding to help fabricate or generate ideas for future research and development in Industry 4.0 for quality management. This paper is outlined as follows with Section 2 presents the opportunity and advantages of quality management in Industry 4.0 transformation from the context of production/manufacturing sectors. Section 3 presents the challenges and disadvantages of quality management in Industry 4.0 transformation from the same context of Section 2. Finally, Section 4 is the conclusion and summarization of this paper.

2. Exemplary Literature of Industry 4.0

Industry 4.0 is able to lead to more significant challenges. Widespread competition can further enhance economic growth and profitability to the industry. It just not only focuses on the new technologies, but the basics, mission, vision and policies will change the direction of the industry respectively especially in manufacturing industry. Industry 4.0 improve cost, speed and quality. It takes lot of cooperation and commitment in order to enable this planning to be achieved. Eventually, the manufacturing industry is able to earn more revenue and profit by applying Industry 4.0. Basically, if the industry can managed the challenge well, then the opportunity to propel the company's name will become higher and well known worldwide. Nowadays, the requirement of manufacturing industries must to maneuver in an extreme economical and tremendously, then, they need to continuously increase the product quality at lowest costs and within the shortest possible time in order to retain their position in the market especially satisfy what customer need [18]. For example, manufacturers need to provide one or two products to enable customers to make a choice. With emphasis on cost and quality, the customers can choose easily for the product. However, for existing products, either the quality good or bad, for the terms of delivery, it may be troublesome to customers especially the duration that may take a long time. Therefore, the key to accomplishment the expansion global market share and an indispensable requirement is to concentrate on quality management [18]. Moreover, Industry 4.0 determined change of accountability and responsiveness from the manufacturing progression to the company's product [19], and it will lead to a smart and interrelating key part of manufacturing companies especially in the information infrastructure [20]. In term of that, Industry 4.0 were designed to change all the necessary finding and it leads to

opportunities for the company to improve their production. Generally, opportunities of quality management industry 4.0 are divided into 3 things including strategy, operations and environment and people. To be highlighted, table 1 showed the exemplary literature on opportunities of quality management that is relevant with the Industry 4.0.

Table 1. Exemplary literature on opportunities of quality management Industry 4.0

Classification	Authors	Main Contribution
Strategy	- Arnold et al., 2016; - Rennung et al., 2016 - Kagermann et al., 2013; - Laudien et al., 2017; - Arnold et al., 2017;	-Innovative business representations - New assessment offers for improved effectiveness
Operations	- Rehage et al., 2013; - Saberi and Yusuff, 2011; - Erol et al., 2016; - Lee et al., 2014; - Meyer et al., 2014; - Oettmeier and Hofmann, 2017; - Kagermann et al., 2013;	- Reducing costs - Improved competency - Consignment balancing & stock reduction - Increased speed & flexibility - Higher quality
Environment And People	-Berman, 2012; - Hirsch-Kreinsen, 2014; - Kagermann et al., 2013; - Kiel et al., 2017; - Herrmann et al., 2014; - Gabriel and Pessel, 2016; - Hofmann and Oettmeier, 2017;	- Reduction of environmental effect - Age-appropriate workstations - Lessening of repetitive work

Source: Develop for this research

In the following, we clarified the three classification opportunities of quality management Industry 4.0.

2.1 Opportunities of Quality Management in Industry 4.0

2.1.1 Strategy

From a strategic perception, Industry 4.0 is a good modeling implication business model that enhanced competitiveness. By understanding the strength and the weakness of the company, it can optimized the business model output to achieve a high potential market. Research has recognizes that some of the important parts was related to the business model variations, for instance, enhanced customization, increased customer interactions, key resources that related to IT and software, data-based value design and propositions, changeover from product to system offerings, and moreover on enhancing the collaboration with share associates holder [21]. Usually, the company must also set a duration to achieve a better production at least five to ten years upward. Every system model that has been introduced by the company must be measured the transition and cost. In order to increase the transition business plan, top management and stakeholder need to with a clear based number so that it can be easily measured. By creating a better planning and satisfy the customer, the company also need to improve their profitability and productivity. To gathered data and information as well as quality management needs, the evaluation and a better decision making must be used in the organization process [20]. Particularly, all the defect product need to be check on the quality so that in order to avoid the delivery that may affected the performance with maximum efficiency of all developments of an organization [23]. Perhaps, to have a great competitive market place, the

literature reach to agreement that the business model improvement is a key foundation of unique marketing intentions and strategic diversity [24]. Beside, recent research also agreed that there are slightly positive impact especially on apparent strategic recompenses on improvement implementation [29- 31].

2.1.2 Operations

From operations perspective, operation is a part of business association that include of good and delivering products toward customer. Operation involve a unique physical equipment that was include rough resources, subassemblies, for instance, personal computers with the main motherboard, and also hand phone and automobiles. The business association must meet the perfect circumstance to make sure that it reach to accomplish a match of free market activity. By having too little means of lost opportunity and conceivable client disappointment, it may generate to facing the abundance supply or overabundance limit that has led to inefficient and exorbitant that may affected the operation performance for the company. The authorities of the administration must appoint all activities in production that they must be in charge especially on making the products. For example; when the business of the company is an automation, so the production would be the motor. For that, anything other than that are prohibited to be used. Besides, the used of smarter machine on the production can increase the product quality consequence on adjusting the production limitation [22]. Smarter machine is capable to learn, making decision, sensing, manipulating data, great mobility and also reliability to do a work. It will increase the efficiency, speed, quality and flexibility for the product. But, usually the production will also face with miscalculation in demand and stock level when there is subsequent make-to-order cost formation and accessibility of real-time data that is related with entire supply chains and the materials [29]. Meanwhile, service of good product was also in the operation perspective. Besides, there are many reason such as perishability, instantaneous creation and consumption, imperceptibility and heterogeneity when delivered a produce that is different from the service [33]. Compare to construction and manufacturing industries, there is no standard on producing tangible or intangible product as long as quality is smooth as the compatible on customer conditions, specification and necessities [34].

2.1.3 Environment and People

Industry 4.0 can trace the carbon trail release by using data-centered and also reduce the greenhouse gas emissions [35]. In order to control the pollution in the country, the resources and energy consumption must be taken carefully. Besides that, by recycle all of the waste is the preferable choice to secure the pollution. For that, the process of logistic and transport were reduces to make a better opportunities by focusing on the most famous core manufacturing in Industry 4.0. [29,36]. Stricter ecological directions, to be precise economic market share and the future of the company will be measure on how good the process quality, product and services while maintaining the operation and competitiveness around the area [37]. This will lead to a better quality management and also increase the corporate management of the company [38]. The reduction of environmental impact is a good way to make sure that the company follow the rules from the government for the pollution issue. In spite of the fact that the coherent organization improvement vivaciously underscored the specific parts of work diagram, the human relations advancement focused on the hugeness of the human segment in work design. In fact, lot of company has introduce to use automation robot to counter the manpower problem. For the long term, by using the assistance of high technology advance robot and devices, the employee will feel burned especially it can lead to ergonomically situation on work handling and also on health of the worker [39]. The trend keep continuously increase for the demand of the industrial robot because of the improvement and high quality production achieve since 2010 [40]. For that, the people especially age-appropriately were involve with the demographic challenge since the used and implementation of high advance technologies [40].

3. Challenges of Industry 4.0

3.1 Vertical Integration

The Industry 4.0 is categorized by a large volume of generated data. This is due to the new accessible data aggregates that combines from various places which was impossible long time ago. By processing and managing the large quantities of data can provide transparent and useful information which is understandable by people is an upcoming challenge [43]. For example, analyzing production data and coordinating the findings with customers' information systems. Virtual quality management (vQM) concept can be beneficial from the new information usage. Additionally, vQM can offers chances to try, test and use virtual process chains right before the real thing take place. Thus, the new data available from all interacting products and machines will provide great potential for vQM. Besides that, vertical integration allows chances to transfer control of quality and data diagnostic from the floor of the shop straight to each level of decision making or the opposite. It provides advanced backward reason and higher degree of machine condition. Plus, the products are all traceable through RFID tag which can tell any error to the next production. This can further improve quality error in management and diagnostic fault [44]. Based on the statements, questions such as below arise:

1. Is it possible for the large quantity of info and data evolving via Industry 4.0 used to build and applying ways to estimate the efficacy and efficiency of every essential operation in factory production?

2. Is it possible for the large quantity of info and data change via Industry 4.0, used to determine the intention of avoiding nonconformities and discard their source?

3. Is it possible for the large quantity of info and data evolving via Industry 4.0, used to achieve optimal resources used to achieve quality objective?

3.2 Horizontal Integration

There arise a few new business models of companies according to horizontal aspect of Industry 4.0. Customers will be able to use services to monitor and trace their parcels or order items in actual time without needed to actually know that exact progress of the parcel [41]. With this, consumers can change sudden order which can immediately be transmitted to the production team. Horizontal integration also enables customers to coordinate with the product activities at all time along the value chain. It is important to corporate with suppliers on the quality in these new rapid changing horizontal network. The smart machines are capable of searching suitable experts who can do repairing with the required comprehension platform online. It will then improve the ways of engineering straightly from a main telepresence hub [41]. Every member has certain quality and capabilities associated objective so it is challenging and tough to handle the quality across international value chains system. According to the statement, the following challenges arise:

4. Which quality related methods need to be taken so that it is consistent with actual objectives and policies of quality to control the rules, limit of which products and machines can act and decide by themselves?

5. In what way seamless virtual collaboration and integration of all roots, machines and items, in terms of CPSs can be used to improve continual improvement process?

3.3 End-to-end Engineering Integration

Industry 4.0 is unable to work on complex or not repetitive works. Although the machines offer high quality and redundancy but the technology of automation currently has been made not be able to tell the problem of complicated production. We are the only one as Human are able to work on customizable or complicated production works [45]. However, the CPS concept which enabled a digital end-to-end and modelled way which handle each edge of consumers' demands from product architecture till the finish manufacturing product. Plus, concept of vQM which retrieve quality and process parameters via modelling and simulation can be beneficial in many ways with an end-to-end combination engineering. It will then inspires the challenge such as:

"*How should engineering responsibilities and processes be arranged along an end-to-end digital integration of engineering to contribute to the quality policies and achieve quality objectives?*" [46].

3.4 Huge Investment

Industry 4.0 requires a huge investment. Automations will eventually save money of management in for long term but they will need an amount for startup investment. They have to think of a way to begin the new approach by saving some budget. That transformation will usually be the resolution and issue of CEO or similar level [42]. Nonetheless, proper action must be taken to account for the changes. Plus, the changes will need a large amount of money which might cost them a fortune probably market share too. Most stated that the uncertain economy and the huge capital required are the toughest issues [42]. Major factories have yet plan any progress for the use of Industry 4.0 in their production. The investment has yet been done too due to the new method is brand new for most factories and they need more convincing and major change. The degree of its benefits are too diverse and complex. Thorough introduction and market experiences are required along the industry for implementation of Industry 4.0.

3.5 Experience and Specialists

It also requires to be fix and employee to be trained. Current workers should be prepared to legitimately actualize, work and keep up the mechanized frameworks to guarantee their worthiness. There is still a lack of qualified and experienced specialists to implement these new systems. Abilities and training of laborers dealing with Industry 4.0 need to be improved. Labors need to obtain unique or brand new set of abilities [42]. It may increase employment rate but it will also distance up a lot of labors. The labors who are doing repetitive work may face the biggest challenge in staying in the industry. Diverse forms of education must be presented, however it does not solve the problem of older workers. It requires to educate staff to adopt 4th industrial revolution. Considerable time is needed as well as efforts across the industries.

3.6 Shrinkage in Job Markets

The shrinkage in the job markets as the machines are becoming more intelligent and starting to replace humans in high risk, dangerous tasks with more reliability. Less human supervision and the loss of high paying jobs could become a barrier for businesses to embrace industry [42].

4. SUMMARY

Not surprise for the domain of quality management has now in progress becoming corporate management indispensable and integral role for every factory as Industry 4.0 further offering significant chances for management of quality. According to that and taking quality management and ERP systems into account are actually complementary resources which both are required to gain competitiveness advantage and enhance organizational performance. The paper starts with a compact general main concepts of Smart Factory then a short briefing on the management of quality domain. The opportunities of Smart Factory are then addressed in the following context. Due to the practical

insights of specific industry, the challenges of Industry 4.0 are finally presented further grounded on DIN ISO 9000 management of quality systems which explaining the three key aspects (vertical, end-to-end and horizontal engineering integration) of Industry 4.0.

5. Contribution Note

This work was a MBA class project. The first 3 authors wrote this work; Dr Shahryar was lecturer of the course who taught and advice the topic.

6. REFERENCES

[1] H. Kagermann, W. Wahlster and J. Helbig, (2013). Recommendations for implementing the strategic initiative Industrie 4.0 - Final report of the Industrie 4.0 Working Group. *National Academy of Science and Engineering*, German.

[2] R. Drath. (2014). Industrie 4.0. Open automation, 3(14), 16-21.

[3] Working Group Industry 4.0. (n.d.). Retrieved May 10, 2018, from: https://www.bosch-si.com/solutions/manufacturing/industry-4-0/working-group.html.

[4] Plattform INDUSTRIE 4.0 (n.d.). Retrieved May 9, 2018, from http://www.plattform-i40.de/.

[5] Industrie 4.0 Collaboration Lab. Retrieved May 9, 2018, from https://www.imi.kit.edu/2449.php.

[6] M. Hermann, T. Pentek and B. Otto. (2015). Design Principles for Industrie 4.0 Scenarios: A Literature Review, Technische Universität Dortmund - Fakultät Maschinenbau, *Audi Stiftungslehrstuhl Supply Net Order Management*.

[7] A. Supe. (2017). What is your definition of Industry 4.0? Retrieved May 9, 2018, from: https://www.capgemini.com/2017/03/what-is-your-definition-of-industry-40/.

[8] B. Chen, J. Wan, L. Shu, P. Li, M. Mukherjee and B. Y. (2018). Smart Factory of Industry 4.0: Key Technologies, Application Case, and Challenges, *IEEE Access*, 6, pp.6505-6519.

[9] Y. Liao, E. d. F. R. Loures and F. Deschamps. (2018). Industrial Internet of Things: A Systematic Literature Review and Insights, *IEEE Internet of Things Journal*.

[10] K. Zhou, T. Liu and L. Zhou. (2015). Industry 4.0: Towards future industrial opportunities and challanges in Fuzzy Systems and Knowledge Discovery (FSKD), in 12th International Conference, China.

[11] M. Peris-Ortiz, J. Álvarez-García and C. Rueda-Armengot. (2015). Achieving Competitive Advantage through Quality Management, Springer, Cham.

[12] ASQ, Quality Resources. Retrieved May 10, 2018, from https://asq.org/quality-resources/quality-glossary/q.

[13] D. A. Garvin. (1984). What Does 'Product Quality' Really Mean? *MIT Sloan Management Review*, 26, pp. 25-48.

[14] ISO: Quality management systems. (2005). Fundamentals and vocabulary, (ISO 9000:2005).

[15] A. V. Feigenbaum. (1991). Total Quality Control, New York: McGraw-Hill.

[16] Z is for Zero-Defects, 1964, *Industrial Quality Control October*, pp. 182-185.

[17] H. Foidl and M. Felderer. (2016). Research Challenges of Industry 4.0 for Quality Management.

[18] Singh, M., Khan, I.A., Grover, S. (2012). Tools and Techniques for Quality Management in Manufacturing Industries. In: National Conference on Trends and Advances in Mechanical Engineering, pp. 853-859.

[19] Valdez, A.C., Brauner, P., Schaar, A.K., Holzinger, A., Ziefle, M.(2015). Reducing Complexity with Simplicity - Usability Methods for Industry 4.0. *19th Triennial Congress of the International Ergonomics Association*.

[20] Putnik, D.G., Varela, R.L., Carvalho, C., Alves, C., Shah, V., Castro, H., Ávila, P. (2015).Smart objects embedded production and quality management functions. International Journal for Quality Research 9, 151-166.

[21] Arnold, C., Kiel, D., Voigt, K. I. (2017). The Driving Role of the Industrial Internet of Things for Strategic Change: The Case of Electronic Engineering Business Models. In Proceedings of the 24th Innovation and Product Development Management Conference (IPDMC), Reykjavik, Iceland, 11–13.

[22] Singh, M., Khan, I.A., Grover, S. (2012). Tools and Techniques for Quality Management in Manufacturing Industries. In: National Conference on Trends and Advances in Mechanical Engineering, pp. 853-859.

[23] Amit, R., Zott, C. (2012). Creating value through business model innovation. MIT Sloan Manag. Rev., 53, 41–49.

[24] Mitchell, D.; Coles, C. (2003). The ultimate competitive advantage of continuing business model innovation. J. Bus. Strategy, 24, 15–21.

[25] Schneider, S., Spieth, P. (2013). Business Model Innovation: Towards an Integrated Future Research Agenda. Int. J. Innov. Manag, 17, 1340001.

[26] Teece, D. J. (2010). Business models, business strategy and innovation. Long Range Plan. 43, 172–194.

[27] Voigt, K.-I., Buliga, O., Michl, K. (2017). Business Model Pioneers—How Innovators Successfully Implement New Business Models; Springer: Cham, Switzerland, ISBN 978-3-319-38845-8.

[28] Oettmeier, K., Hofmann, E. (2017). Additive manufacturing technology adoption: An empirical analysis of general and supply chain-related determinants. J. Bus. Econ. 87, 97–124.

[29] Au, A.K.M., Enderwick, P. (2000). A cognitive model on attitude towards technology adoption. J. Manag. Psychol. 15, 266–282.

[30] Bierma, T., Waterstraat, F. (2001). Overcoming Barriers to Pollution Prevention in Small Businesses, Waste Management and Research Center Reports RR-E075; Illinois Department of Natural Resources: Champaign, IL, USA.

[31] Lee, J., Kao, H.-A., Yang, S. (2014). Service innovation and smart analytics for Industry 4.0 and big data environment. Procedia CIRP 16, 3-8.

[32] Zeithaml, V.A. and Bitner, M.J. (1996). Services Marketing, McGraw-Hill Companies, Inc.

[33] Morris, B. and Johnston, R. (1987). Dealing with inherent variability: the differences between manufacturing and services. International Journal of Operations & Production ManagemenT. 7 (4): 13-23.

[34] Peukert, B., Benecke, S., Clavell, J., Neugebauer, S., Nissen, N.F., Uhlmann, E., Lang, K.-D., Finkbeiner, M. (2015). Addressing Sustainability and Flexibility in Manufacturing via Smart Modular Machine Tool Frames to Support Sustainable Value Creation. Procedia CIRP, 29, 514–519.

[35] Gabriel, M.; Pessel, E. (2016). Industry 4.0 and sustainability impacts: Critical discussion of sustainability aspects with a special focus on future of work and ecological consequences. Int. J. Eng. 1, 131–136.

[36] Singh, M., Khan, I.A., Grover, S. (2012). Tools and Techniques for Quality Management in Manufacturing Industries. In: National Conference on Trends and Advances in Mechanical Engineering, pp. 853-859.

[37] Brüggemann, H., Bremer, P. (2012). Grundlagen Qualitäts management. Springer Vieweg, Wiesbaden.

[38] Hirsch-Kreinsen, H. (2014). Smart production systems. A new type of industrial process innovation. In Proceedings of the 2014 DRUID Society Conference, Copenhagen, Denmark.

[39] Executive Summary World Robotics. (2017). Industrial Robots.

[40] Kagermann, H., Wahlster, W., Helbig, J. (2013). Recommendations for Implementing the Strategic Initiative Industrie 4.0—Final Report of the Industrie 4.0 Working Group; Acatech—National Academy of Science and Engineering: Frankfurt am Main, Germany.

[41] Martin. (2017). Industry 4.0. Definition, Design, Principles, Challenges and the Future of Employment. Retrieved May 17, 2018, from https://www.cleverism.com/industry-4-0/

[42] AMMC. (2016, Jan 6). Advantage and Disadvantage of automating for the industrial industry 4.0. Retrieved May 17, 2018, from http://ammc.com/advantages-and-disadvantages-of-automating-for-the-industrial-industry/

[43] Mayer, F., Pantförder, D. (2014). Unterstützung des Menschen in Cyber-Physical-Production-Systems. In: Bauernhansl, T., ten Hompel, M., Vogel-Heuser, B. (eds.) Industrie 4.0 in Produktion, Automatisierung und Logistik, pp. 481-491. Springer Vieweg, Wiesbaden.

[44] Colledani, M., Tolio, T., Fischer, A., Iung, B., Lanza, G., Schmitt, R., Váncza, J. (2014). Design and management of manufacturing systems for production quality. CIRP Annals - Manufacturing Technology 63, 773-796.

[45] Kagermann, H., Wahlster, W., Helbig, J. (2013). Recommendations for implementing the strategic initiative INDUSTRIE 4.0 - Final report of the Industrie 4.0 Working Group.

[46] Bodi, S., Popescu, S., Drageanu, C., Popescu, D. (n.d.) Virtual Quality Management elements in optimized new product development using genetic alogorithms. Joint International Conference: Managing Intellectual Capital and Innovation for Sustainable and Inclusive Society - Management, Knowledge and Learning.

*****