Management aspects of smart manufacturing[1]

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ABSTRACT

In the world of future production systems, companies become increasingly interested in the application of new technologies in order to ensure long-term competitiveness and adapt to dynamically changing environmental conditions such as shortening product lifecycles, increasing diversity of variants and ever-changing customer expectations. However, smart manufacturing poses significant challenges to the manufacturing companies not only from the technological but also from the organizational and management point of view. This paper through qualitative research aims to explore what are the driving forces for introducing new technologies and which are the main barriers of smart manufacturing. Besides production factors, the authors found that management's aspiration to increase control and to enable real-time performance can be significant driving forces to smart manufacturing. Furthermore, organizational resistance - and its inadequate management - which should be emphasized not only at the employee but also at the middle management level can significantly hinder the introduction of technologies related to smart manufacturing. Finally, the authors found that the application of new digital technologies results in the transformation of management functions.

Keywords: Digital strategy, barriers, management functions, lean, qualitative, supply chain

1. INTRODUCTION

Smart manufacturing sets a number of challenges for manufacturing companies not only from the technological but also from the organizational and management point of view. With the application of new technologies and the transformation of processes, significant changes are expected in the field of work and future production systems demand new competencies from employees (Gehrke et al., 2015; Erol et al., 2016; Hecklau et al., 2016). In order to ensure long-term competitiveness and adapt to dynamically changing environmental conditions - such as shortening product lifecycles, increasing diversity of variants and ever-changing customer expectations -, companies become increasingly interested in the application of new technologies. However, in spite of increasing pressure, a number of hindering factors of smart manufacturing can be identified and researches about the topic are still in early stages.

In the light of these circumstances, our research aims to explore what are the driving forces for introducing new, digital technologies and which are the main barriers and challenges of smart manufacturing. By answering the questions presented, we aim to give a wider picture of smart manufacturing and provide useful insights for corporate managers thereby enriching the literature background about smart manufacturing. In order to answer these questions, a qualitative exploratory research was conducted among top executives of companies operating in Hungary. The companies under investigation operate in different industry sectors, and suppliers, users or suppliers and users (dual role) of smart manufacturing technologies.

2. SMART MANUFACTURING

Smart manufacturing, through the use of cyber-physical systems, refers to the increasing digitization of the entire supply chain which makes it possible to connect the actors, objects and systems based on real-time data exchange (Spath *et al.*, 2013; Dorst *et al.*, 2015). As a result of this interconnection, products, machines and processes with artificial intelligence will be able to adapt to the spontaneously changing environmental factors (Hecklau *et al.*, 2016). Posada *et al.* (2015) and Roblek, Mesko and Krapez (2016) defined the five key elements of smart manufacturing as follows: (1) digitization, optimization and customization of production; (2) automation and adaptation; (3) human-machine interaction; (4) value-added services and stores, and (5) automatic data exchange and communication. According to Zezulka *et al.* (2016), the term of smart manufacturing is used for three mutually interconnected factors: (1) digitization and integration of networks, (2) digitization of products and services, (3) new market models.

Schuh *et al.* (2014) defined the following definition regarding smart manufacturing: *"The integration of information and*

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communication technology into the industrial environment". According to Thramboulidis (2015) by the application of connected and embedded systems with software solutions, it is possible to control and monitor the production through the processing and analysis of information extracted from the production process. Therefore, smart manufacturing technologies largely support decision-making and thus significantly contribute to increasing productivity (Saucedo-Martínez *et al.*, 2017).

Driving forces of smart manufacturing: In addition to the conceptual presentation, the discussion of factors that may encourage companies to move towards smart manufacturing becomes necessary. As a result of the growing competition, it is essential for organizations to increase their innovation capacity, productivity and to reduce time-to-market (Lasi et al., 2014; Bauer et al., 2015). Next to the ever-diminishing product life cycles, constantly changing customer expectations and markets becoming more and more heterogeneous over time requiring changes from manufacturers regarding production systems (Spath et al., 2013; Adolph, Tisch and Metternich, 2014; BMBF, 2014; Karre et al., 2017). By improving productivity the quality of manufacturing can be significantly increased and wastage can be reduced (Paritala, Manchikatla and Yarlagadda, 2016). As a result, companies can enhance their sales volumes and achieve significant cost savings potential (Kiel et al., 2017). In addition to the increased productivity, by collecting and processing production data from the field, many other benefits can be realized e.g. faster decision making and support for knowledge management (Cimini et al., 2017; Inezari and Gressel, 2017; Uden and He, 2017). Accordingly, smart manufacturing can be defined as the basic pillar of the future competitiveness of manufacturing companies, but firms have to face many challenges in the world of future production systems.

Barriers of smart manufacturing: Adolph, Tisch and Metternich (2014), Erol *et al.* (2016), Shamim *et al.* (2016), Karre *et al.* (2017), and Müller and Voigt (2017) and Kiel *et al.* (2017) all agreed that one of the major challenges is the lack of skilled workforce and the retraining of staff in accordance with the changed circumstances. According to the PwC's report (2014), Erol *et al.* (2016), Müller and Voigt (2016) and Kiel *et al.* (2017) the lack of financial resources which are required for the implementation of new technologies also generates a significant obstacle. Müller and Voigt (2016) found that low degrees of standardization, a lacking understanding of integration and concerns regarding data security can also be considered as hindering factors in addition to the listed obstacles. This fact was also supported by the McKinsey&Company's (2016), Cimini's *et al.* (2017) and Kiel's *et al.* (2017) researches, who emphasized concerns about cybersecurity and data ownership issues, and also by Weber and Studer (2016) who discussed the legal issues of cybersecurity. Furthermore, Kiel *et al.* (2017) have found that the most potent inhibitory factor is the need for technological integration. In addition to technological integration, the reliability and stability of the systems must be ensured, which is a critical factor in machine-to-machine communication (Sung, 2017).

Based on the research of McKinsey&Company (2016) the intensive communication required by smart manufacturing projects and thus the introduction of new technologies can be significantly impeded by the difficulty of coordination between the various organizational units. According to the PwC (2014), business cases and feasibility studies that clearly support the need for investing in data and system architecture required for the introduction of smart manufacturing applications, have not yet been developed in many companies, thereby also forming a significant barrier.

Additionally, it is essential to emphasize the role of the organizational culture, which is usually not identified despite of the fact that the management of organizational resistance and the cultural acceptance of innovations will become a priority task during smart manufacturing projects (Automation Alley, 2017; Kiel *et al.*, 2017; Leipzig *et al.*, 2017; Vey *et al.*, 2017).

3. RESEARCH METHODOLOGY

In order to answer our research questions, we conducted semi-structured interviews with top executives of companies operating in Hungary. During the design of the research sample, we aimed to investigate both domestic-owned and foreign-owned companies. The companies investigated were also different in terms of their industry sector. It was also important to classify the companies surveyed according to their role in smart manufacturing. In line with this, we defined three roles:

- **Provider:** manufacturers of smart manufacturing technologies
- **User:** users of smart manufacturing technologies,
- **Provider and user:** companies that both manufacture and use smart manufacturing technologies.

Furthermore, we first sought out companies that are members of the Hungarian Industry 4.0 National Technology Platform. We conducted interviews with eleven companies who are members of the platform and with three companies who are not members. Altogether, we conducted interviews with top executives of 14 companies. The interviews lasted between 60 and 240 minutes.

Our interview guide was developed based on the review of the related literature, which served as a kind of navigation tool during the research. In addition, in line with Agee (2009), the interview guide has also allowed us to explore completely new, unexpected areas and thereby to discover new aspects of smart manufacturing. The interview consisted of two main areas. In the first part we examined general questions such as the company's activities, history, the interviewee's position, experience and the company's way towards smart manufacturing. In the second part we examined the driving forces, challenges as well as other organizational and management aspects of smart manufacturing. In addition, we did not set up hypotheses about the interviews nor inserted pre-defined answers into the interview questions, in order to avoid processing errors and bias (Solt, 1998). Based on Patton's (2002) and Golafshani's (2003) guidelines, in order to increase the reliability and validity of our research, we used triangulation and checked the companies' websites and annual reports. Moreover, the interviewees were assured of anonymity and confidentiality, thereby also reducing bias and increasing the reliability of the results.

After the interviews, we coded the answers based on the following structure:

- Driving forces of smart manufacturing
- Challenges and barriers of smart manufacturing
- Organizational and management aspects of smart manufacturing including management tools and best practices, goal setting and planning, organizational structure and processes, direct management and encouragement, verification and measurement;

- Necessary skills and competences including employee and top management level.

4. RESULTS

Driving forces and barriers of smart manufacturing: Based on the interviews, we have identified several factors along which motivational and inhibitory factors of smart manufacturing haven been grouped.

The first group is human resources. Representatives of the surveyed companies have highlighted the increasing labour shortages as one of the main drivers of digital transformation. Furthermore, by using smart manufacturing technologies, many companies aim to allocate their employees to the tasks that generate higher added value.With regard to the barrier side of human factors, a major challenge can be, that companies do not currently have skilled workforce who possess those competences that will become indispensable in the world of future production systems. In addition, retraining of employees can take a long time, thereby increasing costs.

The next group is financial resources and profitability. On the one hand, increasing digitization of production processes can provide a number of financial benefits such as the significant reduction of costs, including among others human resources, inventory management and operating costs. On the other hand, since the introduction of new technologies requires the possession of significant amount of financial resources, their lack may also hinder a large number of companies. Many companies are concerned about profitability and return issues. Limited access to financial resources (e.g. through tenders) also constitutes an obstacle. Based on the expert interviews, the availability of financial resources may be hampered, among others, by the existence of shortcomings in tendering systems. This regulatory gap also results in a too long evaluation period of related tenders.

Intense market competition and pressure from competitors can be identified as additional factors on the side of driving forces. Companies can increase their market share and competitive advantage through innovative developments based on smart manufacturing technologies. Additionally, in the case of providers who mainly deliver to foreign markets with more developed economies, digitization can be identified as a condition for staying on the market.

Furthermore, expectations from the management can also encourage the introduction of smart manufacturing technologies. The top management of the company wants to increase control by using digital technologies. Additionally, their goal is to realize continuous, real-time performance measurement. Analysing the other side of market conditions and management expectations, it becomes necessary to discuss management reality as a barrier. In parallel with the increasing digitization of production processes, there is a need for a leader within the company who has the necessary skills, experience and can properly control smart manufacturing projects. The lack of such a leader, based on the interviewees' opinion, is mainly a challenge for smaller businesses. Finally, during the introduction of smart manufacturing technologies, proper planning is necessary already at the beginning of the projects, in which the objectives to be attained, as well as the steps and resources necessary to achieve them, are defined and broken by time periods. Consequently, these projects cannot succeed without conscious planning.

Another important aspect is productivity and efficiency which involves several factors. First of all, a meaningful element is the effort to reduce error and scratch ratio. Reduction of lead times and thereby to increase production efficiency has also a prominent role. Overall, by implementing all of these factors a much more reliable operation can be achieved.

By improving productivity and enhancing quality, companies also aim to increase customer satisfaction. High quality is defined by the interviewees as a basic condition for participating in market competition. Additionally, by increasing flexibility, companies will be able to respond to unique customer needs more quickly.

However, besides efforts to increase productivity, companies need to account for various organizational barriers. The success of introducing smart manufacturing technologies can be determined in a significant way by organizational processes and structure. If corporate processes are not properly optimized and the structure is not flexible, does not support fast flow of information, the introduction of new technologies is expected to fail.

Organizational resistance - and its inadequate management - can also be a major obstacle for companies. Additionally, organizational resistance can not only be attributed to employees but also to middle management. On the one hand, employees may be frightened of losing their jobs in parallel with the increasing digitization and may afraid of not having the appropriate skills to handle new technologies. On the other hand, over time, the scope of activities of middle managers will be completely transformed and instead of their current role, they will need to carry out highly qualified expert tasks.

Both during the pursuit of increasing productivity and responding to customer demand, technological, process integration and cooperation inhibiting factors need to be considered. For smart manufacturing technologies, system integration becomes necessary not just within the company, but also at an inter-firm level. In order to ensure technological integration across the entire supply chain, the development a unified communication protocol is required. Additionally, it is also indispensable to develop back-end systems with business intelligence that support the processing of large amounts of data generated during production processes. The integration of smart manufacturing technologies across the supply chain can also be hampered by the lack of willingness to cooperate and the lack of standards. Lack of standards not only refers to the need for technology standards, but also the need for process standardization. In addition, during the introduction of new technologies developing a common way of thinking at all levels of the company becomes indispensable. Moreover, in order to ensure data security, companies need to build secure data storage systems. Due to the increasing amount of data, the extension of the storage capacity of data storage systems is also needed.

5. SUMMARY AND DISCUSSION

In our research, we examined the driving forces of introducing new, digital technologies and the main obstacles of smart manufacturing.

During the research of the driving forces of smart manufacturing, management expectations as an important aspect has been explored which is usually not presented in the related literature. Accordingly, it has become apparent that besides production

factors, managements' aspiration to increase control and to enable real-time performance can be a significant driving force for introducing smart manufacturing technologies. By applying digital technologies, management can receive strong support in decision making as well as in employee and company performance appraisal.

Furthermore, based on the reviewed literature and our research results, it can be seen that smart manufacturing presents a number of challenges for companies. As with any change, during the introduction of new digital technologies, organizational resistance can be expected. However, it is important to emphasize that among all the inhibitory factors, organizational resistance can be the most powerful barrier which if not properly handled, can significantly impede the successful introduction of new technologies. Based on our research, organizational resistance may come from employees who are afraid of losing their jobs over time or do not have the necessary skills for new technologies. Additionally, resistance is also expected from the middle management layer. Loss of employees disrupts the social environment within the company and as the organization becomes more flat, the importance of middle managers as leaders will cease and instead of managing people they must have expert work requiring high qualifications.

Among the emerging barriers and challenges of smart manufacturing, standardization and management and leadership aspects should also be emphasized. The introduction of new digital technologies requires not only technological standards, but also process optimization and standardization. Furthermore, the presence of open-minded, creative leaders who think not only at the organisation level, but at the whole network level during the developments, will be needed within the company.

Besides to technological and organizational changes, management functions will also be significantly transformed. *Objective setting and strategy creation* will require even more steps and much more iteration in the future. In this context, agile approach within the organization is inevitable as well as a more frequent revision of objectives and strategy. In the case of *organizational function*, the proper design of structures and processes will become even more important in the rapidly changing environment of smart manufacturing. Continuous rethinking of the structure and processes becomes necessary and besides to solving individual problems, principally system-level interventions are needed for smooth operation. The third feature is *personal leadership*, which will also significantly transform in the world of future production systems. Social support will be even more important for employees remaining in the company and organizations must take care of the social security of their staff. In the case of *control* as a management function, traceability will be much better in the future and it will be possible to track performance by employees in real time. Consequently, thanks to the up-to-date information, employees will become more accountable. In addition to accountability, individual responsibility will increase, and the cost of measurement will be significantly reduced for well-definable activities.

One of the main limitations of our research is that we primarily targeted companies that are members of the Hungarian Industry 4.0 National Technology Platform. As a result, these companies are likely to be more open and more advanced in smart manufacturing. In order to find further obstacles, it would be worth examining companies that are not members of the platform and consequently are less experienced in smart manufacturing. In addition, in our research we examined 14 companies, so a larger sample can also help detect additional factors.

Nowadays the examination of organizational and management aspects of smart manufacturing is still in early stage. As a new area, the volume of available literature is limited, which opens several research questions. As a future direction, researches should be conducted that reveal additional management aspects and best practices supporting companies in smart manufacturing projects. It is also worthwhile to extend the geographical focus during the smart manufacturing researches, in order to compare the similarities and differences in the different regions.

6. REFERENCES

[1] Adolph, S., Tisch, M. and Metternich, J. (2014) 'Challenges and approaches to competency development for future production', **Educational Alternatives**, 12, pp. 1001–1010.

[2] Agee, J. (2009) 'Developing qualitative research questions: a reflective process', **International Journal of Qualitative Studies in Education**, 22(4), pp. 431–447. doi: 10.1080/09518390902736512.

[3] Automation Alley (2017) **Technology Industry Report. Industry 4.0 is here. Are we ready?**

[4] Bauer, W. *et al.* (2015) 'Transforming to a hyper-connected society and economy – towards an "Industry 4.0"', **Procedia Manufacturing**. Elsevier B.V., 3, pp. 417–424. doi: 10.1016/j.promfg.2015.07.200.

[5] BMBF (2014) **Die neue Hightech-Strategie - Innovationen für Deutschland**. Berlin.

[6] Cimini, C. *et al.* (2017) 'The transition towards Industry 4.0: business opportunities and expected impacts for suppliers and manufacturers', in **Advances in Production Management Systems. The Path to Intelligent, Collaborative and Sustainable Manufacturing. APMS 2017. IFIP Advances in Information and Communication Technology**. Springer, Cham, pp. 119–126.

[7] Dorst, W. *et al.* (2015) **Umsetzungsstrategie Industrie 4.0. Ergebnisbericht der Plattform Industrie 4.0.**

[8] Erol, S. *et al.* (2016) 'Tangible Industry 4.0: a scenario-based approach to learning for the future of production', **Procedia CIRP**. Elsevier B.V., 54, pp. 13–18. doi: 10.1016/j.procir.2016.03.162.

[9] Gehrke, L. *et al.* (2015) **Industry 4.0. A discussion of qualifications and skills in the factory of the future: A German and American perspective.**

[10] Golafshani, N. (2003) 'Understanding Reliability and Validity in Qualitative Research', **The Qualitative Report,** 8(4), pp. 597–606.

[11] Hecklau, F. *et al.* (2016) 'Holistic Approach for Human Resource Management in Industry 4.0', **Procedia CIRP**. The Author(s), 54, pp. 1–6. doi: 10.1016/j.procir.2016.05.102.

[12] Inezari, A. and Gressel, S. (2017) 'Information and reformation in KM systems: big data and strategic decision-making', **Journal of Knowledge Management,** 21(1), pp. 71–91.

[13] Karre, H. *et al.* (2017) 'Transition towards an Industry 4.0 state of the LeanLab at Graz University of Technology', **Procedia Manufacturing**. The Author(s), (9), pp. 206–213. doi:

10.1016/j.promfg.2017.04.006.
[14] Kiel, D. *et al.* (2017) 'Sustainable Industrial Value Creation: Benefits and Challenges of Industry 4.0', in **International Society for Professional Innovation Management (ISPIM***)*. Vienna, pp. 1–21.
[15] Lasi, H. *et al.* (2014) 'Industry 4.0', **Business & Information Systems Engineering**, (4), pp. 239–242. doi: 10.1007/s12599-014-0334-4.
[16] Leipzig, T. Von *et al.* (2017) 'Initialising customer-orientated digital transformation in enterprises', **Procedia Manufacturing**. Elsevier B.V., 8, pp. 517–524. doi: 10.1016/j.promfg.2017.02.066.
[17] McKinsey&Company (2016) **Industry 4.0 after the initial hype: Where manufacturers are finding value and how they can best capture it.**
[18] Müller, J. and Voigt, K.-I. (2016) 'Industrie 4.0 für kleine und mittlere Unternehmen', **ProductivITy Management**, (3), pp. 28–30.
[19] Müller, J. and Voigt, K.-I. (2017) 'Industry 4.0 - Integration strategies for SMEs', in **International Association for Management of Technology, IAMOT 2017 Conference Proceedings**. Vienna.
[20] Paritala, P. K., Manchikatla, S. and Yarlagadda, P. K. (2016) 'Digital Manufacturing- Applications Past, Current, and Future Trends', **Procedia Engineering,** 174, pp. 982–991.
[21] Patton, M. Q. (2002) **Qualitative evaluation and research methods.** 3rd edn. Thousand Oaks, CA: SAGE Publications.
[22] Posada, J. *et al.* (2015) 'Visual computing as a key enabling technology for Industrie 4.0 and industrial internet', **IEE Computer Graphics and Applications**, 35(2), pp. 26–40.
[23] PwC (2014) *Industry 4.0* - **Opportunities and Challenges of the Industrial Internet.**
[24] Roblek, V., Mesko, M. and Krapez, A. (2016) 'A complex view of Industry 4.0', **SAGE Open**, 6(2).
[25] Saucedo-Martínez, J. A. *et al.* (2017) 'Industry 4.0 framework for management and operations: a review', **Journal of Ambient Intelligence and Humanized Computing.** Springer Berlin Heidelberg, pp. 1–13. doi: 10.1007/s12652-017-0533-1.
[26] Schuh, G. *et al.* (2014) 'Collaboration Mechanisms to increase Productivity in the Context of Industrie 4.0', **Procedia CIRP**. Elsevier B.V., 19, pp. 51–56. doi: 10.1016/j.procir.2014.05.016.
[27] Shamim, S. *et al.* (2016) **Management Approaches for Industry 4.0: A human resource management perspective**.
[28] Solt, O. (1998) '**Interjúzni muszáj**', in Solt, O. (ed.) *Méltóságot mindenkinek, Összegyűjtött írások I-II.* Budapest: Beszélő Szerkesztőség, p. 29–48.
[29] Spath, D. *et al.* (2013) *Produktionsarbeit der Zukunft - Industrie 4.0*. Stuttgart.
[30] Sung, T. K. (2017) 'Industry 4.0: A Korea perspective', **Technological Forecasting & Social Change**. doi: http://dx.doi.org/10.1016/j.techfore.2017.11.005.
[31] Thramboulidis, K. (2015) 'A cyber–physical system-based approach for industrial automation systems', **Computers in Industry**, 72, pp. 92–102.
[32] Uden, L. and He, W. (2017) 'How the Internet of Things can help knowledge management: a case study from the automotive domain', **Journal of Knowledge Management**, 21(1), p. 57–70.
[33] Vey, K. *et al.* (2017) 'Learning & Development in Times of Digital Transformation: Facilitating a Culture of Change and Innovation', **International Journal of Advanced Corporate Learning**, 10(1).
[34] Weber, R. H. and Studer, E. (2016) 'Cybersecurity in the Internet of Things: Legal aspects', **Computer Law & Security Review**. Elsevier Ltd, 32(5), pp. 715–728. doi: 10.1016/j.clsr.2016.07.002.
[35] Zezulka, F. *et al.* (2016) 'Industry 4.0 – An Introduction in the phenomenon', **IFAC-PapersOnLine**, 49(25), pp. 8–12.