The Relevance of Humans and Structure: Managerial and Organizational Challenges in Smart Factories

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Abstract. Rapid technological change that permeates all areas of life characterizes the Industry 4.0. This forces companies to develop digital strategies and transform their businesses into the so-called "smart factory". However, many managers still understand digitalization as simply automation of production processes and therefore disregard the complexity and challenges it brings for their companies. This paper identifies managerial and organizational challenges from two dimensions: human and structural. From the human dimension, organizations must offer intelligent training concepts, as future employees will increasingly collaborate with machines and therefore need a holistic view of production facilities and comprehensive knowledge. From the structural perspective, organizations need to decentralize the classic management task and create the environment for self-organizations, so that the company is more agile and can quickly respond to changes within the digital era.

Keywords: Digitalization, Industry 4.0, Smart Factory, Organizational challenges

1 Introduction

The convergence of industrial production and information and communication technologies, called Industry 4.0, is currently one of the most frequently discussed topics among practitioners and academics [1]. It originated in 2011 as an approach to strengthening the competitiveness of the German manufacturing industry [2]. Promoters of this idea expect Industry 4.0 to deliver "fundamental improvements to the industrial processes involved in manufacturing, engineering, material usage and supply chain and life cycle management" [2]. Enabled through the communication between people, machines, and resources, Industry 4.0 is characterized by a paradigm shift from centrally controlled to decentralized production processes. A key element in Industry 4.0 is the so-called smart factory, also termed digital or intelligent factory [3]. A smart factory is a digitized factory that is equipped more efficiently and flexibly through the networking of the components involved in value creation [4]. The goal is a production environment that organizes itself by being completely digitally networked. All sub-areas of a factory are included, from the manufacturing systems to the logistics systems. The basis for the smart factory are cyber-physical systems (CPS) and the Internet-of-Things (IoT). CPS and IoT establish the connection between real (physical) and virtual (cyber) elements via networks and information technology [5]. This link enables machines and products as well as entire warehouses and production facilities to communicate with each other. In the ideal smart factory, people no longer have to intervene in the actual production process, but merely monitor the processes.

Even though a smart factory represents “a future state of a fully connected manufacturing system”, it is no longer a vision, as multiple cases show [4]. The German automobile manufacturer Audi has introduced the modular assembly concept to replace the traditional rigid assembly line. It is based on small, separate workstations between which driverless transportation systems move the vehicles and the components [6]. Besides, the electronics producer Siemens has established a smart factory in Amberg. In this plant, products can communicate with production machines. Product codes tell production machines what requirements they have and which production steps must be taken next. Furthermore, products and machines determine which items on which production lines should be completed when to meet delivery deadlines [7]. The advantages of a smart factory compared to a conventional factory are individualized production processes and greater flexibility [8]. However, while new technologies automate production processes increasingly, it can be observed that managers have not yet recognized that smart factories go much further than "automation". This can be seen from statements such as "We have been represented on the internet for many years and have achieved a high degree of automation in our business processes through consistent use of IT" [9]. As correct and important as such statements may be, they do not reflect a central aspect of smart factories, namely the fact that their technological possibilities enable completely new business models that go far beyond automation and optimization of business processes [10]. The rapid technological change of digitalization permeates all areas of life and consequently forces companies to comprehensive transformation processes. That means new management concepts may be needed – towards the agility of an organization that uses new methods and promotes self-organization within Industry 4.0.

This conceptual paper studies the managerial and organizational challenges in smart factories. The objective is to identify the challenges that companies face when they aim to transform their manufacturing to smart factories through reviewing academic articles searched from Business Source Complete (EBSCO), ScienceDirect (Elsevier), Scopus and Google Scholar with a publishing period between 2009 and 2019. Apart from journal articles, we also included some conference papers, books, consulting reports and websites related to industry 4.0” and “smart factories”. Review of the prior literature provides a focused assessment of the current state of the art as regards to our research question: *What type of managerial and organizational challenges emerge when traditional factories are transformed to smart factories?* We address the challenges related to transforming manufacturing companies to smart factories from two perspectives: human and structural. From a human perspective, we shed light on the role of people and their relevance in a smart factory. From a structural perspective, we provide insights how the organization should be designed and structured to meet the requirements of digitalization.

2 Smart Factories

A smart factory is characterized by a socio-technical interaction of all in the production participating actors and resources. At the centre are sensor-based and spatial distributed production resources (e.g. production machines, robots, storage systems, operating resources) that are networked, self-directed and self-configuring [2]. Consistent engineering of both the production and the product being manufactured allows the digital and physical world to mesh seamlessly. The basis for a smart factory are cyber-physical systems (CPS). These systems detect physical data by means of sensors and act by means of actuators on physical processes, store data, evaluate it and interact with the physical and digital world. Furthermore, they have human-machine interfaces and thus provide communication and control options. Over the Internet of Things (IoT), CPS communicate and cooperate with each other and humans in real time [11]. The CPS makes it possible for the first time to handle and manage the complexity arising from this interconnectedness [12]. Due to the networking ability of CPS, they are sometimes referred to as socio-cyber-physical systems [13]. Another important feature of CPS is that they have their own intelligence and, based on real-time data, they can make independent decisions about how the further process steps - for example in the production of a product - should proceed [12]. This intelligence is made possible by so-called embedded systems. These are embedded in the CPS and consist of hardware and software components for the realization of system-specific functional features [14]. Through this interconnectedness, the digital and the real-world merge to form the smart factories.

The fully developed smart factory will create a completely new production logic. In a smart factory, the products know their production history, their current and target state, and actively steer themselves through the production process by instructing machines to perform the required manufacturing tasks and ordering conveyors for transportation to the next production stage [15]. All sensors and actuators in the smart factory provide their data as semantically described services that can be specifically requested by the resulting products. Semantic machine-to-machine communication with active digital production memories makes the product an information carrier, an observer and an actor [16]. Characteristic of this view of the factory is that the systems of the factory are no longer centrally managed but decentralized in cloud-based systems that connect to the described CPS. This also defuses the question of highly integrated systems, since integration is replaced by communication. Furthermore, licensing costs are eliminated and replaced by pay-per-use models. Everything becomes a service, and everything is only paid for when it's used, and the customization costs for software will go down accordingly, as more granularity based on those apps will allow more flexible user customization [17]. Thus, the customer is actively involved in the value-added chain in order to carry out the desired requirements or requested services himself. To run a smart factory, you need smart products as well as smart services. Smart products know all of their properties, which are required, for example, to manufacture a product or how they need to be assembled together with the required product components [16].

Information about the product, its production parameters or the necessary configurations of plants are in the right place at the right time and can be further processed digitally. In addition, the product history such as the continuous process steps or the actually manufactured features are stored directly on the product. In order to generate smart services, it is necessary to evaluate the digital data from the smart products. This will be achieved by allowing manufacturers to access the usage data from networked products in the future. As soon as the smart products leave the factory, they connect to the Internet and are then reachable digitally. Sophisticated data analytics enable manufacturers to filter out disparate patterns from usage data to develop new business models [17].

3 The role of Humans in Smart Factories

Even before smart factories existed, there was already an approach to penetrate the production technically. This approach was called "Computer Integrated Manufacturing" (CIM) and ran under the metaphor "The deserted factory". CIM was technology-automation-driven and saw the function of humans only in the task of controlling and monitoring, similar to the monitoring personnel in a nuclear power plant. Due to its disregard for human values, CIM completely disappeared in the 1990s [18].

Will the situation be similar for Industry 4.0, especially for smart factories? There are opposing views in research regarding this issue. Frey and Osbourne [19] argue that human labor will become outdated in the industrial sector. Machines and robots will fulfill the tasks that were originally performed by humans, leading to massive job losses. Similarly, Balliester and Elsheikhi [20] point out that especially low and middle-skilled workers are at a high risk of losing their jobs.

However, the majority of authors believes that people will still be needed, nor will the deserted factory be aimed at in the same way as CIM, since, according to the current state of technology, it is not feasible either. According to Shrouf, Ordieres & Miragliotta [16], one reason for this is that the smart factory will not be deserted, since humans with their day-to-day intelligence are also superior to the best expert software in exceptional situations. The authors add that if fully automatically, we will not be able to cope with the flexibility requirements of volatile markets for the near future, and people are still in demand here with their skills. These statements are supported by Cantoni & Mangia [21] to the effect that the tactile abilities of humans are very difficult to realize by sensors and that the human's ability to associate is superior to artificial intelligence solutions. Furthermore, people can be trained relatively quickly for new tasks and can quickly adapt to situations that change at short notice. In contrast, a machine can only handle and react to what it was designed for, but then very quickly and with high repeat accuracy.

Even if, according to today's assessment, humans are still relevant, there will be a lot of changes for them in the context of smart factories. For instance, humans will interact and collaborate with robots in their daily work. This requires new skills and competences for the workers. They will be faced with increased complexity, abstraction and problem-solving requirements. Nevertheless, a high degree of self-directed acting, communication skills and self-organization skills will still be needed [22]. In spite of the digital penetration of the self-organizing value-added chain, humans are given a central role in this, up to the statement that in the future production will follow the tact of humans [21]. However, to what extent this can be achieved or even be effective from the customer's point of view remains an open question, even if it is assumed that the deployment of staff will be much more flexible than is often the case today.

Furthermore, the flexibility offered by CPS contribute to work organization models that better meet the needs of workers regarding work-life balance. For instance, Kagermann et al. [2]. argue that machines release workers from doing routine tasks and enable them to focus on more creative activities. This would lead to physical relief and especially allow older workers to remain productive for longer.

Remarkably many authors emphasize that technological progress fosters the unique abilities of humans and that they will also be able to assert themselves as strategic decision-makers and flexible problem solvers in the overall CPS. However, what it means for employees with "ordinary" skills has not yet been answered. It is clear that there was hardly a worse time for these employees to become redundant as digitalization progressed [22].

4 The organizational Structure for Smart Factories

In order to implement smart factories, a new level of organization and governance is required [23]. The question is how the organization should be designed, if automation and real-time-oriented control systems take on more and more tasks along the value chain. An important element is decentralization, which means that decisions that were previously made centrally are now delegated to the respective areas. In contrast to the CIM approach (the deserted factory) of the 1980s, people are included in smart factories and are regarded as a key variable, which - despite increasing automation and digitization - makes a smart factory a socio-technical system [24]. This poses questions as regards the organization of smart factories. Respectively, it is postulated by a majority of scientists and expert committees that an adequate and employee-friendly organization is necessary, so that digitalization can also be realized [17]. However, this goes without specifying in detail the elements included in the organizational structure. This suggests that technical conceptualization is much more advanced than the basic concepts of organization required for successful implementation.

In theory, the smart factory manages the value-added process, the intelligent product recognizes the production process, its' processing status, as well as possible deviation steps, in order to be able to adjust them, and also triggers the logistics process, as it also knows its customers [16]. It is clear that organizations must build new business models to achieve customer value from smart factories. However, the question arises as to how an organization must be built and designed to be supportive of all this (technological) intelligence. And the question that follows - what is left of "non-intelligence", which also falls to the organization and must be collected organisationally The BCG model provides first clues to answer these questions [25]. This model was developed based on the following considerations: With the increasing decentralization of autonomous value chains due to digitalization, the centrally organized processes, structures and resources of planning and control must be broken up in order to make decentralized and agile decisions. As a result, centrally organized management functions can be decentralized to achieve shorter reaction time and self-organization. As stated by Kagermann et al. [2] self-organization is required when dealing with flexible working hours, locations and tasks in a smart factory. Managers must be able to delegate, cooperate, and share their existing power with employees. Odważny, Szymańska and Cyplik [26] even suggest organizations to create a digital culture. In this culture, employees not only possess the digital competences, but are also initiators of change. The ability to change must become daily business in every organization. This is critical, as an organization must remain proactive and constantly ask what digitalization means for it.

Thus, rules must be defined for the management of digital technologies, which are capable of intercepting increasing volatility throughout the system. This means that organizations need a high degree of adaptability and thus the technological, structural and organizational suitable environment for self-organization. For the transformation of technology, organization and processes of companies, the classic management tasks (leadership, planning, implementation, monitoring) must be broken down for the levels of change to digitalization. Successively, the management of a company will have to deal with these tasks in order to ultimately transform the value-added activities. This extensive change requires the adaptation of planning and control structures and processes, the selection and introduction of new (autonomous) technical systems and the monitoring and control of the economic viability of this change.

5 Discussion

Our review of prior literature on smart factories suggests that the role of humans will change to some extent as manufacturing companies are transformed to smart factories. It can be assumed that the activities in factories become more demanding due to their diverse digital networking. A continuous qualification build-up takes place on the basis of the digital competence model. This includes beside the technical topics and the overall understanding of the digital enterprise a maximum of personal responsibility and motivation. Subject-specific topics include the obvious use of the widely available online functions for quality and order management, the mastery of communication methods and tools, the derivation of concrete measures from current information and real-time decision-making in their own responsibility [27]. In order to retain these employees and their know-how and to be able to use them in other areas, the employees have to upgrade their qualifications and expand their knowledge. Training is necessary to offer employees these options. This requires well-trained people who are both technically and personally suitable for carrying out training. Such training staff have to bring with them a great deal of new knowledge in dealing with business processes, new technologies and the cooperation between humans and machines in order to provide their trainees with the knowledge that is important for the future area of activity [28]. Overall, the employee in the smart factory will determine the superior production strategy, monitor the implementation of this strategy and if necessary, intervene in the cyber-physical production system (CPPS). As part of a cyber-physical system, the employee will assume a greater degree of responsibility overall and complete his tasks with the support of various human-technology solutions. Challenges related to these changes are entangled to the role of humans in smart factories, which were presented in section 3. The ones that managers and organizations have to address are summarized in Table 1.

Table 1. Managerial and Organizational Challenges regarding people

	Organizational Challenges regarding people
-	To promote and develop the required competences with intelligent training concepts
-	To cover the upcoming need for skilled workers with adequate measures
-	To promote low-skilled employees accordingly for the requirements of digitalization
-	To coordinate the human-machine / robot collaboration
-	To use the better design of work and leisure announced by the new technologies to achieve physical relief and contribute to the work-life balance

On the one hand, implementing a smart factory requires the development of suitable and appropriate methods and concepts for the necessary step "away from central management systems". This is a task of the normative level to actively shape the framework conditions and the environment for the required degree of mutability and self-organization and control [29]. On the other hand, a socio-technical design perspective is needed in which employees and technology are coordinated with one another in order to create the necessary framework conditions and to be able to realize the expected potential [29]. Smart factories will need completely new economic and organizational structures to tap their potential [17]. Therefore, in order to achieve this, the organizational structure and successful implementation of smart factories requires agreement with the employees [21]. Managerial and organisational challenges regarding the structure in smart factories were discussed in section 4 and are summarized in Table 2.

Table 2. Managerial and Organizational Challenges regarding structure

Organizational Challenges regarding structure
- To formulate and develop adequate business models, which are also economical and generate customer value
- To create the necessary environment for self-organization of the transformation of value chains, so that the ability to change becomes daily business
- To design the classic management tasks in such a way as to enable the decentralization demanded by smart factories
- To remain proactive and constantly ask what digitalization means for your company and what the consequences are

While this paper has discussed challenges related to the role of humans and to organizational structure separately, they can be seen to interact. For example, creating environment for self-organization may foster employees' abilities to develop their competences. Analyzing such interconnections further could be an intriguing topic for future research in the area of smart factories.

6 Conclusion

This paper has developed an understanding of smart factories by presenting their technologies, and their effects on the role of humans and the structure of organizations. From these two perspectives, we have identified the challenges that organizations and their management face and that they must address.

The endeavor to create a networked, intelligent world in real time, in which the separation of physical and virtual world is removed, becomes a driving force in the Industry 4.0. Value chains are broken, and humans are placed in a one-to-one relationship in the production of their goods or for the maintenance of their services. They control the smart factory in the cloud for the purchase of smart products and smart services via the Internet of Things. The role of humans in the smart factory will be to network automatic subsystems. Factory workers' required abilities will probably shift from motor skills toward associative and sensory skills. With the networking of production systems and the increasing automation, skilled workers with a holistic view of production facilities and comprehensive knowledge are needed. Organizations must therefore decentralize the classical management tasks to allow a shorter reaction time and to enable self-organization. From this point of view, it legitimizes to speak of an (upcoming) paradigm shift, and this against the background that it is not yet clear what the consequences of this technological change will be, both economically and socially. However, they will be particularly serious if the scenarios presented in this article will realize. Hence, the manager's role as a change agent in the organization aiming to transform traditional factories to smart factories is an important topic for further research.

Current technological changes and their identified potential in transforming manufacturing practices raise the question of what still includes factory work in the future, if everything that can be digitized is digitized. The impacts of smart factories to factory workers and to society pose interesting avenues for future research.

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