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Research paper

Industry 4.0 and the current status as well as future prospects on logistics

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ABSTRACT

Industry 4.0, referred to as the "Fourth Industrial Revolution", also known as "smart manufacturing", "industrial internet" or "integrated industry", is currently a much-discussed topic that supposedly has the potential to affect entire industries by transforming the way goods are designed, manufactured, delivered and payed. This paper seeks to discuss the opportunities of Industry 4.0 in the context of logistics management, since implications are expected in this field. The authors pursue the goal of shedding light on the young and mostly undiscovered topic of Industry 4.0 in the context of logistics management, thus following a conceptual research approach. At first, a logistics-oriented Industry 4.0 application model as well as the core components of Industry 4.0 are presented. Different logistics scenarios illustrate potential implications in a practice-oriented manner and are discussed with industrial experts. The studies reveal opportunities in terms of decentralisation, self-regulation and efficiency. Moreover, it becomes apparent that the concept of Industry 4.0 still lacks a clear understanding and is not fully established in practice yet. The investigations demonstrate potential Industry 4.0 implications in the context of Just-in-Time/Just-in-Sequence and cross-company Kanban systems in a precise manner. Practitioners could use the described scenarios as a reference to foster their own Industry 4.0 initiatives, with respect to logistics management.

1. Introduction

> "The implementation starts with small steps here and there, there won't be a big bang that is going to introduce Industry 4.0. On the contrary, it will come step by step. But if we look back in ten years we will see that the world has changed significantly." *([1]Hartmut Rauen, Deputy Executive Director Mechanical Engineering Industry Association (VDMA), 2012).*

In recent years, complexity and requirements in the manufacturing industry have steadily increased. Factors such as growing international competition, increasing market volatility, demand for highly individualised products and shortened product life cycles present serious challenges to companies [2]. It seems that existing "approaches" of value creation are not suited to handle the increasing requirements regarding cost efficiency, flexibility, adaptability, stability and sustainability anymore. On one hand, requirements in the manufacturing industry have increased. On the other hand, the rapid technological progress in the more recent past has opened up a range of new business potentials and opportunities. Trends and new catchwords such as digitalization, the internet of things (IoT), internet of services (IoS) and cyber-physical systems (CPS) are becoming more and more relevant. Against this backdrop, Germany, which is well known for its strong manufacturing sector, launched the so-called "Industrie 4.0" initiative in 2011 as part of its high-tech strategy, introducing the idea of a (fully) integrated industry [3,4]. Since then, Industry 4.0 has gained attention importance – also beyond the German-speaking area – and has even been listed as a main topic on the 2016 World Economic Forum's agenda.

Prophetically, Kagermann et al. [5] expect that strong industrial nations such as Germany will only remain successful if they manage to actively participate in the Industry 4.0 initiative. In concrete terms, this means participating in the development, merchandising and operation of autonomous, knowledge- and sensor-based, self-regulating production systems. The opportunities and benefits that are anticipated to come along with Industry 4.0 seem to be manifold, e.g. resulting in highly flexible mass production, real-time coordination and optimisation of value chains, reduction of complexity costs or the emergence of entirely new services and business models.

As far as the field of logistics is concerned, major implications are predicted, too. In fact, logistics represents an appropriate application area for Industry 4.0 [3]. The integration of CPS and IoT

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into logistics promises to enable a real-time tracking of material flows, improved transport handling as well as an accurate risk management, to mention but a few prospects. In fact, one could argue that Industry 4.0 in its pure vision can only become reality if logistics is capable of providing production systems with the needed input factors at the right time, in the right quality and in the right place.

As promising as the idea of a self-prophesying "Fourth Industrial Revolution" may sound at first sight, it is essential to remark that there is a multitude of challenges, risks and barriers with regard to its implementation. Traditional industry boundaries will vanish due to the reorganisation of value creation processes and cause severe changes within and across organisations. Defining appropriate infrastructures and standards, ensuring data security and educating employees are among the issues that need to be addressed on the road to Industry 4.0.

Unsurprisingly, a huge number of practitioner-oriented articles and papers address the opportunities of Industry 4.0 and seek to motivate (or even urge) companies to participate in the initiative. Although the term Industry 4.0 roots back to Germany's high-tech strategy and thus has received a lot of attention recently, it still lacks a precise, generally accepted definition. This situation must be considered unsatisfying, especially from a scientific point of view.

The present paper picks up on this deficit and aims to sharpen critically the picture of Industry 4.0 with regard to logistics management, since major consequences are expected in this field. Based on a theoretical and conceptual ground work, the authors select some prominent logistics concepts so as to describe potential implications and pitfalls of Industry 4.0 in detail. After that, the findings are reflected and discussed with experts in terms of practical feasibility.

Against this backdrop, our ambitions are reflected by the following research question:

What are the implications of Industry 4.0 for future logistics management? In particular: How may Industry 4.0 affect logistics concepts, namely Kanban and Just-in-Time/Just-in-Sequence?

Current research still lacks consistent knowledge about how the "Fourth Industrial Revolution" is going to affect future industries. Against this background, we follow a conceptual research approach as described by Meredith [6], serving an exploratory purpose so as to provide a better understanding of this rather undiscovered topic. The research process can be divided into the following phases: The initial phase was devoted to narrowing down the topic and its scope. This was accomplished first through multiple unstructured discussions within the affiliated research team of the authors as well as through desk research. Following that, the authors conducted a literature review on the topic of Industry 4.0 in the second phase. The reason for examining past and current literature was twofold: On one hand, the review was conducted in order to investigate the background and origin of Industry 4.0. On the other hand – with respect to the fact that Industry 4.0 has become a buzzword recently but still lacks a generally accepted conceptual understanding – it served the purpose of identifying its key components and characteristics so as to sharpen the picture. In the third and main phase of this paper, we try to investigate potential implications and pitfalls of Industry 4.0 in the field of logistics management and thereupon construct and describe a number of scenarios with regard to specific logistics concepts. The findings are summarized in propositions. Moreover, eight experts in the field of logistics and supply chain management are interviewed in order to evaluate the propositions. The final phase comprises a (self-)critical review of the research process and findings by the authors.

With regard to the structure of this paper, four main parts can be distinguished: The first section of the paper is devoted to introducing and emphasizing the topicality of Industry 4.0. Moreover, the aim, research question, structure and methodology are covered. Following that, a comprehensive literature review on the subject of Industry 4.0 is conducted in the second part so as to lay a solid theoretical foundation for the subsequent research. In Section 3, two well known logistics concepts are analysed with respect to potential Industry 4.0 consequences. Experts from different industries are then questioned in order to evaluate the findings in terms of practical relevance. The last part of the paper comprises a critical review of the core findings and thereupon offers suggestions for future research.

2. Literature review

2.1. Industry 4.0 emergence

The industrial sector plays a crucial role in Europe, serving as a key driver of economic growth (e.g. job creation) and accounting for 75% of all exports and 80% of all innovations [7]. However, the European manufacturing landscape is twofold. While Eastern Europe and Germany show a constantly growing industrial sector, many Western European countries such as Great Britain or France have experienced shrinking market shares in the last two decades. While Europe has lost about 10% of its industrial share over the past 20 years, emerging countries managed to double their share, accounting for 40% of global manufacturing. A few years ago, Germany started thinking about initiatives in order to maintain and even foster its role as a "forerunner" in the industrial sector. Eventually, the term Industry 4.0 was publicly introduced at the Hanover Trade Fair in 2011, presented as part of Germany's high-tech strategy so as to prepare and strengthen the industrial sector with regard to future production requirements [8]. While the IoT is assumed to take on a leading role in the Industry 4.0 era, Hermann et al. [9] found that the IoS will find its way into factories, too. CPS, which are able to interact with their environment via sensors and actuators, constitute another element of Industry 4.0, since they are expected to enable factories to organise and control themselves autonomous in a decentralised fashion and in real time [4]. Due to their capabilities, these factories are often referred to as "smart factories". Given all these concepts, the difficulty of finding a unique and concise definition for Industry 4.0 becomes apparent, and it is hardly surprising that opinions among researchers and practitioners diverge. Moreover, it is still uncertain how Industry 4.0 will manifest itself in practice and how much time that will take. With respect to a more precise understanding of the topic, we now try to clarify the core components of Industry 4.0.

2.2. Industry 4.0 key components

Hermann et al. [9] identified four Industry 4.0 key components based on a review of academic and business publications, using different publication databases so as to ensure objectivity. These key components are now briefly described.

Cyber-physical systems (CPS): Industry 4.0 is characterised by an unprecedented connection via the internet or other distributed ledgers and so-called CPS, which can be considered systems that bring the physical and the virtual world together [10]. More precisely, "cyber-physical systems are integrations of computation with physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa" ([11]; p. 1). In the manufacturing context, this means that information related to the physical shop floor and the virtual computational space are highly synchronised [12]. This allows for a