

A Practical Variation of Industry 4.0 and Lean Management

Bibhuti B Pradhan¹, Mr. Sachin Kumar Sharma²

¹Department of Management, Siksha 'O' Anusandhan (Deemed to be University), Bhubaneswar, Odisha

²Department of Management, Sanskriti University, Mathura, Uttar Pradesh

Email - ¹bibhutibhusanpradhan@soa.ac.in, ²sachin.mba@sanskriti.edu.in

ABSTRACT

Applying lean will dramatically improve a company's efficiency by focusing on value-adding activities. Manufacturing 4.0 is also considered to be another positive development in manufacturing. The synthesis of these advances led to words such as "lean 4.0". However, an extensive and detailed combination of both paradigms is lacking in the existing literature. This paper builds on this research gap with a twofold objective: First, to draw on established groundwork to infer that lean management (LM) and Industry 4.0 (I4.0) can complement one another. Second, this study takes into account how I4.0 will help different lean methods. This is exemplified by a use case for the manufacture of electric drives. This paper explores various viewpoints for a LM / I4.0 conjunction. In summary, the authors conclude on a conceptual level, that LM and I4.0 complement each other. Building on that idea, this paper explains how eight lean approaches can be assisted by different I4.0 resources.

Keywords

Industry 4.0, Lean management, Production management, Cyber physical systems, Internet of things.

Article Received: 10 August 2020, Revised: 25 October 2020, Accepted: 18 November 2020

Introduction

The capability to manufacture individual and personalized products is the key for success in a globalized and digitally connected world. Customers are used to receiving specifically fitted goods for their needs. These high customer expectations lead to an increase in variant diversity and intensify the complexity of the production environment.

One solution to this issue that reduces complexity within the industrial area is the Toyota Production System (TPS). This production philosophy developed by the Toyota Motor Corporation in the last century aims to reduce waste in the value chain in order to minimize lead time. By applying this ideology and permanently focusing on customer value in a continuous improvement process, Toyota was able to gain a world leading position in the automotive industry. Nowadays, the TPS is well known as lean management (LM) or lean manufacturing and widely deployed as a standard in various industries[1]–[3].

Another possibility to handle the increasing complexity in manufacturing is given by the relatively new research field Industry 4.0 (I4.0). It aims to improve transparency through the digital linkage of each element involved in the production. It is based on cyber-physical systems (CPS) which organize the value creation process by themselves. Another key feature of I4.0 is the realization of an internet of things (IoT) which allows a worldwide data communication in real time.

Both production paradigms, i.e. LM & I4.0, are promising to solve future challenges in manufacturing. Hence, the question arises if and how these developments can possibly support each other. Thus, this paper aims to contribute to this research area. More precisely, the authors provide answers to the following research questions: How can LM and I4.0 supplement each other on a conceptual level? And which I4.0 tools can support specific lean methods?

Within this paper an initial overview on relevant groundwork is given and a proposal to link LM and I4.0 in a conceptual way is developed. Thereby, existing literature is classified in three research streams. Furthermore, it is shown how I4.0 tools can contribute to optimizing specific lean methods, namely just-in-time (JIT), heijunka, kanban, value stream mapping (VSM), total productive maintenance (TPM), single minute exchange of die (SMED), visual management (VM), and poka-yoke. This evolutionary approach to enhance lean methods will help scientists as well as practitioners to design a versatile production system for a constantly changing environment. Lastly, a use case on applying the machine learning-based condition monitoring (CM), as well as cloud computing to TPM exemplifies how both paradigms can act jointly to improve the production of electric drives. The authors conclude by discussing the developed concept and summarizing the key findings.

Preliminary work related to lean 4.0

Following Dombrowski et al., the existing literature is structured into two perspectives: Either LM is considered as a prerequisite for introducing I4.0 tools or I4.0 tools are regarded as promoters of LM [5]. Another widely acknowledged perspective is that the combination of both topics yields in positive synergies. This is added as a third, more general perspective. Table 1 gives an overview of literature which supports these perceptions. After outlining these three views limitations of extant research are analyzed.

Table 1. Existing perspectives on combining I4.0 and LM

Perspective	Authors
LM as enabler towards I4.0	[6, 7, 8, 9, 10, 11, 12, 13, 14, 15]
I4.0 advances LM	[16, 17, 18, 19, 20]
Positive correlation between LM & I4.0	[21, 22, 23]

Lean management as enabler towards Industry 4.0

Several authors name LM as a prerequisite for the successful introduction of I4.0 solutions. This is supported by the hypothesis from Bill Gates that automating inefficient processes will magnify their inefficiency [4], [5]. Collectively the insights can be summarized as follows:

- Standardized, transparent, and reproducible processes are of fundamental significance for introducing I4.0.
- Decision-makers require LM competence for considering customer value and avoiding waste.
- By reducing product and process complexity LM enables the efficient and economic use of I4.0 tools.

Hence, lean processes are regarded as a basis for the efficient and economic implementation of I4.0. However, Nyhuis et al. annotate that LM and I4.0 implementation may influence each other iteratively. Thus, the progression is not necessarily purely sequential.

Industry 4.0 advances lean management

Wagner et al. as well as Pokorni et al. describe that lean processes can be stabilized and refined by applying I4.0. While Ruettimann et al. emphasize the ability to improve the flexibility of modern lean production systems, Kolberg and Zuehlke state that I4.0 can enhance LM. Hence, I4.0 contributes to addressing limitations of LM. Exemplary, the economic production of goods in a lot size of one is a way to enhance production economies beyond traditional Economies of scale. Data in real-time improves transparency and information quality. Moreover, I4.0 is promising to cope with a fluctuating market demand superior to a levelled production in LM. Eventually, the increased flexibility through I4.0 helps to cope with the rising complexity [3], [6]–[8].

Correlation between lean management and Industry 4.0

Mrugalska and Wyrwicka support the statement that I4.0 and lean can coexist and support each other. In accordance Vogel-Heuser et al. reject a contradiction between I4.0 and LM. Moreover, committing into I4.0 can help to overcome existing barriers for implementing lean.

For combining LM and I4.0 the extant literature manifested terms like lean 4.0, lean automation, smart lean manufacturing, and lean industry 4.0. As elaborated, the majority of authors approve of the general compatibility of LM and I4.0. This perspective can be attributed to similarities concerning targets like the reduction of complexity, central pillars, and lean principles as a common ground (see Fig. 1). Accordingly, both paradigms are managed in a decentral way. Kanban in LM as well as self-organizing systems in I4.0 distribute responsibility in subsystems. Moreover, LM and I4.0 focus on a pivotal role of employees.

Use of automation technology	Decentral production management	Resource employee efficiency, sustainability	Holistic work tasks, no Taylorism
Avoiding waste, continuous improvement, customer value, value stream, pull, flow, perfection			

Fig. 1. Commonalities of LM and I4.0 Limitations of existing research approaches

Despite the analyzed linkage between the two topics, the literature research reveals several limitations. Hence, Kolberg and Zuehlke conclude that a common framework is lacking as concepts are discussed in an exemplified way without a structured approach. Moreover, existing contributions were often found to address LM on a generic level. Hence, the reference to particular lean methods is often found to be missing. Solely Wagner et al. use a matrix to illustrate the impact of eight I4.0 tools on several lean principles which include specific methods. However, only the influence of CPS on JIT is described in detail [9]–[12]. Thus, this limits the transparency of the remaining evaluation. Building thereon, this paper addresses eight specific lean methods instead of basic principles like waste reduction. Moreover, a wider range of I4.0 tools is covered. Additionally, a critical discussion and consideration of limitations is often found to be absent.

Just-in-time/just-in-sequence 4.0

The lean method JIT/just-in-sequence (JIS) aims to deliver the right product, at the right time, place and quality in the right quantity for the right costs.

Automated guided vehicles (AGV), for instance, can transport objects within the material flow automatically. This minimizes human mistakes as well as empty trips. Besides, material is supplied to workstations in accordance to the requirements. In case of obstacles the transportation system will reroute the vehicle to an alternative path.

Furthermore, intelligent bins and smart products also pursue self-optimization. A digital object memory stores every necessary manufacturing parameter. In combination with monitoring the condition of the transported goods, it is used to navigate the AGV efficiently. This self-organization helps to build robust logistics networks for production.

In addition, Auto-ID technology, such as RFID, can be applied to track material in real-time and to localize objects in the value chain precisely. This results in reduced search time as well as improved process transparency. Additionally, part recognition allows the identification of incorrect components. Parts can then be removed, which contributes to the idea of poka-yoke. Moreover, the automated selection of RFID tags enables continuous stock monitoring which eventually results in reduced inventory levels. Besides, it facilitates an automated replenishment process from suppliers.

The JIT/JIS 4.0 method additionally applies big data and data analytics techniques. The opportunity to analyze detailed real-time process information provides insights into parameters, helps to identify trends, and allows to deduce rules for the production system. Furthermore, a continuous material flow is supported by reducing machine downtimes through predictive maintenance actions. In general, data analysis has the potential to contribute to an improved system performance of the whole supply chain. Overall, JIT/JIS 4.0 convinces with higher transparency, shorter lead times and improved flexibility.

Conclusion

This paper explores various viewpoints for a LM / I4.0 conjunction. In summary, the authors conclude on a conceptual level, that LM and I4.0 complement each other. Building on that idea, this paper explains how eight lean approaches can be assisted by different I4.0 resources. The results indicate that the implementation of I4.0 methods will help realize the achievement of lean goals. A matrix visualizes in a simplified manner through I4.0 tools help the tested lean methods.

A use case is an example of how CM and cloud computing help to improve TPM in the development of electric drives for a sheet metal stamping press. Furthermore, one perspective sketches how digital twins help to conquer. A use case is an example of how CM and cloud computing help to improve TPM in the development of electric drives for a sheet metal stamping press. In addition, an outlook further sketches how digital twins help to transcend the VSM's static character.

Future work will concentrate beyond the technological problems, on how to incorporate lean 4.0 as a comprehensive framework. One main field is employee integration to prevent repetition of faults from computer-integrated manufacturing implementation. In addition, trade-offs and disagreements over priorities offer a fertile avenue for potential study.

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