The Lean Production System 4.0 Framework – Enhancing Lean Methods by Industrie 4.0

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Abstract. Industrie 4.0 is one of the major approach towards an increased production effectiveness. For the evaluation of Industrie 4.0 impact on production systems and the followed implementation, a common understanding of all participants and interdisciplinary stakeholders of Industrie 4.0 projects is required. A common and application-orientated framework might support the common understanding. However, a general, common and application-orientated has not been invented and described so far. Furthermore, it has been analyzed, that Lean builds the basis for the implementation of Industrie 4.0. Thus, this paper presents an application-orientated Industrie 4.0 framework and the interdependencies of Industrie 4.0 and Lean Production Systems (LPS), resulting in the Lean Production framework 4.0 (LPS 4.0). Based on this LPS 4.0, a toolbox respectively a catalogue of LPS methods, enhanced by using the Industrie 4.0 framework, has been developed - the LPS 4.0 method catalogue. This supports companies to identify Industrie 4.0 potentials and evaluate the individual benefits of Industrie 4.0.

Keywords: Lean Production Systems, Industrie 4.0, Industry 4.0, framework Industrie 4.0.

Introduction

Due to the volatile and globalizing market as well as the accompanying intensified competition, manufacturing companies face new challenges in terms of cost, quality and time. The increasing number of competitors and the change from the seller's to the buyer's market, enable customers to choose from a variety of different products with a high degree of freedom. This increases the need for individual products, whereby a constant cost and quality level is demanded. Thus, the importance of an economic production in lot size 1 will increase for manufacturing companies in the future. This trend can be summarized under the term `mass customization`. In order to remain competitive as a manufacturing company in high-wage countries like Germany, processes along the entire value chain have to be designed in a productive, efficient and flexible way. To cope the above mentioned continuous increasing challenges, the approach of Industrie 4.0 has been presented at the Hanover Fair in 2011. Industrie 4.0 can be defined as “real

time, intelligent and digital networking of people, equipment and objects for the management of business processes and value-creating networks" [1].

A detailed literature analysis from 2017 shows the need, that LPS are building the basis for Industrie 4.0 and the successful implementation of modern information and communication technologies. [2] However, according to a study from 2017, Industrie 4.0 has not been successfully established within the production and companies struggle with the operational implementation of Industrie 4.0 elements [3]. The most important aspects, which hinder especially small- and medium sized companies implementing Industrie 4.0 elements, are the missing understanding of Industrie 4.0 and the absent idea of using Industrie 4.0 elements within the own company and enhancing the individual Lean Production Systems (LPS) and processes. Thus, a practical Industrie 4.0 framework is needed to get a common understanding of Industrie 4.0.

Industrie 4.0 framework

Since the publication of the Industrie 4.0 in 2011, the approach has been under strong discussion and research in science, economics and politics. Many articles regarding Industrie 4.0 have been published, trying to interpret the term Industrie 4.0, including several terms, definitions and description. [4] However, an explicit and consistent understanding and common view is a necessary prerequisite for the Industrie 4.0 implementation. Linguistic and conceptual inaccuracy and misunderstandings are obstacles and hindrances regarding the implementation of Industrie 4.0. [5].

According to a study, 50 % of the analyzed companies stated, that the complexity of Industrie 4.0 is a major obstruction implementing Industrie 4.0. [6] [7] To address the mentioned hinders and challenges, a simple and application-orientated framework of Industrie 4.0 needs to be developed. As a consequence, the framework needs to be reduced in complexity and more application-orientated in comparison to the already existing models, which have an IT background and are focusing on the technical aspects of Industrie 4.0 (for example RAMI [8], SIMMI 4.0. [9]).

The IPO-model (Input-Process-Output) is a widely used and common approach for describing the structure of IT processes. Even in the Industrie 4.0, the IPO-model will still be valid and be kept in principle. However, the data acquisition (Input) on the shopfloor (I), the transformation and distribution, the processing & analysis (Process) (II), as well as the output and utilization of these data (Output) (III) will change in the Industrie 4.0. Data will be collected on the shop floor (through sensors or human machine interfaces (HMI)). These data are processed via the Internet of Things (IoT) to be stored, saved and analyzed in cloud servers. That basically means that the collected data are directly and in real time transferred to cloud computers via the internet of things, without using the currently existing automation pyramid and its interfaces and layers (field, control, supervision, management and ERP). Within these cloud computers, data will be analyzed by smart algorithms, pre-defined rules and artificial intelligence. Afterwards, these data will be transferred by the Internet of Things directly to actuators or HMI on the shopfloor level. Thus, the process on the shopfloor level is either controlled by these data automatically or these data are provided by HMI to enable workers on the

shopfloor to adjust and adopt process [10] – supported by assistant systems and tools like for example smart glasses (Fig. 1).

Another crucial aspect while implementing Industrie 4.0 is the IT-Security and the Management of the IT-Interfaces. Thus, an Industrie 4.0 framework needs to consider the IT security and the management of IT Interfaces as well. Due to the real-time, intelligent and digital networking of people, equipment and objects, some specific process "features" or "attributes" (IV) will be available, which generate the actual value for the management of business processes [11]. Typical "features" or "attributes", for example, are "traceability/ real-time", "data consistency", "smart data", "vertical integration", and "horizontal integration". However, these "features" or "attributes" are a result of the company's individual production system, processes and Industrie 4.0 application.

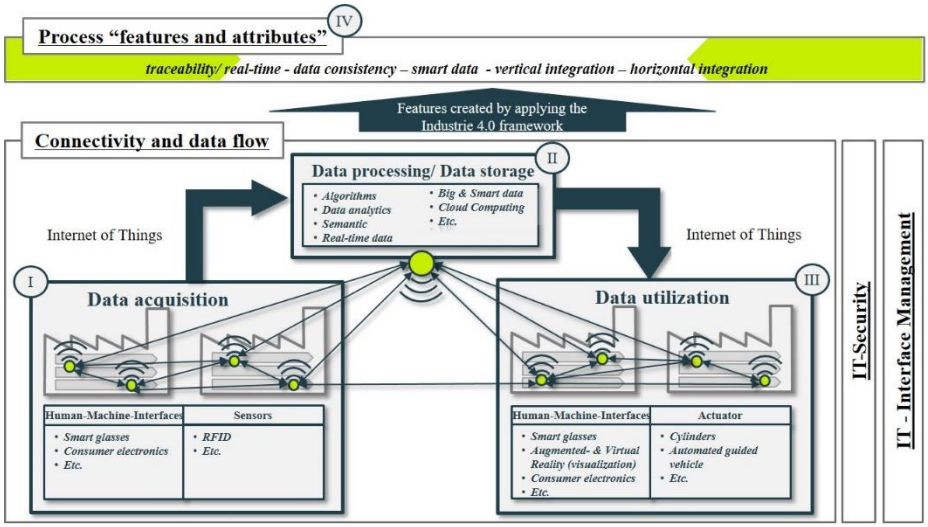

Fig. 1. Industrie 4.0 framework

Lean Production System 4.0

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In the past, companies have introduced Lean Production Systems (LPS) to create efficient and target-orientated processes. Thus, processes and procedures of manufacturing companies are currently designed according to Lean principles and methods. LPS can be described as "an enterprise-specific methodical system of rules for the continues orientation of all enterprise processes to the customer in order to achieve the largest by the enterprise management" [12] and pursues the goal of a systematic and continuous reduction of non-value-adding activities and the alignment of all processes to the customer's perspective. [13] LPS are targeting to achieve a continuous improvement process (CIP) within the entire enterprise. [12] In the meantime, LPS have been established

in almost all industries and has become an industry standard with the publication of the VDI 2870. Nowadays, 90% of manufacturing companies have already implemented the principles and methods of a LPS in the production environment. [14, 15] The processes and procedures of these companies are often structured and organized according to the LPS principles, using different company-specific individual configured methods of the LPS.

A detailed literature analysis by [2] shows, that the application of modern information and communication technologies (ICT) into LPS can improve the performance of Lean Productions Systems by gaining more efficient production and logistics processes. 2/3 of the analyzed articles have stated explicitly, that Lean builds the basis for Industrie 4.0. [2] Therefore, Industrie 4.0 needs to be integrated into the existing LPS framework and a catalogue of the enhanced LPS methods is required.

The LPS framework (Fig. 2 – left side) with its structure of goals, processes, principles, methods and tools will still applicable for future production systems. [1] Nevertheless, the data management and the provision of the required data is a prerequisite to generate the actual Industrie 4.0 potential and benefit within the management of processes. People, equipment and objects do have a certain need for specific information to take decisions and adjust processes. Therefore, data will be collected, processed and provided to all related and relevant stakeholders of the processes. Thus, the "data management - provision of information / data" has been integrated in the process layer of the LPS 4.0 framework (see Fig. 2 – right side). This data management and the application of the IPO-model will lead to specific "features" and "attributes". These "features" and "attributes" will have a direct benefit while managing the business processes and the existing methods and tools of current LPS will be enhanced and sophisticated by Industrie 4.0 [1, 2] and will lead to a new maturity of these methods and tools and the entire LPS.

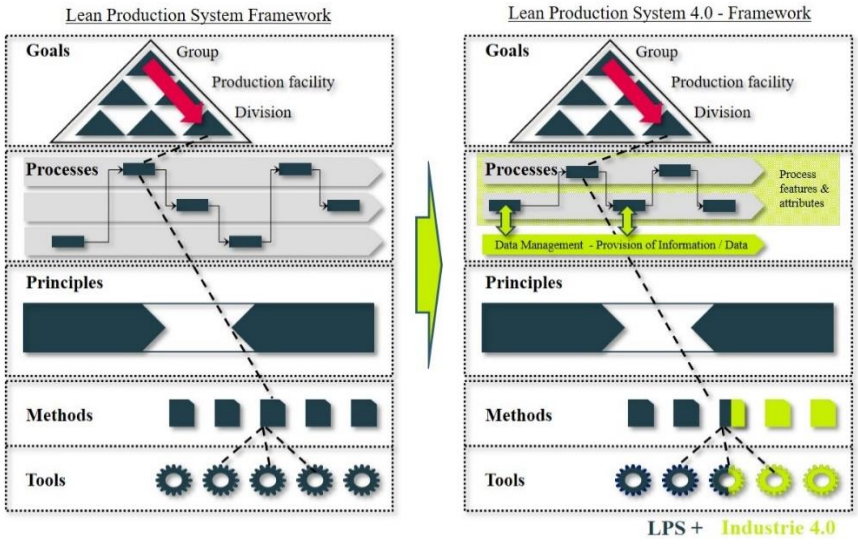

Fig. 2. Lean Production System 4.0 framework

Lean Production System 4.0 Methods

As stated above, a common catalogue of sophisticated and enhanced LPS methods supports companies to identify Industrie 4.0 potentials and to configure the individual LPS 4.0. Based on the integration of Industrie 4.0 elements into LPS, some of the existing and known LPS methods of the VDI-Guideline 2870 [12] will be enhanced and sophisticated. However, Industrie 4.0 has a different impact on specific methods, some are influenced more than others and some might have higher potential by applying Industrie 4.0 than others. The impact analysis has been done quantity wise by analyzing 260 existing German Industrie 4.0 use cases from a data base of the "Plattform Industrie 4.0" 1 in the first step. [2, 16] In the second step, the results have been analyzed quality wise with an interview of five production engineers and eight Industrie 4.0 scientist, who evaluated the impact from Industrie 4.0 on the specific Lean Production System Methods with the impact factor from 0 (now impact) to 5 (high impact). Based on the evaluation, LPS methods with an impact factor higher than 2 have been further developed and described to LPS 4.0 methods.2 Furthermore, some additional methods, supplementing the described LPS methods in the VDI 2870, needs to be taken into consideration and have to be part of the LPS 4.0 method catalogue as well. The LPS 4.0 methods have been evaluated regarding the goal-contribution (quality, cost, time) and the risks, the potential and the effort while implementing and performing the method by the above mentioned participant group of production engineers and Industrie 4.0 scientists. The derived LPS methods and the evaluation is shown in Tab. 2. The catalogue serves production engineers and production planners to get a brief overview of the methods and supports the identification of potentials for the individual processes according to the distinct production system. Nevertheless, the configuration of the individual company's LPS 4.0 requires a specific implementation procedure to ensure an efficient and systematical implementation of the LPS 4.0 methods.

[1] Plattform Industrie 4.0 is a joint project founded in 2013 by the associations BITKOM, VDMA and ZVEI with the aim of developing and implementing the high-tech strategy of Germany. In 2015, the project has been taken over by the BMBF and BMWi to take additional social and political aspects into account. Within the organization of the Plattform Industrie 4.0, there are various working groups investigating the future project Industry 4.0.
https://www.plattform-i40.de/

[2] The evaluation has been done by 13 Industrie 4.0 experts. To secure the evaluation and the results, the amount of participants could be enlarged regarding the quantity and the background.

Table 1. Lean Production System 4.0 method catalogue

Method catalogue LPS 4.0	Quality	Cost	Time	Risk	Potential	Effort
Digital 5S	●●●	●●	●●	●	●●	●
Dynamic/flexible standards	●	●●	●●	●●	●●	●●
Data & digital supported shop floor Management	●●●	●●●	●●●	●	●●●	●●
Data & digital supported 5 W-Analysis	●●●	●	●●	●	●●●	●●
Data & digital supported 8D-Report	●●	●●	●●	●	●●●	●●
Data & digital supported A3 Sheet	●●	●●	●●	●	●●●	●●
Data & digital supported Ishikawa	●●	●●	●●	●	●●●	●●
Digital Poka Yoke	●●●	●●	●●	●	●●●	●●●
Short term feedback loops	●●	●	●●	●	●●	●●
Data driven process control	●●●	●	●	●●	●●	●●
Simultaneous engineering	●●●	●●	●●●	●●	●●	●●
Data & digital supported Continuous Improvement Process (CIP)	●●●	●●●	●●●	●●	●●●	●●●
Dynamic milk-run	●	●●	●●	●●	●●	●●●
Dynamic KANBAN	●	●●	●●●	●●	●●	●●
Digital twin	●●●	●●●	●●●	●●●	●●●	●●●
Digital factory and process planning	●●	●●	●●	●	●●	●
Real-time value stream analysis:	●	●●	●●●	●	●●●	●●●
Live Sankey Diagram	●	●●	●●●	●	●●●	●●●
Short term layout adaption	●	●●	●●●	●	●●●	●●●
Data & digital supported Total Productive Maintenance	●●●	●●●	●●●	●●	●●●	●●●
Worker assistant systems	●●●	●	●●	●●	●●●	●●
Smart autonomous assistant systems // Algorithms	●●●	●●●	●●●	●	●●●	●●●
One piece flow // realtime production planning	●●●	●●●	●●●	●●	●●	●●●
JIS/JIT	●	●●	●●	●	●●●	●●●
Real-time leveling	●	●	●●	●●	●●	●●●
Data driven waste analysis	●	●●●	●●●	●●●	●●●	●●●
Autonomation / online analysis	●●●	●●	●●	●	●●●	●●
SMED	●	●●	●●●	●	●●	●
Target management	●●	●●	●●	●	●●	●●
IT Security	●●	●●	●●	●●	●●	●●
Interface Management	●●	●●	●●	●●	●●	●●

● high
●● medium
● low

Review and Outlook

Within this paper, a general and application-orientated Industrie 4.0 framework has been presented. The Industrie 4.0 framework supports a common understanding of all (interdisciplinary) stakeholders of Industrie 4.0 and LPS projects, independent of the specific background of the project members. As a LPS is a prerequisite for Industrie

4.0, a LPS 4.0 framework has been developed. It is shown, that the “features” and “attributes” of Industrie 4.0, which will be generated by connecting people, equipment and objectives in real-time, have a direct impact on managing the business processes within LPS. Furthermore, LPS 4.0 methods have been developed and evaluated. This evaluation serves as a basis for generating and evaluating ideas of Industrie 4.0 applications in individual processes and LPS. Nevertheless, the individual configuration and implementation of Industrie 4.0 respectively the LPS 4.0 requires a systematical implementation procedure. The evaluated LPS 4.0 method catalogue could be integrated into this systematical implementation procedure. The development of that systematical implementation procedure is part of current research activities at the Institute for Advanced Industrial Management - Technische Universität Braunschweig - Germany.

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