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ScienceDirect

Procedia CIRP 106 (2022) 58–63

www.elsevier.com/locate/procedia

9th CIRP Conference on Assembly Technology and Systems

Competence Requirements in Manufacturing Companies in the Context of Lean 4.0

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Abstract

Traditional production systems today are often based on Lean Production. With the advent of Industry 4.0, new digital and networked solutions are emerging that offer new opportunities and challenges combined with Lean Management principles and methods. The successful implementation of Lean Management requires that the employees in the production environment have internalized the associated philosophy, integrated the methods into their daily work, and implemented the necessary competencies into their processes. The different emerging technologies through Industry 4.0 lead to new changes for both the company and the employees. In order to master the challenges of this comprehensive industrial change and to remain competitive on the global market, timely training and further education of production employees are indispensable. The employees contribute significantly to the success of a company and the implementation of Lean 4.0. The prerequisite for sufficient qualification of employees is identifying relevant competencies. This scientific contribution aims to present a structured and comprehensive approach to develop a Lean 4.0 competence model for manufacturing companies that depicts the requirements for employee competencies due to Lean 4.0 elements and job profiles. The focus will be on assembly and manufacturing areas as well as the production-related areas maintenance and internal logistics.

Keywords: Lean Management, Lean Production, Industry 4.0, Lean 4.0, competencies

1. Introduction

In the current production environment manufacturing companies are facing significant changes and challenges. Besides the increasing complexity of products and processes, challenges due to saturated markets or globalization are characteristics of the changes [1, 2].

Lean Production offers an approach many companies have already implemented to increase process efficiency by systematically eliminating non-value-adding activities, achieving quality, and focusing on the customer [3, 4]. In order to manage the high complexity and flexibility requirements, further development of the current paradigms in industrial production is necessary [5, 6]. Concerning the fourth industrial revolution, "Industry 4.0" was introduced in 2011, describing the latest revolution in the industrial environment [7]. It focuses on networking processes, humans, and machines [8] to increase the adaptability of production systems besides developing smart factories [9, 10].

Since the linking of both paradigms to the concept "Lean 4.0" [11], the fusion of different work areas is occurring [12]. The accompanying increase of new methods and technologies places new requirements for the skills and abilities of employees in the production environment [7, 13].

The objective of this paper is to capture the changing requirements for employees in the context of Lean 4.0 and present them transparently using a competence model. Therefore, it is essential to analyze and develop existing

10.1016/j.procir.2022.02.155

competencies to identify the need for new ones. This paper offers an approach for a Lean 4.0 competence model that links selected methods and technologies with specific job profiles and the resulting competencies. The model thus supports manufacturing companies in the targeted configuration of competencies for operational employees and significantly contributes to maintaining long-term competitiveness

The following section sets up the reference frame of the paper's scientific fields and introduces Industry 4.0, Lean Production, and Lean 4.0. Afterward, the current research and a methodological approach to creating a Lean 4.0 competence model are presented.

2. Fundamentals

2.1. Lean Production

After World War II, Toyota Motor Company began to develop the Toyota Production System (TPS) to address challenges such as low raw material availability and low sales potential [3, 14]. Today, various industries have implemented and modified the TPS as a holistic production system, also known as Lean Production [15, 16].

The main objective of Lean Production is to eliminate waste. In this context, waste includes all non-value-adding operations, meaning activities that do not benefit customers [3]. The employee is at the center of this value-based approach, contributing to continuous improvement through a systematic problem-solving process [11]. To achieve this goal, the company focuses on the Lean philosophy and values as well as its principles and methods.

The Lean methods are described and classified in detail in the VDI-2870-2 [17]. In the following, three methods are described, which are of high importance in the course of the paper. The first one is Poka-Yoke which is a method to avoid unintended mistakes. Therefore, low-cost but intelligent devices are a measure that can be used on machines, products, or tools to prevent common but avoidable errors [17]. Another Lean method is Kanban, which has its language origin in Japan and means card or can be translated in a broader sense as a signal [14]. The return of a Kanban to the supplier triggers an order or subsequent delivery. Thus, production or delivery is based on the pull principle [18]. One further method is Single Minute Exchange of Die (SMED) which is part of the flow principle and covers a three-stage process to minimize set-up times [19]. First, internal set-ups are separated from external ones. Afterward, internal set-up processes are transferred to external set-up processes as far as possible to reduce the idle time of the machine. In the last step, both set-up processes are optimized and standardized. This continuous improvement takes place with all employees participating in the production process [19].

2.2. Industry 4.0

Industry 4.0 is a technology-oriented approach in which cyber-physical systems (CPS) play an essential role [20]. By connecting production and communication engineering processes, material and information flows along the value chain can be optimized [21]. Therefore, all participants of the value creation process are equipped with sensors and actuators that can communicate via IoT [22].

As mentioned at the beginning, Industry 4.0 includes various innovative technologies that influence the work content of people in the production environment. Therefore, a selection of technologies will be examined in more detail below to finally derive the necessary competencies for them.

Human-Machine-Interaction (HMI), Virtual Reality (VR), and Augmented Reality (AR) are technologies that can be assigned to assistance systems [1]. HMI describes the interaction between man and machine and the way they work together. Thereby, it is essential to separate between different levels of automation [1]. AR describes the computer-based representation of virtual objects and additional information to expand the real human perception of the environment [23]. Whereas with VR, humans are entirely immersed in a computer-generated virtual environment where they receive the necessary data and information, without any superimposition on the real world [24].

Big data and data analytics are also part of the considered Industry 4.0 technologies. Big data includes velocity, variety, and volume beyond the average level [25]. In order to obtain Big data, sensors are used that collect an enormous amount of data on different states, areas, and circumstances within a short time [25]. To make use of the collected data, they have to be analyzed and interpreted. As a result, recommendations for actions can be derived, and necessary measures can be taken. This step is called data analysis.

2.3. Lean 4.0

While Industry 4.0 is a technology-centric approach, Lean Production focuses on people and the organization [21]. Therefore, the question arises of how both domains interact with each other. As shown in figure 1, three approaches describe the interdependencies of Lean Production and Industry 4.0 [4].

	Perspective	Description
	Lean Production as an enabler towards Industry 4.0	• Avoid digitalization of inefficient processes leading to inefficient digital processes
	Industry 4.0 advances Lean Production	• Industry 4.0 to face challenges that Lean Production could not handle • Industry 4.0 positively influences Lean Production methods in terms of achieving goals and increasing effectiveness
	Positive correlation between Lean Production and Industry 4.0	• Additional synergy effects can be generated • Benefits in both domains can be increased through a targeted combination of Lean Production and Industry 4.0 elements

Fig. 1. Existing perspectives on combing Industry 4.0 and Lean Production

Although these approaches are based on different assumptions, they do not contradict each other, even though there is currently no scientific consensus on the relationship between the two paradigms Lean Production and Industry 4.0. Nevertheless, the approaches presented pursue the same

objective of reducing production costs while increasing efficiency [3, 20, 21]. Hence, combining the two concepts of Lean Production and Industry 4.0 is called Lean 4.0 [11, 21, 26]. The change in the working environment caused by Lean 4.0 leads to a fundamental transformation of work [27]. Innovative technological development combined with Lean methods results in new tasks, and thus additional and new competence requirements arise. Therefore, competence management is an essential factor for the organization's ability to respond to the challenges faced by technology, organization, and people [27].

2.4. Competences

According to McClelland [28] and Klemp [29], a person's competence is described as a characteristic leading to improved or more effective work performance. Therefore, experiences and learnings acquired from past dealings with competencies serve as a resource for individuals to act competently [30]. This is based on integrity, which means that the individual's ability to act is detached from the situation [27].

Various authors have presented ways to cluster competencies [31-34]. A scientifically accepted approach to classify them is elaborated by Erpenbeck and Sauter [32] and Heyse and Erpenbeck [34]. They distinguish between technical-methodical, personal, social-communicative, and activity- and action-oriented competence (see table 1).

Table 1. Competence types, according to Heyse and Erpenbeck [34].

Type	Description
Professional-methodical	Ability to creatively master even almost unsolvable problems.
Personal	Ability to be self-critical and wise, to develop productive attitudes, ideals, and values.
Social-communicative	Ability to cooperate, communicate and interact with others on its initiative.
Activity- and action-oriented	Ability to implement all knowledge, the results of social communication, and personal values in a strong-willed and active way, integrating all other competencies.

The competencies presented in table 1 are often used in company-specific competence models to classify employee requirements [32]. Therefore, systematic competence management is needed to define, capture and develop competencies by identifying competence gaps [35]. Thus, competence development potentials can be determined [36].

For the successful implementation of new methods and technologies and their further development, functional competence management is indispensable. It supports a positive corporate culture and, at the same time, improves the companies' competitiveness [36].

3. State of the art

The following section presents relevant Lean Production (number I-II) and Industry 4.0 (number III-IV) competence models based on comprehensive literature analysis. In addition to the relevant competence models, other research by Young [37], Schöning & Mendel [38], and Klendauer et al. [39] exists, but it does not focus on production or production-related areas. Furthermore, there are approaches created by Hegmanns et al. [40] or Buck and Witzgall [41] that do not take Industry 4.0 or Lean Management into account. The findings and structuring are nevertheless incorporated into the model development (section 4).

(I) The authors Groth & Kammel [42] deal with the effects of the company's Lean Production implementation on employees. The authors mention the relevance of new and changing competence requirements, which arise from merging task fields and the established new mindset. Also, the importance of flexibility, adaptation to information technology conditions, and a holistic mindset are noted. (II) Brunner [43] also addresses necessary competencies that arise from Lean Production. The author investigates that ongoing education is a prerequisite for maintaining qualified and capable employees. In this framework, he addresses the importance of continuous improvement, an essential component of both initiative and problem-solving. In addition, he emphasizes the relevance of self-management skills for employees in companies to expand their leadership activities and thus fully exploit their potential.

Besides the Lean Production competence models also Industry 4.0 competence models could be identified. (III) An Acatech study [44] investigated the changes through Industry 4.0 occurring for employees in production and the logistics environment. It points out that these employees need new or further developed skills to cope with increasing complexity and be adaptable. The authors emphasize the increasing importance of interdisciplinary and data analytical skills as well as sound process knowledge. (IV) In the approach of Gehrke et al. [13], the authors distinguish between three prioritization types that future production employees must, should, or can have, taking into account the categories of technical and personal competencies. This classification highlights both the importance of skills such as communication and teamwork and capabilities in dealing with software interfaces or the IT infrastructure. In addition, they examine the importance of acceptance and trust towards technologies and conclude that future production employees have more generalistic than specific skillset.

Table 2 provides an overview of the presented approaches' competence clusters. Hence, it can be seen that the contents are based on the competence model of Heyse and Erpenbeck [34]. The competence models are further specified (Lean I-II) or extended by technological aspects (Industry 4.0 III-IV). Thus, the approaches focus mainly on identifying future competence needs caused by the change.

Table 2. An excerpt of competence classifications in the Lean 4.0 environment.

Approach	Competence types (Cluster)
I	Professional, methodological, participatory, social, learning, process, and project competence
II	Professional competence, problem-solving competence, learning ability, self-management competence
III	Technology and data-oriented, Process- and customer-oriented, Infrastructure and organization-oriented competence
IV	Technical and personal competence

Also, it can be observed that there is a lack of competence models that offer the possibility to distinguish the requirements of different job profiles or relate them to several tasks, as can be seen in table 3. Mansfield [45] identified this problem, and to date, no competence model has been found in the Lean 4.0 context that manages to represent these links. Concerning this paper, this means to provide a competence model that represents the different employees' requirements in the production environment, maintenance, and logistics. Moreover, it is essential to provide a competence model that links the role profiles in the production environment and their tasks resulting from Lean 4.0 methods and technologies.

Table 3. The framework of the considered approaches.

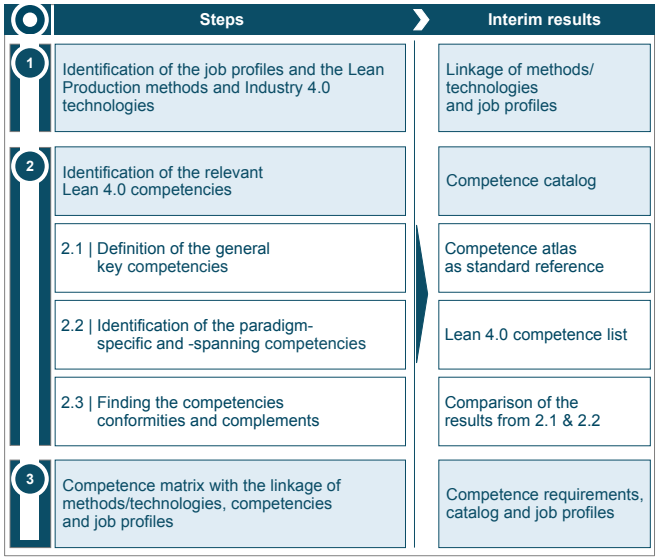
Comparison of the models							
		Industry 4.0	Lean Production	Production	Logistics	Maintenance	Methods/Technologies
I	Groth & Kammel [50]	●	○	○	○	○	○
II	Brunner [51]	●	○	●	○	○	○
III	Acatech [52]	○	●	●	●	○	○
IV	Gehrke et al. [53]	○	●	●	○	○	○
	Legend:	● fulfilled		○ not fulfilled			

Based on the identified gaps in the current state of research, a competence model will be developed that visualizes the required competencies of different job profiles for methods and technologies from Lean Production and Industry 4.0.

4. Methodological procedure and Derivation of the Competence model

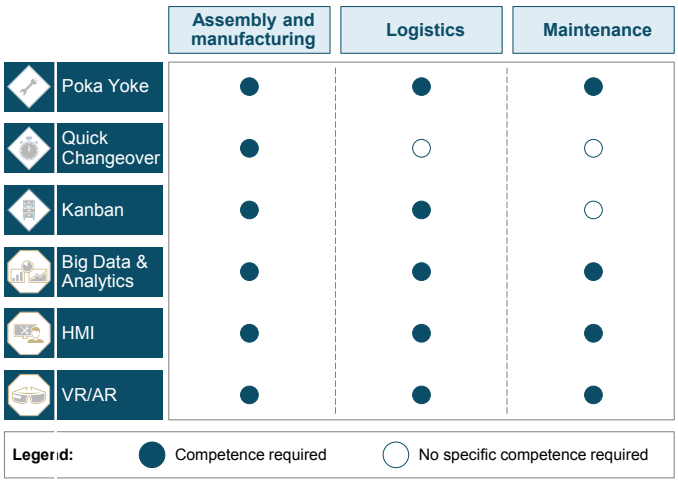
In the following, the methodological procedure is presented to identify employees' Lean 4.0 competence requirements in the production environment. Figure 2 provides an overview of the main phases, steps, and the interim results, which specify the objective's form. The presented procedure can be divided into three main phases, whereby the second phase consists of three steps. In the first phase, it is necessary to identify the technologies and methods used by the employees to determine the considered job profiles' competencies. Therefore, already implemented and in the future relevant Lean Production methods and Industry 4.0 technologies are identified and assessed to define the job profiles. Additionally, job profiles can be considered at different levels. For example, one possible distinction can be made based on the hierarchical levels of the jobs. Further separation can be made by looking at different operational activities. Concerning Lean 4.0, the focus needs to be on the operational employees who are directly involved in the value creation and continuous improvement process and are affected by technological innovations.

Fig. 2. Procedure for the development of the competence model



Subsequently, the selected methods and technologies must be explained in detail to precise their contents and procedures. The role profiles should also be described to reach a common understanding of the considered jobs and their fields of activity. Based on these results, a link between these two levels is established so that it is possible to conclude whether a considered job profile in the production environment requires competencies related to a selected method/technology or not. Figure 3 visualizes an example of a connection between job profile and methods or technologies.

Fig. 3. Competence requirements: Assignment of method and technology to job profile (Excerpt)



The second phase's overall objective is to create a competence catalog that includes all Lean 4.0 competencies essential for employees in the production or production-related environment. The first step is to select a reference competence model and to define the general framework in which the competencies should be clustered. Therefore, the widely and frequently used approach of Heyse and Erpenbeck [34] is chosen. They differentiate between four types of competencies,

shown in table 1, and visualize them with their associated competencies in a competence atlas. Based on this approach, the next step of Phase 2 is to examine scientific contributions concerning Lean Production, Industry 4.0, and Lean 4.0 competencies. In addition, interviews have to be conducted with experts from HR and production to identify and supplement competencies. As a result, a list of domain-specific and cross-domain competencies will be created to complement the reference competence model and work as input for creating the competence catalog.

Using the intermediate results of steps 2.1 and 2.2, the last step of phase 2 is accomplished in two levels of consideration. First, the intermediate results are examined for common competencies. Here, the focus is mainly on cross-paradigm competencies included in the competence atlas and the competence list from step 2.2. These competencies can be described as generally relevant competencies. Second, the intermediate results are reviewed for complementary competencies. Those not included in the competence atlas can be identified as paradigm-specific competencies and are therefore required by employees in the production environment whose work is influenced by Lean 4.0.

Combining these findings, a competence catalog, as shown in Table 4, was created. According to Heyse and Erpenbeck [34], the competence catalog's structure is divided into four competence clusters (see table 1). By listing general and paradigm-specific competencies as well as their descriptions for the considered job profiles, the competence catalog serves to provide an overview, concretization, and precision of the regarded competence framework.

Table 4. Excerpt from the competence catalog

Professional-methodical	
Interdisciplinary understanding	Ability to deal with interdisciplinary knowledge in an integrative manner
IT understanding	Ability to understand information technology challenges…
…	
Social / Activity- and action-oriented	
Problem-solving ability	Ability to successfully shape problem solutions
Ability to work with modern interfaces	Ability to accept new developments in terms of cooperation and execution of modern interfaces and to integrate them into the work routine…
…	
...	

In the final step, the connection between competence, role profile, and technology and method is established by linking the competence descriptions, the individual job contents, and information whether technology or method is used by the considered job profile or influences it in a way that a competence need arises. Therefore, expert interviews need to be conducted to achieve a competence model visualized in a matrix. Figure 4 shows the competence model with the five most essential competence requirements per job profile and subdivided according to Lean Production methods and Industry 4.0 technologies. The competencies were verified and ranked by five experts in the field "humans in the digital factory" at the TUM Institute for Machine Tools and Industrial Management.

	Assembly and manufacturing	Logistics	Maintenance
Poka Yoke	· Creative ability · Ability to modify & further develop · Ability to teamwork · Problem solving · Analytical ability	· Creative ability · Ability to modify & further develop · Ability to teamwork · Problem solving · Analytical ability	· Creative ability · Ability to modify & further develop · Ability to teamwork · Problem solving · Analytical ability
Quick Changeover	· Responsibility · Initiative · Discipline · Ability to modify & further develop · Analytical ability	-	-
Kanban	· Responsibility · Initiative · Ability to cooperate · Discipline · Integration ability	· Responsibility · Initiative · Ability to cooperate · Discipline · Integration ability	-
Big Data & Analytics	· Responsibility · Initiative · Communication · Discipline · Interdisciplinary thinking & acting	· Responsibility · Initiative · Communication · Discipline · Interdisciplinary thinking & acting	· Process know-how · Problem solving · Analytical ability · Ability to judge · Data evaluation and analysis
HMI	· IT Understanding · Openness to change · Ability to innovate · Ability to learn · Ability to work with modern interfaces	· IT Understanding · Openness to change · Ability to innovate · Ability to learn · Ability to work with modern interfaces	· IT Understanding · Openness to change · Ability to innovate · Ability to learn · Ability to work with modern interfaces
VR/AR	· Self management · Openness to change · Ability to innovate · Ability to learn · Ability to work with modern interfaces	· Self management · Openness to change · Ability to innovate · Ability to learn · Ability to work with modern interfaces	· Openness to change · Ability to learn · Ability to judge · Ability to work with modern interfaces · Data evaluation and analysis

Fig. 4. Competence model in the context of Lean 4.0 (Excerpt)

In summary, different statements about Lean 4.0 competencies for cross-functional job profiles can be made. For example, concerning HMI, all operative employees in the production environment need the same competencies. This can be attributed to the increasing penetration of machinery in the production system at the operational level, which increases the relevance of acceptance and uses in HMI. Furthermore, the competence model can be used to make the employees' requirements transparent and comparable. A further advantage of the competence model is that the need for competence development can be identified, and thus steps for qualification can be initiated to enhance the company's competitiveness.

5. Conclusion and Outlook

A functioning and holistic competence management system makes a decisive contribution to the company's success and employee satisfaction. Using a structured and comprehensive approach, the competency model derived in this paper provides a fundamental basis for defining competence requirements for employees, making them comparable, and developing them further. Moreover, by applying the methodology, an exemplary excerpt of all intermediate steps and an example for the final competence model was provided to visualize the identified competence requirements in the production environment.

The results show that employees in the Lean 4.0 production environment should have general competencies such as personal responsibility and initiative and paradigm-specific competencies like the ability to modify and further develop or to deal with interfaces. By creating such a competency model, general and paradigm-specific competencies can be identified to prepare employees for future challenges in the digital production environment. In addition, the competency model

can contribute to the successful implementation of the methods and technologies under consideration. Moreover, it ensures that employees can be informed in time, and thus the failure of the implementation due to preparation, involvement, and training of the employees can be avoided.

Building on these findings, the competence requirements for Lean Production methods and Industry 4.0 technologies should be researched in more detail. Future studies should therefore investigate the characteristics of individual competence assignments. One possible approach would be to use a scale to distinguish whether the employee has general, advanced, or expert knowledge in the considered competence. This level of detail could then be used to derive concrete and individual training offers.

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