APPLICATION OF LEAN MANAGEMENT TOOLS IN INDUSTRY 4.0: A SYSTEMATIC REVIEW

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ABSTRACT

The concept of Industry 4.0 is very recent and has not been fully consolidated, and, for this reason, comprehensive implementations by the industrial sector may not be prudent. Studies show that only fundamentals of Industry 4.0 do not guarantee characteristics such as quality, for example, in production processes. Thus, lean production concepts are probably being used together to cover deficiencies in Industry 4.0. In this work, a literature review is proposed that points out where lean production tools are being used in the production processes of Industry 4.0. Using the results of this search, an analysis of the most important lean production tools, which appear in the works, has been made. The analysis has shown what is being used, in terms of the lean tools, in the production processes of Industry 4.0, and what improvements are provided from these tools.

Keywords: lean; industry 4.0; review of bibliography; PRISMA

s856

1. INTRODUCTION

The industry's interest in the search for tools to improve the production performance of consumer goods is constant. Within this context, two concepts stand out: Lean and Industry 4.0.

After World War II, the world saw rises the Toyota Production System (STP) or Lean Management (LM) in Japan. The Lean philosophy, also known as lean production or STP, is a multidimensional approach that includes a wide variety of management practices in an integrated system. The Lean Management is considered "slim" because it uses fewer resources for mass production. The basis of STP is the complete waste elimination, supported by two pillars: just-in-time and autonomation[1]. Just-in-time means ensuring that each process receives the necessary item, when necessary and in the required quantity. Autonomation involves giving intelligence to the machine, in order to detect abnormal conditions and stop the process automatically, avoiding the generation of defective products (Bento, Gomes & Tontini, 2019).

On the other hand, the Industry 4.0 (I4.0) concept emerged at a congress held in Hannover, Germany, in 2011, bringing a wave of development to the industry. Countries that have been investing in other industrial production technologies had even more government investments for collaborations between industry and academia for Industry 4.0 projects, generating a new revolution (Souza et al., 2020). For the implementation of Industry 4.0 to be viable, there must be an entire structured base on some pillars, such as the Cyber-Physical systems, the Internet of Things and Digitization (Ustundag & Cevikcan, 2017).

Lean and Industries 4.0 are from different moments in the industry history, however both aim at the search for improvement and constant efficiency of the means of production. Nevertheless, I4.0 is a very recent concept, which has not yet been fully consolidated, and the idea of a comprehensive implementation through the industrial sector frightens businessmen (Tortorella et al., 2019).

In addition, some authors believe that only fundamentals of I4.0 cannot guarantee some desired characteristics, such as quality in production processes (Pagliosa, Tortorella & Ferreira, 2019) and that Lean Production concept should probably be used together to cover certain deficiencies of I4.0 (Tortorella et al., 2019). For these reasons, it is

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[1] Grants the operator or machine the autonomy to block the process whenever it detects any abnormality

understood in this work that the LM tools are being associated with the production processes of I4.0. Thus, the following question arises:

"What lean tools are being applied to the I4.0 production processes?"

Therefore, the objective of this article is to carry out a systematic literature review on scientific articles available in CAPES Journals, and thus to identify which LM tools are used in I4.0 and where they are applied. Thus, it will be possible to draw the current scenario of what has already been done in the scope of research and guide future steps.

In addition to the introductory part, a review of the literature is presented in this article in the second part, the methodological steps in the third part, in the fourth part the results obtained in this analysis are presented and, finally, in part 5 the conclusions are highlighted.

2. THEORETICAL REFERENCE

LM seeks to eliminate waste, absorbent resources activities that do not add value (Oliveira et al., 2017) and is based on tools that seek continuous improvements such as Lean Six Sigma (LSS), Lean Construction, Overall Equipment Effectiveness (OEE), Value Stream Management (VSM), Glenday Sieve and others. LSS is a methodology that aims to integrate Lean and Six Sigma philosophies, which is a set of practices to systematically improve processes by eliminating defects (Sony, 2020). Lean Construction is a current practice that aims to better reconcile the needs of customers using the least number of resources possible and is also based on the principles of production management (Amaral, Oka & Camargo Filho, 2018).

One of the main performance indicators in Lean is OEE, which is based on the multiplication of three parameters associated with the equipment: availability, performance, and quality. Used as a tool in total productive maintenance (TPM), OEE is the key to indicate the performance of all organizations committed to eliminating waste (Besutti, Machado & Cecconello, 2019). VSM is an important LM tool to evaluate criteria related to the process flow. The VSM analysis is based on roadmaps of the manufacturing processes, showing each step of value or non-value added.

These steps can cost, process time, and other factors mapped from the orders received. VSM creates a link between material, information, and process flow (Lugert, Völker & Winkler, 2018). The Glenday sieve is a methodology for identifying a high volume of the production process, which focuses on implementing process improvements

based on introducing color-coding or subtitles for the output volume in each part of the process. With this methodology, it is possible to identify small portions of the business that are responsible for a large part of sales (Rosienkiewicz et al., 2018).

LM concepts can be applied to advanced manufacturing processes, such as I4.0, leading to several improvements such as quality, waste, and others. I4.0 allows more production autonomy as the technology becomes more interconnected and the machines can influence each other (Villalba-Díez et al., 2020). The basis of I4.0 is composed of some pillars such as: Artificial Intelligence; Cyber-Physical Systems; Big data; the Internet of Things (Besutti, Machado & Cecconello, 2019). Artificial Intelligence is a branch of computer science that using algorithms defined by specialists can recognize a problem, or a task to be performed, analyze data and make decisions, simulating human capacity (Causa, 2018). Cyber-Physical Systems, in the context of I4.0, refers to the strong conjunction and coordination between computational and physical resources. The impact on the development of such systems is a new paradigm of technical systems based on collaborative embedded software systems (Villalba-Díez et al., 2020).

The amount of data generated by humanity is climbing sharply, the so-called Big Data, and traditional production processes will not be able to handle dealing with this gigantic amount of data, whether to allow production forecasts or mere information processing (Villalba-Díez et al., 2020). In I4.0 artificial intelligence algorithms can be used to mine this data and separate the essential information that will be used to support management decisions (USTUNDAG; CEVIKCAN, 2018).

3. METHODOLOGY

For the selection of the articles to be analyzed, it was necessary to choose a method for this purpose. It must be study, understand and evaluate the various methods available for conducting academic research, in order to determine its effectiveness in the search (Filser, Silva & Oliveira, 2017). The Preferred Reporting Items for Systematic Reviews and Meta-Analyzes (PRISMA) is presented in the literature as one of the most effective methods (Moher et al., 2009). Once the method was determined, the search terms were defined within the platform of the *Portal Periódico Capes* (the only one we have institutional access), Cafe.

They are "Industry 4.0", "Lean Manufacturing" and "Lean Management". At first, the term "Industry 4.0" AND "Lean Manufacturing" was used, which resulted in a total of 180 publications. After, "Industry 4.0" AND "Lean Management" returning a total of 71.

Figure 2 shows the filtering procedure used. Filtering parameters were used, such as ENGLISH, document type ARTICLES, published between 2014 and 2020. After defining these criteria, it was possible to verify a total of 166 articles with the search for terms "Industry 4.0" and "Lean Manufacturing" and 62 articles in the search for "Industry 4.0" and "Lean Management", among these 29 were repeated. Then, 199 were defined for verification in the next analysis phase and 228 articles were removed.

The next step was to analyze the titles and abstracts of each article to find out if those publications fit the proposal presented. Thus, 39 articles were selected for a full reading. With the full reading, 2 articles that were not related to the proposal's theme were discarded.
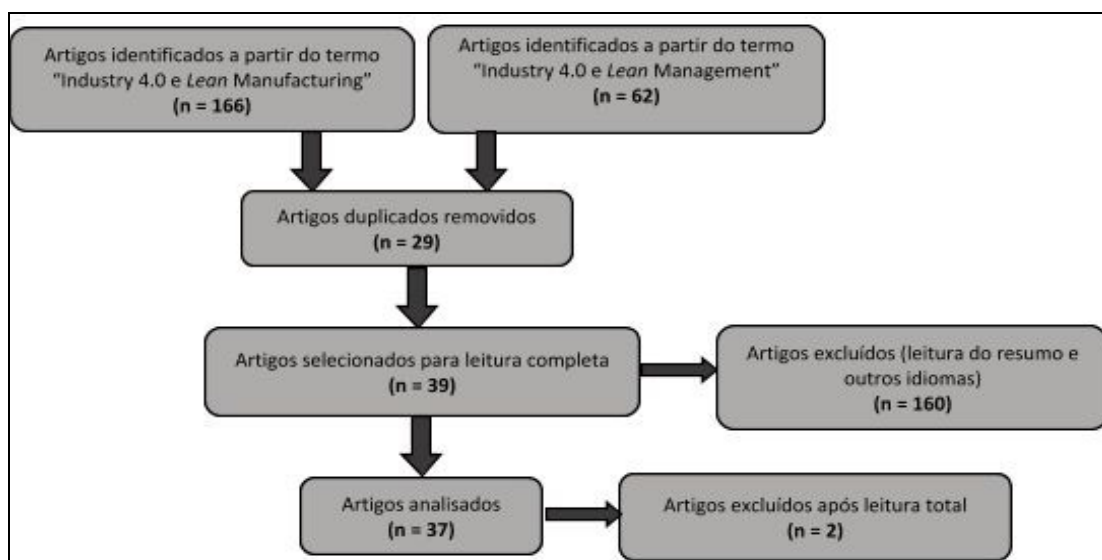

Figure 1: Prisma Protocol
Source: Own elaboration (2020)

An analysis of LM tools used in I4.0 was made on the 37 articles, but we only identified concrete applications of LM in I4.0 in 8 of these works and the result of this analysis is presented in Chapter 4.

4. RESULTS AND DISCUSSION

Analyzing the data obtained, it was possible to identify 8 examples of the application of the SC in I4.0, as shown in Table 1. Dallasega et al. (2020) argue that lean construction allowed improvements in the quality and sustainability of production that were reflected by key indicators that measure production progression in general, production time, and waiting time. Lauria and Azzalin, (2019) find similar results applying lean construction and pointed out a 15% cost reduction. Sony and Michael (2020) state that the strategic connection project using the LSS methodology saves the cost of

unnecessary data collection and is more effective because it is linked to the customer's needs.

Table 1: Examples of LM application in I4.0

Author	Year	Journall	Tools
Dallasega et al.	2020	ScienceDirect Journals (Elsevier) - Procedia Manufacturing, 2020, 45, 49-54	Lean Construction
Sony	2020	Taylor & Francis (Taylor & Francis Group) - Production & manufacturing research, 2020, 8(1), 158-181	LSS
Huang et al.	2019	ScienceDirect - Journal of ManufacturingSystems, 2019, 52, 1-12	VSM
Besutti, Machado and Cecconello	2019	Directory of Open Access Journals (DOAJ) - Scientia cum Industria, 2019, 7(2), 52-67	OEE
Lauria and Azzalin	2019	© ProQuest LLC All rights reserved - Techne,2019, 18, 184-190	Lean Construction
Lugert, Völker and Winkler	2018	ScienceDirect Journals (Elsevier) - Procedia CIRP, 2018, 72, 701-706	VSM
Rosienkiewicz et al.	2018	Portal de Revistas Científicas e Profissionais Croatas - Hrčak - Drvna Industrija, 2018, 69(2), 163(11)	Peneira Glenday
Rafiq et al.	2018	ScienceDirect Journals (Elsevier) - Procedia Manufacturing, 2018, 23, 237-242	VSM

Source: Own elaboration (2020)

The design of the parts of the I4.0 systems carried out with the support of the 5 LSS principles helped to bring a structured and strategic analysis of the total, minimizing the waste of resources (Sony, 2020). Huang et al. (2019) state that VSM can be used to improve the multiple flows of processes in I4.0, providing valuable information for decision making. Lugert, Völker and Winkler (2018) also point out that the VSM-based methodology was successful in providing increased productivity and flexibility in the process.

On the other hand, Rafiq et al. (2018) use VSM in I4.0 to make the whole process more efficient and effective. Highlighting as a result that the execution time of the whole process went from 210 minutes (before VSM) to 137 minutes (after VSM). Besutti, Machado and Cecconello. (2019) argue that OEE can be used to assist in quality control in I4.0. The design of 4.0 component replenishment systems that use Glenday sieve combined with AI systems capable of making effective predictions that can significantly increase the speed and productivity of processes (Rosienkiewicz et al., 2018).

s861

The results show that several LM tools are used in I4.0 such as LSS, OEE, and VSM, the latter being the most cited. Of the articles analyzed, two articles say that the LM tool used has allowed for an improvement in the quality and sustainability of production processes. In these two articles, Lean Construction and OEE were used. There was a reduction in the costs of the production process and the tools Lean Construction and LSS are used. In one article there was an improvement in the multiple flows of processes using VSM.

In two articles, the authors report that the VSM allowed an increase in productivity, but another author also achieved an increase in productivity using the Glenday sieve. Thus, strong evidence was presented that there is a use of LM tools in I4.0 applied to improve the production process, however, they are limited to the areas of simulation software. It is possible to see that in all the examples raised, LM tools are applied in virtualization layers (cyber-layers) to assist in optimization processes or even as restrictions in operational research problems related to complex computational calculation processes.

5. CONCLUSION

In this article, a systematic literature review of the application of LM tools in I4.0 was carried out. This mapping was carried out on the Capes Periodic Platform through the PRISMA protocol from 2014 to 2020. For the search, the terms "Industry 4.0", "Lean Manufacturing" and "Lean Management" were identified. 228 articles were initially found, but after a detailed analysis and application of the protocol, only 8 articles remained.

The analysis revealed that there are several LM tools applied to improve I4.0 production processes, such as Lean Construction, Value Stream Management, Lean Six Sigma, Overall Equipment Effectiveness, and Glenday Sieve. Several forms of improvement were identified, such as, improving the quality and sustainability of production processes, reducing costs in the production process, improving the multiple flows of processes, and increasing productivity, and it has demonstrated the applicability of LM tools in I4.0. However, the only area of industry 4.0 that receives the LM tools is the virtualization layer (cyber-layers). It is believed that this is due to a more computational nature of the LM tools that are used in the optimization processes, for example in constraints variables in operational research problems.

The next steps in this research include understanding the reason why LM tools are

found in applications only assisting the computational process in the virtualization layers in I4.0.

6. ACKNOWLEDGMENT

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s864