How Industry 4.0 and Lean Management Are Interrelated with Green Paradigm

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Abstract. Recently, sustainability has been tackled several times due to the impending climate change the earth is facing. Numerous techniques have been applied to reverse the direction companies were going into. In this paper, it is explained the importance that Lean Manufacturing tools and Industry 4.0 technologies can have on the sustainable side of a company. The aim of this work is to fill the scientific gap related to studies deepening the combination of these different paradigms, Industry 4.0-Lean-Green, which have been scarcely investigated together. Thus, a Systematic Literature Review has been performed to detect which were the key variables of these three fields and then, it was studied what their interaction was. This study is giving the opportunity to understand the main variables of Industry 4.0 and Lean manufacturing on which companies have to act in order to have an impact on green variables and their overall sustainability.

Keywords: Green · Industry 4.0 · Lean Manufacturing

1 Introduction

Nowadays, customers' requests and environment's claims push industries to be even more precise, correct, fast and respectful. Customers wants products to be still more customized, flexible, durable with the least possible cost and the highest possible quality which can respect their private and social needs. On the other side, the environment asks for the reduction of resources' usage and the release of the minimum possible pollution, tackling the climate change and working to preserve the eco-system. As a result, industries, as part of our society, are pushed by an urgent call for action. To answer to these combining needs, companies select and team up different approaches. In this paper we will discuss in particular about the Industry 4.0 technologies, Lean practices and the Green paradigms. Lean manufacturing is one of the most applied methodologies and according to Womack and Jones [1], it is about the implementation of a continuous improvement which allows companies to reduce costs, improve processes and eliminate wastes in order to increase customers satisfaction. The fourth industrial revolution, recognized as the Industry 4.0 (I4.0), involves a hyper-connected system of smart materials, factories, suppliers, distribution channels, and even customers. It

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can provide higher levels of productivity and customizations [2] by delivering a value-add to end users. The Green paradigm (GP) was born as a philosophy to reduce the negative ecological influence of an organization. It aims to reduce environmental risks and impacts while improving ecological efficiency and eliminating environmental waste in organizations [3]. Despite the strong interest on the Industry 4.0-Lean Manufacturing implementation from a sustainable perspective, the literature lacks of real knowledge to adequately address all these topics within companies. In order to address this lack, this paper will identify the relevant variables, coming from the GP, the I4.0 and Lean Manufacturing (LM) paradigms, and their relationship.

2 Research Question

The aim of this paper is to combine three different paradigms, Industry 4.0-Lean-Green, which have been scarcely investigated together. The detection of variables in each domain is of paramount importance as also the existing associations between them. Given these premises, the developed research question (RQ) is: "What are the key variables and their relationship that the manufacturing organizations have to take care of in implementing the Industry 4.0 together with the Lean paradigm towards the Green one?". This question has found an answer in the paper through the conduction of a Systematic Literature Review (SLR) and a subsequent table showing the linkages among the identified variables.

3 Methodology

3.1 Systematic Literature Review

The Systematic Literature Review (SLR) represents the starting point and it is beneficial to answer to the focal question of this work. Firstly, to guarantee valid results, each of the three paradigms was defined. Secondly, to study all the three topics, it has been decided to focus the attention on three investigations made by the combination of the three paradigms. A structured methodology was applied for each of the investigations and relied on a five-steps process showed in the following Fig. 1.

The database selection was fundamental to base the research on a reliable source. Papers have been selected from Scopus containing renowned publications like Emerald, Taylor and Francis, Springer, IEEE, and Elsevier. The keywords have been chosen with the aim of reaching more inherent articles possible. The filtering performed after the research was based both on inclusion criteria as document type (review), subject area (Business, Management and Accounting; Engineering; Energy; Environmental Science; Social Sciences; Decision Sciences; Computer Science; Economics, Econometrics and Finance) and language (English) and on additional screening techniques looking at the Journal Quality type (Q1), title, keywords and abstract. Finally, the reference analysis was done checking the inherent topic, the Journal Quality type (Q1), title, keywords and abstract of the cited documents.

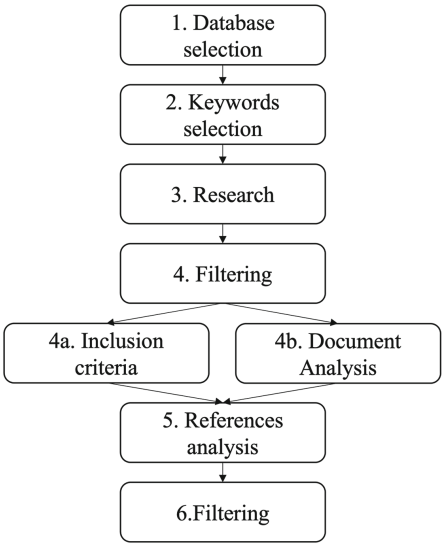

Fig. 1. Structured Methodology of five-steps adopted for conducting the literature research.

3.2 Interrelationship Table

To continue answering the research question, it is necessary to understand the relationships between the variables found thanks to SLR. Thus, the relations identified in the literature have been collected in the Table 1. The first column represents the "impacting variable" that influences the "impacted variable", put in the second column. In the latter column, for the affected variable, there are indicated also the references to the considered articles which talk about that specific relationship.

4 Results

4.1 Systematic Literature Review

As a result of single researches about the three topics, the I4.0 and the LM represent analyzed and well-defined topics in the literature, while the boundaries around the Green paradigm result still more blurred, because addressed in recent years. Then, the involved combinations have been the following: the understanding of how Industry 4.0 technologies and Lean practices link each other, how Digital technologies (DTs) can influence the GP and how Lean practices impact on the GP. To each of them the 5-steps process has been applied.

Industry 4.0 & Lean Manufacturing. The analysis related to the combination of Industry 4.0 and LM concepts saw the selection of "Lean AND Industry 4.0 AND Literature review" as keywords to conduct the research. The initial quantity of found documents was 110. After filtering them and taking into account references, 30 articles have been considered. Industry 4.0 and lean tools are presented as complementarities to support system design and improvement [4]. Although LM practices can be carried out without the help of IT tools, manufacturing digitization is crucial to the LM implementation and its continuous improvement to achieve benefits in term of productivity improvement [5].

The literature evidences that is unclear, on a quantitative basis, which practices could be combined, which ones are complementarities, and which contradict each other, concluding with the lack of a framework quantifying all the possible links between Industry 4.0 and LM [6].

Industry 4.0 & Green Paradigm. In order to analyze the Industry 4.0 and Green context, the keywords have been "Green AND Industry 4.0 AND Literature review". The research has given 201 documents as a result. After the filtering phase, 9 papers remained, and the next phase of the reference analysis added 31 more. Through sustainability practices (sustainable production, sustainable purchasing, sustainable performance measurement and management, sustainable governance, sustainable marketing, sustainable design and circular economy), Industry 4.0 contributes to sustainability performances (environmental, social and economic ones). Such practices offer advantages such as manufacturing productivity, resource efficiency and waste reduction [7] and control of energy consumption. Overall, DTs will have a positive impact on the environmental performance, even if fully automated production could lead to a higher energy consumption or an increased demand for scarce raw materials. Only those companies able to integrate a sustainable use of Industry 4.0 standards in their systems will be competitive in the long run.

Lean Manufacturing & Green Paradigm. For the analysis between the LM and the GP, "Lean AND Green AND Literature review" as keywords have been chosen. This time the research led to 38 documents of which just 5 were selected according to the inclusion criteria. The final number obtained from that investigation resulted to be 44, because other papers were added after the reference analysis phase. Researchers conclude that LM and GP are overlapping in terms of obvious similarity: the LM considers as the main objective the reduction of time and waste, as well as the GP consider the reduction of the environmental footprint, but the definition of waste represents a conflicting point. LM focuses on workforce and space reduction to increase flexibility, while GP aims at reducing, recycling and reusing (3Rs). Additionally, LM aims at reducing non-value adding activities which could be translated as the reduction of energy and natural resource consumption. Considering the lean practices, the Value Stream Map (VSM) is one of most used tool because it is adaptable to the context with just a change in the meaning of the type of non-value added activity. 5S allow to achieve less defects, cutting the environmental waste; the Human Resource Management (HRM) has a positive effect considering the training and commitment of the people. Total Productive Maintenance (TPM) also has a positive effect through the proactive and preventive maintenance, reducing emissions, resources and scraps; JIT is one of the most conflictual, in both positive and negative way [8–10]. Tools, principles, resources, practices and strategies, proper of each of the three cited paradigms, can be promoted as variables to achieve the common goal: the exploitation of the I4.0 and LM paradigms to impact the Green one. Thus, the SLR allowed to answer to the first part of RQ with the identification of twenty-seven variables distributed in the following three clusters showed in the Fig. 2:

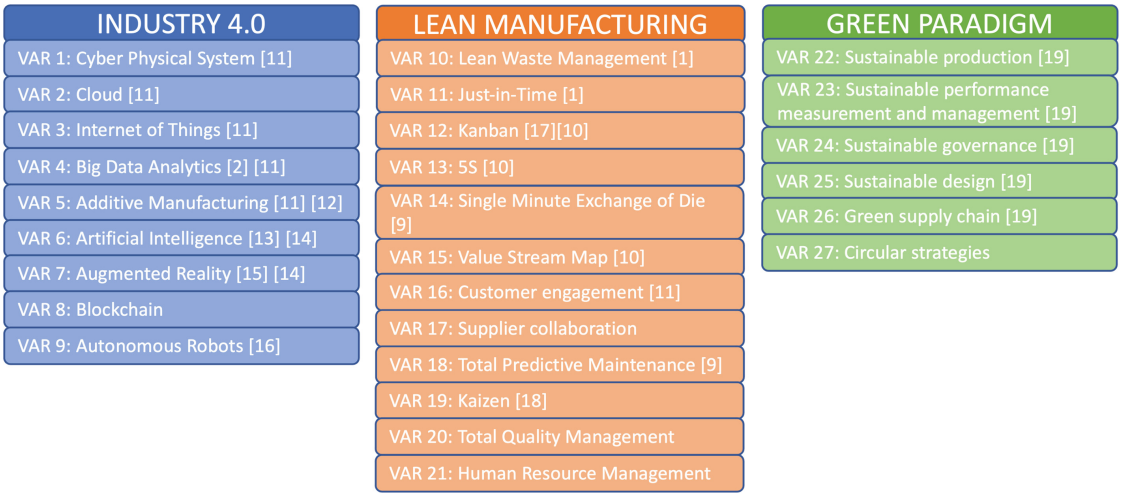

Fig. 2. Three clusters of key variables.

4.2 Interrelationship Table

This passage is very important, because a variable can be affected not only by increasing and dedicating to it more resources but also influencing other variables on which it depends. In this paper the relations under analysis were the ones identified in the Systematic Literature Review between the variables of three domains: the I4.0 and the GP, the LM and the GP and the I4.0 with the LM. The influence of "variable 1" to "variable 2" for each of these three combinations is meant to be unidirectional. As a result, the following table (Table 1) is showing all the of the 21 variables (I4.0 and LM ones), according to the directed and chosen combinations.

Table 1. Interrelationship table

Impacting variable	Impacted variable [references]
1	12, 15, 18 [16], 21, 22, 25, 27
2	11 [20, 21], 12 [7], 14, 16 [21], 17 [21], 23 [19], 24, 25, 26 [19], 27 [22]
3	12 [21], 15 [6], 22, 23, 25 [20], 26, 27
4	11 [10], 12 [7], 13 [7], 14 [5], 16 [16], 17 [16], 18 [16], 20 [21], 21, 22 [19], 23, 24 [23], 25 [20], 26 [19], 27 [24]
5	11, 12, 14, 18 [10], 22 [25], 25, 27 [25]
6	11 [13], 12 [13], 15 [13], 18 [13], 19 [13], 20 [16], 22 [26], 23, 24 [23, 27, 28], 26, 27
7	11, 12 [29], 13 [16], 15 [4], 21, 23, 27
8	16 [30], 17 [30], 23, 26

(*continued*)

Table 1. (*continued*)

Impacting variable	Impacted variable [references]
9	11 [21], 12 [5], 13 [21], 21, 22, 23
10	1, 3, 4 [6], 9 [13], 22, 23, 26, 27
11	2 [16], 22, 23, 26
12	5 [12, 13], 22, 23, 26
13	7 [13], 9 [13], 22, 23, 26, 27 [8]
14	22, 23
15	2 [16], 4 [16], 22 [9], 23, 25, 27 [9]
16	23, 25, 26, 27
17	23, 26 [18], 27
18	22, 23, 27
19	2 [16], 4 [6], 9 [6], 22 [9], 23 [18], 25, 26, 27
20	22, 23, 26, 27
21	22, 23 [8], 26, 27 [17]

5 Discussion

From the interrelationship matrix, the most impacting I4.0 variable for the green ones is VAR 4, as Lopes de Sousa Jabbour declared, the collected data foster sustainable operations management decisions, contributing to the connection between the principles of circular economy and I4.0 [11]. It affects all the GP variables identified, thus it is convenient to manage it cleverly. The most impacted green variables from I4.0 and LM ones were VAR 22, VAR 27 and VAR 23 an example is provided by Tan in the case of green logistics implemented by blockchain [31]. While the less affected variable from the Green paradigm was VAR 24, where sustainability should be considered at a business long-term decision level, thus more complicated to reach.

6 Conclusions

An answer to the formulated research question has been given in two steps. Firstly, the Systematic Literature review referred to the three combinations of the domains and produced an outcome of 27 key variables. Secondly, the relationships between these variables were analyzed. As a result, the most impacted green variables from Industry 4.0 and Lean manufacturing variables were identified. Indeed, in manufacturing contexts, where DTs and lean tools can be recognized, they can be used as levers from the company to reach, through their performances, yearly company's sustainable goals.

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