The Bilateral Effects Between Industry 4.0 and Lean: Proposal of a Framework Based on Literature Review

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Abstract

Industry 4.0 (I4.0) is a paradigm based on connectivity, real-time information flows, and decentralized decision-making processes. Lean is a traditional management practice that aims to promote processes that can increase value and minimize waste. Despite these practices appearing in different ages, and with different motivations, the mission that guides them culminates in the same purpose - to increase the level of operational and organizational efficiency. Information Systems (IS), particularly MES and ERP systems, in addition to representing ISs of choice for I4.0, represent data aggregating systems and facilitators of standardization and automation of the processes inherent to these two practices (Lean and I4.0). The present work, based on the literature review, proposes a Lean 4.0 shop floor framework with the main bilateral effects between Industry 4.0 and Lean, based on the challenges established by I4.0 and with the contribution of IS.

Keywords
Industry 4.0; Digitization; Information Systems; Lean Manufacturing

1. Introduction

Industry 4.0 (I4.0) is driven by the principles of connectivity and grounds its decision-making processes on decentralized models (Mantravadi & Møller, 2019a). According to Savastano, Amendola, Bellini, and D'Ascenzo (2019), I4.0 promotes the creation of cyber-physical systems that interconnect physical components with digital elements, thus being able to operate at different time and space scales (Xu, Xu, & Li, 2018).

The manufacturing organizations' shop floor represents the appropriate scenario for the convergence of physical and digital space, in the I4.0 context (Tao & Zhang, 2017). According to Sony (2018), an industrial organization that integrates the cyber and the physical is considered a Smart Factory, with a predominance of flexible production systems, useful in reconfiguring planning using the principles of digitization. For the interconnection of these components, in addition to emerging technologies, such as the internet of things (IoT), artificial intelligence, cloud computing, among others (Sony, 2018; Telukdarie & Sishi, 2019), the literature identifies the Information Systems (IS) as key tools in the context of this industrial revolution. Within the several types of business IS, the Manufacturing Execution System (MES) represents the one that allows connecting, through Programmable Logic Controller (PLC) and sensors, the events that occur on the shop floor with the events planned and normally stored in the highest level integrated systems, as is the case with Enterprise Resource Planning (ERP), and, in this way, supporting the decision making (Mantravadi & Møller, 2019b). However, to materialize the MES in the context of industry 4.0, it is important, at first, to understand the whole process and ensure that it is robust. In most industrial environments, employees are not properly aligned with the company's information flow, even though they are treated as productive resources. From a management perspective, there is a lack of online information on processes, materials and equipment (Oborski, 2018).

Given the importance of this type of systems operating on clearly defined processes, absent of waste sources and properly mapped, the integration of approaches associated with the Lean management philosophy can represent a facilitating factor. It is already mentioned in the literature that Lean practices can support the improvement of processes that are fundamental to automation, and organizations must present a certain level of maturity of Lean practices, before starting an I4.0 strategy (Rossini, Costa, Tortorella, & Portioli-Staudacher, 2019).

This article analyzes the challenges of an Industry 4.0 implementation strategy and how the Lean philosophy can be useful in reaching the answers to those challenges. To this end, an exploratory literature review was carried out in order to evaluate the impact of Lean on I4.0, and vice-versa, culminating the results in the proposal of a Lean 4.0 shop floor framework, capable of summarizing the bilateral benefits of these practices - Lean and I4.0.

In the first section, an analysis of the literature is conducted pondering key concepts such as Industry 4.0, Digitization, Lean and Information Systems (here the two main systems in an organization, MES and ERP are focused). Then, in the second section, the framework is displayed, as well as the explanation of its core elements. Finally, final considerations are highlighted, as well as some further research.

2. Theoretical Background

2.1 Industry 4.0 and the Digitalization necessity

Industry 4.0 emerges with a redefinition and reorientation of processes to digitizing the physical world through the introduction of various technologies, such as artificial intelligence technologies, internet of things (IoT), cloud computing, cyber-physical systems, among others (Sony, 2018; Telukdarie & Sishi, 2019; Xu et al., 2018). The IoT is the crucial technology in the 4.0 environment since it enables the incorporation and communication between the different technological layers of the organization, establishing the integration of processes and data flows in real-time (Govender, Telukdarie, & Sishi, 2019).

Within the scope of I4.0, three types of integration are known: vertical, horizontal, and end-to-end integration (Telukdarie & Sishi, 2019). In vertical integration, the organization is connected in hierarchical terms, thus guaranteeing a continuous data flow between the production systems, usually at the shop floor level, and the management layers through the ERP (Enterprise Resource Planning) system (Govender et al., 2019). Horizontal integration delivers information sharing between the supply chain, involving business partners. Finally, end-to-end integration provides and manages all functions and data flow evolving from product lifecycle management (Govender et al., 2019; Telukdarie & Sishi, 2019).

In the scope of vertical integration, and associated with cyber-physical systems, a new concept emerges, the Digital Twin (DT) (Schroeder et al., 2016). This concept is based on the creation of virtual models using physical entities for this purpose, thus offering the possibility of making decisions in virtual environments, while assessing and analyzing the impacts of these decisions on the physical world (Qi & Tao, 2018). Additionally, DT allows to represent real-time production systems and other organizational components (Zhu, Liu, & Xu, 2019).

However, for the DT concept to be efficiently implemented, it is necessary to transpose the physical world to the digital world, attending to the level of integration of resources, services, as well as the necessary skills to operate in this new reality (Gigova, Valeva, & Nikolova-Alexieva, 2019). Despite the vast literature on I4.0, and DT, few studies report the challenges inherent to the introduction of this paradigm in the context of companies. Table 1 summarizes a set of challenges inherent to the adoption of the Industry 4.0 paradigm, based on different sources present in the literature.

Table 1- I4.0 challenges

I4.0 challenges	Description
Digitizing the shop floor is expensive and time-consuming	Need to acquire new hardware, to update the physical and technological infrastructure, to integrate systems and to carry out and promote in-house training for employees (Ghobakhloo & Fathi, 2020). The installation of equipment with sensors, controllers and data transmission modules is time-consuming for the company (as well as resources) (Ghobakhloo & Fathi, 2020; Haddud & Khare, 2020).
The digitization process needs specialized knowledge	Many companies lack skills for digitization (Ghobakhloo & Fathi, 2020; Haddud & Khare, 2020), and therefore need to use external service/consultants (Ghobakhloo & Fathi, 2020).
I4.0 lacks the definition of a digital strategy	In the scope of I4.0, before its effective operationalization, it is necessary to define a strategic plan for digitization (Haddud & Khare, 2020). The company's digital maturity must be assessed, and the future action plan must be defined, clearly integrating the goals to be achieved (Romero, Flores, Herrera, & Resendez, 2019).
Digitization requires the intervention of all (of people)	It is essential that employees are open to change and willing to participate in it (Ghobakhloo & Fathi, 2020). It is also essential to foster a culture based on factors of innovation, adaptability, openness, transparency, decision based on data and focused on customer requirements (Romero et al., 2019).
Digitization can decrease problem management skills	The introduction of numerous levels of automation can degrade the skills of employees (Stadnicka & Antonelli, 2019). Also, the skills in moderating problem management are less used and decrease by managers and / or team leaders (management is more remote and even autonomous with the introduction of I4.0 technologies) (Meissner, Müller, Hermann, & Metternich, 2018).
Digitization and automation require definition, mapping and standardization of processes	When I4.0 was introduced, all processes must be known, mapped and standardized, thus allowing their reproducibility for virtual environments (Mayr et al., 2018), while ensuring a known data flow (Rosin, Forget, Lamouri, & Pellerin, 2020).
A priori need for the shop floor to have Lean management	For a successful implementation of I4.0, companies must pay attention to Lean management (Wagner, Herrmann, & Thiede, 2017). The Lean implementation combined with I4.0 leads to an improvement in operational performance (Rossini, Costa, Tortorella, et al., 2019).

Taking into account Table 1, it should be noted that, in addition to what is already expected, such as financial investment, companies that wish to embrace this new paradigm associated with the fourth industrial revolution will have to deal with several challenges, namely: (i) acquisition of technological resources (Ghobakhloo & Fathi, 2020); (ii) integration of specialized human resources (Ghobakhloo & Fathi, 2020; Haddud & Khare, 2020); (iii) definition of a digital strategy (Romero et al., 2019); (iv) promoting a culture that fosters everyone's participation, involvement and collaboration from management to the most operational level (Meissner et al., 2018; Romero et al., 2019); (V) guarantee the knowledge (mapping) of all processes, so that they can be reproduced (Rosin et al., 2020); and, finally (vi) take advantage of the lean culture already present in most companies, as this is seen as a facilitator of the principles of I4.0 (Teixeira, Ferreira, & Santos, 2019; Wagner et al., 2017).

2.2 Lean: An organizational management philosophy

The Lean philosophy aims to minimize sources of productive waste, thus ensuring an increase in operational and organizational productivity, as well as the quality of the products and services produced (Haddud & Khare, 2020). Besides, establishes a set of practices aimed at reducing inventory, decreasing the variability of processes, minimizing delivery times and customer satisfaction, as well as lowering cycle times (with minimum delay in processes)

(Mardiana & Alfarisi, 2020). For this, it uses a set of techniques, tools and methods, some of which described in Table 2.

Table 2- Lean tools description

Lean tools	
Value Stream Mapping	Lean tool allows to have a global perspective of the entire production process (materials and data flow). It offers organizations the ability to develop a map of the current state of how the company works and a map of the future state (Kale & Parikh, 2019).
Total Productive Maintenance (TPM)	Total Productive Maintenance Management includes practices that help to anticipate or reduce the frequency of equipment stoppages, ensuring the smooth completion of activities related to production (Yadav et al., 2020).
Hoshin Kanri	Technique that intends to transform the corporate vision of a company into objectives and actions that are cascaded into the organization to achieve multilevel PDCA cycles (Plan-Do-Check-Act) (Romero et al., 2019).
Poka-Yoke	Mechanisms that help employees avoid production errors (Mayr et al., 2018).
Just-in-Time	Method that guarantees the delivery of the right product, at the right time and place, with the appropriate quantity and quality, at the appropriate cost (Mayr et al., 2018).
Total Quality Management	It includes the adoption of innovative quality practices, such as the commitment of top management and the strategic planning of all production processes (Yadav et al., 2020).
Kanban	It intends to maintain a minimum stock level, with a view to the uninterrupted supply of material (Mayr et al., 2018).
Andon	It works as a real-time tool for communicating problems that may occur in the workplace in order to obtain an immediate solution (Bhuvaneshwari Alias Sunita Kulkarni & Mishrikoti, 2019).

2.3 Information Systems (ERP and MES)

Information systems, which include hardware, software, people, processes and data, are essential elements in the context of I4.0. They are considered crucial tools to support business processes, information flows and data analysis. In addition, they are also the basis for the concept of smart factory (Mantravadi & Møller, 2019b), since they already collect and pass on data between different agents. Within the category of Information Systems, the ones that have shown the most relevance in the context of I4.0, are ERP systems and MES systems.

ERP systems have the function of planning material and human resources in a company with a long-term perspective (Hoffmann, Büscher, Meisen, & Jeschke, 2016), focusing, essentially, on management levels (Kim, Jeong, & Kim, 2019; Telukdarie & Sishi, 2019). The MES is more oriented towards the management of shop floor activities, based on production planning (Kim et al., 2019). This type of systems guarantee knowledge of the status of operations in real-time, through the acquisition and analysis of data in an almost instantaneous way, allowing a flow of information in real-time between the shop floor and the business (ERP) (Telukdarie & Sishi, 2019). For the above, some authors refer that the MES system acts as the production cockpit (Mantravadi & Møller, 2019b). Among the various functions of the MES, its role stands out: (i) in the allocation and control of resources; (ii) in the dispatch of production; (iii) in the management of quality; (iv) in the management of processes and monitoring of production; (v) in the analysis of operational performance; (vi) in the scheduling of operations; (vii) in document management; (viii) in the management of maintenance and transportation, and; (ix) in the accounting and tracking of materials (Chen & Voigt, 2020).

Within an organization, MES complements ERP functions (Mladineo et al., 2019; Mladineo, Veza, Jurcevic, & Znaor, 2017). For example, if the planning generated by the ERP is not carried out as planned, the MES can support re-planning, such as assisting decision making affecting the ERP system, creating changes to it (Mladineo et al., 2019).

MES is a type of integrated system that operates closer to the manufacturing floor, working with granular data and suitable to complement and integrate management systems such as ERPs, which work at the highest level of data. In this context, a multi-agent approach is attributed to the MES and, as an agent (physical or virtual entity) it can understand the surrounding environment, act, communicate and cooperate with other agents, whether as data availability suppliers, or as data consumers (Luo, Luo, & Zhao, 2013).

3. Lean 4.0 shop floor framework: the bilateral effects between Industry 4.0 and Lean

It was mentioned earlier that one of the challenges of the industry 4.0 implementation would be the existence of a shop floor with Lean management practices. This idea is reinforced in several studies, not only because of the need to preserve current manufacturing systems and Lean has been a wave of the 90s (mainly in the Western industry) (Teixeira et al., 2019; Wagner et al., 2017), but also because the automation of inefficient processes will only further increase operational inefficiency and, therefore, industrial inefficiency (Mayr et al., 2018). Because the MES system works on shop floor operations, it can benefit from Lean procedures and tools already present in several organizations.

The Lean's core is mainly the specification of value and the discovery, identification, and eradication of waste (Cottyn, Van Landeghem, Stockman, & Derammelaere, 2011). It is a philosophy which is governed by objectives of time, quality, costs, safety, and workers' engagement. I4.0 also considers these objectives in its mission, adding the customization capacity fostered by information and communication technologies, thus empowering new models to operate, flexibility in operations and systems connectivity (Enke et al., 2018; Unver, 2013).

Table 3- Lean's impact on I4.0

Lean's Tools	Lean's impact on I4.0	Author(s)
Just-in-Time	Potentiates the creation of a system that, through the Just-in-Time philosophy, provides the necessary information, at the right time and in the appropriate format, further promoting the reuse of knowledge.	Cattaneo et al. (2017)
Hoshin Kanri	Hoshin Kanri technique makes it possible to scale a company's vision into objectives in a cascading organizational logic (from management to production), facilitating the involvement of all stakeholders following a digital strategy.	Romero et al. (2019)
Poka-Yoke	The introduction of Poka-Yoke's system allows the deposition of greater confidence in robots since, like humans, they can make mistakes.	Stadnicka et al. (2019)
Value Stream Mapping	The Value Stream Mapping tool allows you to understand and establish the value for the consumer and find out where the waste is, to better select and align I4.0 technologies.	Romero et al. (2019)
5 Lean Principles	The vertical hierarchical integration of subsystems must happen with a well-defined strategy that can be designed by the Lean philosophy (namely the 5 Lean Principles).	Sony (2018)
Obeya Room	The purpose of the Obeya Room tool is to conduct daily meetings to discuss process improvements provided by digital technologies, thus boosting a collaborative and innovative culture.	Romero et al. (2019)
Kanban, Kaizen Daily Chart	Tools already used on the shop floor, such as the Kanban, the Kaizen Daily Chart, Batch Construction Chart, etc., can easily be transposed to a digital version, preserving production systems and boosting digital ecosystems.	Mayr et al. (2018)
5 Whys, Ishikawa Diagram, A3 Risk sheet, FMEA	The design of a digital risk management strategy can be promoted through Lean tools, such as the Five Whys, the Ishikawa Diagram and the A3 Risk Sheet. FMEA (Failure Mode and Effect Analysis) reports can be advantageous in terms of prioritizing the risks encountered.	Romero et al. (2019)
DMAIC	The DMAIC methodology (Define-Measure-Analyze-Improve-Control) can and must be incorporated in the MES system in order to improve the process. Thus, this system must contain pre-established metrics and monitor them, such as controlling imposed improvements and still imposing standard work on the shop floor.	Cottyn et al. (2011)

I4.0's principles do not replace the ones aligned with Lean's philosophy, consequently, these two practices can help each other in the achievement of the aforementioned objectives (Kolberg & Zühlke, 2015; Mayr et al., 2018). While Lean's environment promotes a culture receptive to new technologies, especially when they enhance the reduction of waste, at the same time, also allows an accurate knowledge about the processes that create value (Bittencourt, Alves, & Leão, 2019). The approach inherent to the I4.0 context integrated in Lean's philosophy can be seen as an accelerator of Lean practices (Ghobakhloo & Fathi, 2020).

Table 3 and Table 4 summarize some contributions regarding the impact of Lean culture on I4.0 (Table 3) and vice-versa (Table 4).

Table 4- I4.0's impact on Lean

I4.0's impact on Lean	**Author (s)**
Tools that exhibit static behaviour, such as Value Stream Mapping, can benefit from ***IoT technologies***, as these allow the availability of data in real-time, giving dynamism to VSM and making it closer and more real to events presented (starts to deal with stochastic data).	Balaji et al. (2020) and Bittencourt et al. (2019)
I4.0 intends to respond to markets' dynamic behaviour, thus being capable to benefit from a levelling of production based on Lean (Mayr et al., 2018), fostering a ***make-to-order*** business logic (products customized according to consumer specifications).	Enke et al. (2018)
The digitization of some Lean tools, such as ***e-Kanban***, for example, facilitates their adaptation to processes (changes in stocks or cycle times require changes in Kanban cards), also guaranteeing that they are not lost along the flow productive paths.	Ghobakhloo et al. (2020)
Information technologies can support Total Quality Management by offering statistical process management tools through control charts, significantly reducing the cost of quality.	Ghobakhloo et al. (2020) and Sader et al. (2019)
Connectivity and IoT technologies enable more efficient and effective Visual Management, as the data is updated in real-time, with the possibility of identifying anomalies close to the event and, thus, making decisions almost in real-time.	Haddud et al. (2020)
The introduction of I4.0 technologies makes it possible to plan and schedule preventive operations (***TPM-Total Productive Maintenance***) and maintenance requests more effectively and efficiently. Monitoring allows you to create fault patterns on the machines, generating an alert system and automatically calculating OEE (Overall Equipment Effectiveness). The transition from preventive to predictive maintenance is also made easier with the integration of IoT technologies and artificial intelligence.	Ghobakhloo et al. (2020)
The ***simulation*** can anticipate potential difficulties and mitigate process failures (reducing the use of Poka-Yoke systems) and can also detect sources of waste.	Pagliosa et al. (2019) and Rosin et al. (2020)
In the Just-in-Time and Continuous Flow philosophy, ***IoT*** allows tracking and sending progress states to flow managers, the ***simulation*** is able to test different scenarios for the production flow and ***autonomous robots*** to independently adjust production.	Rosin et al. (2020)
Augmented reality enables employees to obtain visual feedback on possible errors (Jidoka), as in conjunction with ***simulation***, it can facilitate employee training.	Rosin et al. (2020)

Considering the challenges previously exposed related to I4.0, Lean will be essential in the preparation of a proactive organizational culture and will be able to solve problems, since it encourages the involvement of employees in continuous improvement. In addition, the design of a digital strategy and the ability to manage risk can be promoted using Lean tools and principles. For the digital strategy, the Five Lean Principles are considered and for the risk management, tools such as the Five Whys, the Ishikawa Diagram and even the FMEA (Failure Mode and Effect Analysis) are highlighted.

The preparation of manufacturing processes is another condition to be considered since they must be standardized. Value Stream Mapping is a Lean tool capable of identifying value for the consumer and, above all, aligning I4.0 technologies with processes.

I4.0, in turn, will allow to assign dynamics to Lean tools (such as VSM and Kanban) and add stochastic data to them. The IoT, together with the tools for real-time data control and Business Intelligence, can improve Total Quality Management, as well as the company's Visual Management, allowing the detection of errors closer to the event in time. Simulation and augmented reality are also two technologies that have revolutionized how certain functions operate, how data is viewed in context, and how skills are guaranteed through employee training.

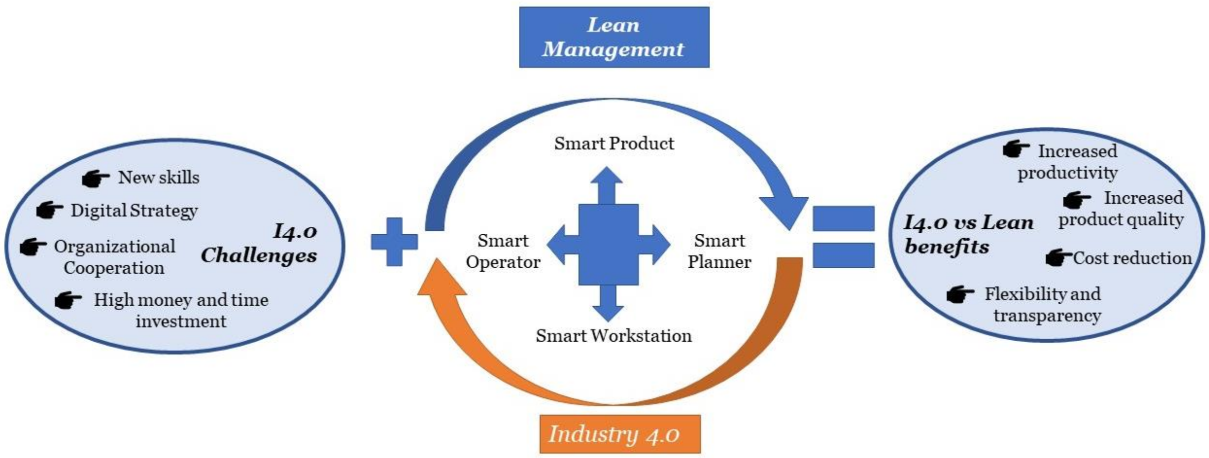

Figure 1- Lean 4.0 Shop Floor Framework

Considering the evidence reported in the literature, a Lean 4.0 Shop Floor Framework is proposed (Figure 1), with the main bilateral effects between Industry 4.0 and Lean, based on the challenges established by I4.0. Thus, the main challenges that emerge from I4.0, can find answers in the integration of Lean philosophy, together with the emerging technologies of the fourth industrial revolution. According to Kolberg et al. (2015), the integration of Lean philosophy with the principles inherent to the I4.0 context gives rise to four new concepts on the shop floor, namely: Smart Operator, Smart Product, Smart Workstation and Smart Planner. Since the MES is the information system connected to the shop floor, its essential elements are based on the components indicated, operator, product, planner and workstation. It is important to realize that these four elements must be integrated with the MES information system and be part of it, thus giving "life" to those elements that were previously static.

The ***Smart Operator*** concept includes the introduction of IoT mechanisms, such as Smart Watches, which will facilitate the notification of employees, using Andon logic, about messages and error locations. Augmented reality can help establish JIT on cycle times, scheduled tasks and even digital work instructions (Ghobakhloo & Fathi, 2020; Kolberg & Zühlke, 2015). Simulation in combination with augmented reality, on the other hand, will facilitate training when new functions or jobs are involved, as well as maintenance actions (Rosin et al., 2020). The establishment of knowledge management systems will make it possible to retain the right knowledge, at the right time and in the right place (JIT), in addition to the potential to foster brainstorming (creating new knowledge) and thus consolidate the skills of the teams (Ghobakhloo & Fathi, 2020).

The ***Smart Product*** concept also includes the integration of IoT components in the final product, in order to allow its tracking and, thus, ensure knowledge of the various stages of the product, from origin to destination, adopting a JIT logic (Rosin et al., 2020). It is also possible to track the various stages of the product throughout production, as well as production needs, relying on the information presented in e-Kanbans (Kolberg & Zühlke, 2015). The real-time monitoring of the products will also allow the generation of performance indicators, in order to control several parameters, from the quality of the products, and may even allow the appearance of FMEA forms, where the number of risk priority is calculated (it is possible to attach documents related to the causes of failure found or actions necessary to expedite existing concerns) (Ghobakhloo & Fathi, 2020).

By ***Smart Workstation*** is meant the use of IoT technologies in order to assign the ability to react to processes, through alerts based on events, and decision-making by the job itself (e.g., stopping the process or even exchanging production products). Communication via RFID (Radio Frequency Identification) of products/materials in progress with equipment is also a reality, which allows to avoid production errors (Jidoka) (Rosin et al., 2020). As with the product, here it is also possible to establish statistical process control systems. In the area of maintenance management, the entire action schedule becomes more agile, the control of equipment inactivity is performed and predictive analysis is possible to be carried out, contributing to a Total Productive Maintenance Management (TPM) (Ghobakhloo & Fathi, 2020; Haddud & Khare, 2020).

Finally, in ***Smart Planner***, the introduction of autonomous robots (example of Automated Guided Vehicles - AGV) is a reality that allows the movement of products and materials between workstations, the information sharing about the destination and delivery times, as well as the readjustment of milk-run routes (logistics system for the collection or delivery of materials with several stops, in order to optimize the route) whenever necessary (Rosin et al., 2020). In this context, visual management benefits from real-time data, offering conditions for better risk management and identification of anomalies in the system (Haddud & Khare, 2020). Simulation techniques will also be essential in the context of testing different production parameters and the design of numerous flows, contributing to better planning of movements and identification of sources of waste (Kolberg & Zühlke, 2015).

Therefore, starting from the challenges inherent to the fourth industrial revolution and relying on the integration of Lean principles and emerging technologies from I4.0, several benefits can be expected such as:

i. **Increased productivity**, since integration enhances agile and intelligent processes (Doh, Deschamps, & Pinheiro De Lima, 2016; Pagliosa et al., 2019);
ii. **Increased quality**, as it is possible to anticipate production errors and manage equipment malfunctions in a more controlled approach (Doh et al., 2016; Pagliosa et al., 2019; Stadnicka & Antonelli, 2019);
iii. **Greater flexibility**, since I4.0 allows flexible and modular production systems, so that highly customized products can be mass produced, with the possibility of demand's adjustment (Ghobakhloo, 2020; Pagliosa et al., 2019);
iv. **Greater transparency** in communication, as there is constant monitoring of production, with real-time data, which promotes more accurate and decentralized decision-making in near real-time (Gigova et al., 2019);
v. **Increased worker safety**, since the heavier and more routine activities, which normally lead to workers' injuries, are likely to be automated (Stadnicka & Antonelli, 2019);
vi. **Cost reduction**, either by eliminating a substantial part of waste or by predictive maintenance enhanced by these environments that lead to a reduction in maintenance costs (Ghobakhloo & Fathi, 2020).

In this way, with the application of emerging I4.0 technologies, integrated with Lean's principles, using for that Information Systems, namely ERP and MES, it is possible to increase operational efficiency and, consequently, organizational efficiency.

4. Final Considerations and Future Work

Although some studies in the literature report effects between I4.0 and Lean, there are few that address the main challenges of I4.0 combined with Lean practices, as well as the impacts and benefits expected from the convergence of these two practices. While I4.0 favors connectivity, flexibility and, therefore, responses to volatile and increasingly demanding markets, integrating information systems to support process and continuous data flows, Lean favors continuous improvement in a logic of waste reduction, acting primarily on production and material processes and flows.

For an adequate association of Lean practices and the principles of I4.0, we have the support of Information Systems, highlighting the role of MES as complementary functions to ERP systems. Particularly with the help of MES, organizations easily plan their production and send planning data in real-time to employees and equipment that will operate in that manufacturing order, as well are capable of re-plan without harming to overprocessing or overproduction. The conditions of the equipment are also verified in real-time, which makes MES the key system in the context of I4.0, with an impact on resource allocation, product quality and, consequently, company productivity (Lee, Nam, & Lee, 2012).

Regarding Lean, a practice already rooted in the Western industry, its ultimate goal is to increase the efficiency of operations and processes that add value, while reducing waste-enhancing activities (Hoellthaler, Braunreuther, & Reinhart, 2018). Transparency is an assumption that encourages digitization, as well as standardization and work organization, being these concepts strongly associated with the Lean philosophy (Bittencourt et al., 2019).

Some studies have already shown that there is strong evidence that companies with a low level of Lean maturity also have a low level of integration of I4.0 technologies (Bittencourt et al., 2019; Rossini, Costa, Tortorella, et al., 2019). There are also authors which defend that Lean principles should first be implemented in a traditional way, and only then an I4.0 approach should be pursued (Adam, Hofbauer, & Mandl, 2019).

It is thus concluded, even if using approaches presented in the literature, that there is a strong relationship between the adoption of I4.0 technologies and the implementation of Lean (Rossini, Costa, Tortorella, et al., 2019). There are also studies that demonstrate the effects of Lean implementation, but, prevail over the benefits evidenced by the implementation of I4.0 in an organizational performance's perspective (efficiency and productivity) (Rossini, Costa, Staudacher, & Tortorella, 2019). Thus, when implementing I4.0 technologies, it is necessary to integrate Lean practices to introduce automation in well-designed and robust processes (Rosin et al., 2020; Rossini, Costa, Staudacher, et al., 2019).

Not only can I4.0 benefit from Lean, but this philosophy can also benefit from I4.0 connectivity, evolving its tools to more dynamic techniques and using stochastic data. I4.0's greater flexibility also promises to cooperate with a market where demand fluctuates, making it possible to produce goods in single and more complex batches, something that goes beyond Lean level and standardized production (Mayr et al., 2018).

It is then possible to establish a shop floor that brings together the two worlds, giving rise to four major elements, that is; 'Smart Operator', 'Smart Product', 'Smart Workstation' and 'Smart Planner', any of which may benefit from the bilateral advantages of both practices, with the mediation of Information Systems, i.e., MES and ERP.

Given the theoretical and exploratory nature of this work, it is suggested for future work practical studies that should be assessed in real context the effects of the convergence of these two practices - I4.0 and Lean - with a view to corroborating (or not) the advantages listed here. The application may consider the different Lean tools and their automation and / or digitization.

Acknowledgments

This work was supported by Portuguese funds through the Institute of Electronics and Informatics Engineering of Aveiro (IEETA) and Foundation for Science and Technology, in the context of the project UIDB/00127/2020.

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Biographies

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