Risks And Opportunities Within Lean 4.0 Systems: SWOT Analysis

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Abstract

Nowadays, companies' first target is to build an intelligent, flexible, integrated and efficient processes, for higher industrial performance. According to this, a new concept emerged within the industrial firms by the name of Industry 4.0 (I4.0). This 4th industrial revolution covers four main aspects: intelligent factory, real-time communication, smart products and more satisfied customers. As strong as are the new technologies offered by this revolution, it is not entirely sufficient if not combined with lean principles. Combining these two paradigms created what is known today as Lean 4.0, a new concept presenting several opportunities for higher performance. Nevertheless, this combination is far from being as simple as it seems. A deep and structured risk analysis is required to ensure a smooth implementation of lean 4.0 system within a company. The purpose of this paper is to discuss I4.0, lean manufacturing and Lean 4.0 risks and opportunities through a systematic literature review, and to study the different barriers to its implementation through the modelling of a case study using sequence diagram and SWOT analysis. Its contribution consists of being a reflection paper to the companies aiming to develop their digital maturity by exploiting Lean 4.0 tools.

Keywords
Industry 4.0, Industrial revolution, Lean 4.0, Risks and opportunities, SWOT analysis.

1. Introduction
Industry 4.0 is a concept that represents a whole new vision of the factory where products and machines become intelligent and are part of a network based on heterogeneous integration of data and knowledge. As one of the most high-tech manufacturing countries, Germany holds many of the most sophisticated manufacturing companies and factories (MacDuffie 1995), which allowed the German government to introduce new technologies aiming to support

its “High-Tech Strategy 2020 for Germany” initiative, leading the 4th industrial revolution (Brettel and al 2014; Hermann and alm 2016). Currently, this new concept has become the most popular term of this age where companies get more and more interested in exploiting the connectivity aspect of I4.0 technologies (Parlanti 2017; Reischauer 2018), especially when it comes to supporting lean manufacturing (LM) system. Indeed, products variety, production environment complexity and unexpected crisis such as COVID19 make it more challenging to cope with customer demand increasingly evolving (Womack et al. 1990).

Lean manufacturing system first appeared in Japan during the 1950s within Toyota production system as a solution to increase the company’s productivity by avoiding waste in the value stream map while continually seeking to reduce resources (Matteo et al. 2019). As a result, Taiichi Ohno, along with his partners, was able to lead the company into a continuous improvement culture (Uriarte et al. 2020). Over the time and with the introduction of I4.0, a fusion of new technologies with lean manufacturing methods and principles was considered, thus giving birth to Lean 4.0 (Schwab 2016). This fusion does not bring any changes to the traditional lean manufacturing principles. It ensures the connectivity and the intelligence of its tools and methods such as TPM 4.0, Kaizen 4.0, Kanban 4.0, Automated guided vehicles (AGV) and Just-In-Time 4.0 (Kolberg and al 2015; Mayr and al 2018; El Abbadi and al 2018, Naciri et al. 2022).

Real-time data, IoT, big data analytics, Cyber-Physical Systems (CPS), predictive algorithms and robots were proven to be the most popular I4.0 technologies used to support this evolution (Marinelli et al. 2021).
In this scope, this paper aims to study the different risks and opportunities of Lean 4.0 implementation. The first section of this paper describes the methodology adopted during this research, when the second one presents literature review results regarding industry 4.0, Lean 4.0 and risks and opportunities within the two paradigms. The third section presents the modelling of a case study based on which a SWOT analysis was held to extract the different risks and opportunities that emerge from the implementation of a smart system. Finally, the article ends with a conclusion and discussion.

1.1 Objectives

This paper was written with the aim to provide companies with a sort of referential on how to exploit Lean 4.0 opportunities, avoid risks related to its implementation, and anticipate the potential roadblocks, for a better performance of their factory, and an easier integration into industry 4.0 fields.
Through a SWOT analysis, the importance of a risk analysis strategy establishment was raised as it is very crucial to the success of any project.

2. Research Methodology

Through a systematic literature review, a study was conducted to explore countries’ involvement in terms of industry 4.0, authors’ findings regarding lean 4.0 paradigm and to identify risks and opportunities within I4.0, lean manufacturing and Lean 4.0 concepts, as well as the different roadblocks that may occur during their implementation. The study was based on scientific Scopus indexed papers, journals, articles, and government report from scientific electronic databases with high impact ratios such as springer, Elsevier (Science Direct), as well as google scholar and research gate.
After scope definition and databases selection, the next step of this literature review was to determine the keywords to use for smooth research. Our selection was: “Risks”, “Challenges”. “Barriers”, “Opportunities” and “Benefits” along with the keywords “Industry 4.0”, “Lean manufacturing”, and “Lean 4.0”.
Based on this process, a set of 40 articles was selected for reading and analysing to come up with enough items to support the aim of this paper.

3. Literature Review

3.1 Industry 4.0

Since 2011, the industrial sector has increasingly improved when it comes to digital maturity, thus thanks to the new technologies offered by the industry 4.0. Nowadays, several countries have become more open to change and are therefore welcoming I4.0 technologies into their systems. For example, in Germany, mother of this new revolution, the number of industrial robots was about 273 per 1000 workers in 2012, as shown in figure 1 (Berger 2014). On the other hand, the USA launched the “Advanced Manufacturing Partnership (AMP)” program in 2012, aiming to increase U.S. competitiveness in advanced manufacturing (Rafael et al 2014). Inspired by Germany, China works on becoming a world leader around 2049 when it comes to new information technologies, robotics, and aerospace through the "Made in China 2025" plan published in 2015. (Bidet-Mayer 2016). In 2013, France worked on increasing its digital competitiveness through "La Nouvelle France Industrielle" (CNI - Conseil national de l'industrie 2013). In the last few years, the I4.0 concept appeared within emerging countries as well such as Morocco, where was adopted an industrial acceleration plan 2014–2020 called "L'industrie, locomotive de la croissance et de l'emploi" (Ministry of Industry, Trade, Green Economy & Digital, 2018). Research found that most Moroccan firms adopting I4.0 technologies are operating within the automotive sector, aerospace and food industry (Gallab et al. 2021).

Figure 1 illustrates some other countries' involvement in terms of I4.0.

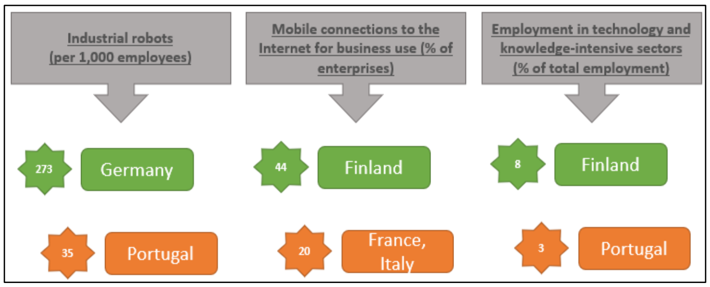

Figure 1. Main I4.0 spotlights (inspired by Berger, 2014).

These driving forces made the I4.0 concept the most popular topic within industrial firms, research centres and universities (Liao et al. 2017). However, numerous companies still can't afford to implement this new concept for its cost and implementation lead-time (Qin et al. 2016).

3.2 Lean 4.0

Various researchers studied the digitalization of lean manufacturing tools and principles using I4.0 technologies such as Internet of Things (IoT), virtual reality (VR), and augmented reality (AR). Results showed a complementarity between the two paradigms: Lean principles ensures the standardization and organization of I4.0 technologies, when I4.0 ensures the intelligence development of lean manufacturing tools. (Naciri et al. 2022). Indeed, lean manufacturing can be used as a foundation to achieve flexible and less complex systems of I4.0 by eliminating all that doesn't bring any benefit or added value to the customer, with employees as a driving force (Adrian et al. 2021).
To better detect the different fusion possibilities, figure 2 and figure 3 presents an overview of lean manufacturing principles and I4.0 technologies based on literature review analysis results.

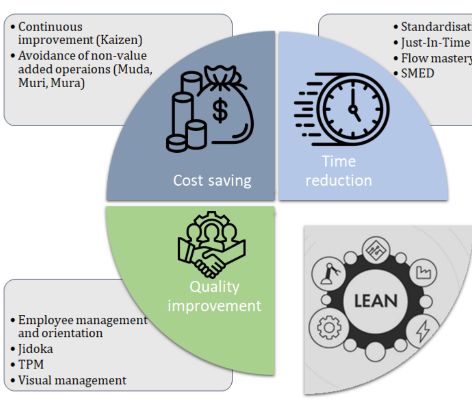

Figure 2. Lean manufacturing concepts.

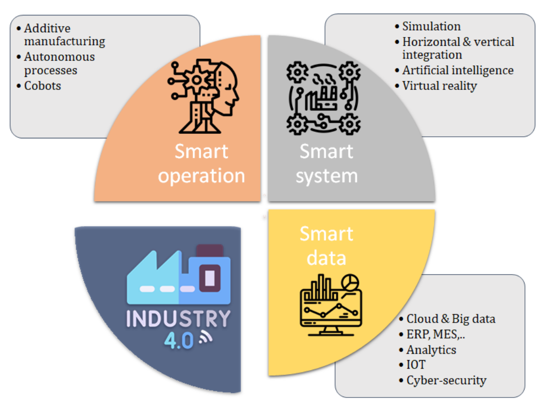

Figure 3. Industry 4.0 technologies.

As we can state from this overview, several fusion aspects can be highlighted. For example, cyber-physical systems provide connectivity and transparency along the supply chain and therefore support the just-in-time concept (Pereira and al 2019). It also ensures real-time communication between men and machine, thus helping with Andon system (Naciri and et al. 2022). Regarding TPM activity, it can be enhanced by the I4.0 technologies through breakdowns prevention using artificial intelligence for efficient maintenance management (Di Nardo et al. 2021). Other digital transformation of LM tools were proposed, such as Digital Value Stream Map (DVSM), a relevant tool that may be used to rationalize and deploy Industry 4.0 improvement (Areya et. al 2021).

As stated by several researches, lean 4.0 elements remain interlinked and complex to implement, which requires the development of strategic implementation steps for manufacturing companies. We can take as an example the guideline built by Dillinger (Dillinger and al 2021) based on 3 phases: actual situation analysis and scope definition; Lean 4.0 elements design; Evaluation, and implementation. Sub-phases of each step are shown in figure 4.

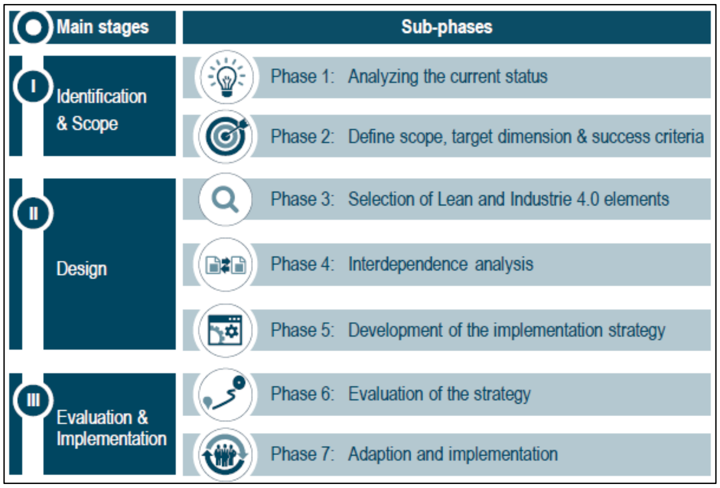

Figure 4. Lean 4.0 implementation phases (Dillinger et al. 2021).

However, regardless of the different lean 4.0 possible applications and implementation strategies, it is primordial to hold a risk analysis to prevent various obstacles that may occur while implementing Lean 4.0, which is the focus of the next section.

3.3 Risks and opportunities

In terms of Industry 4.0, several authors stated that its implementation is a complex process that is very likely to take about ten years to be realized due to scientific, technological, social and economic issues (Mamad 2018). For example, risks can mainly concern data management (different formats for different users) and protection (privacy and data authentication), uncertainties about financial benefits due to lack of demonstrated business cases (Dennis and al, 2017), and the absence of proper strategy (Turkyilmaz et al. 2021). Lack of skills, technical expertise and training modules is also one of the most impacting barriers to I4.0 implementation, as workers will be facing new diversified and complex processes, and high resistance to change may be expressed. In addition to that, significant investments in innovative technologies and skills empowerment are needed (Tay et al. 2019).

On the other hand, I4.0 technologies present several opportunities to enhance companies' performance, such as logistic system management for better control of stock and a shorter delivery time, flexible production structure (Tay Shu Ing, and al, 2019), collaborative work between man and machine (Stock and Seliger 2016), economic and ecological efficiency in terms of production (Saurabh et al. 2018), as well as global competition, resources saving, digital collaboration and real-time information (Magdy et al. 2022).

Regarding Lean manufacturing system, it has known a remarkable low success few years ago. Indeed, a statistic study held in 2015 on the implementation of Lean in the UK stated that 46.15% of Foundry Industry was not entirely using Lean, while 69.23% strongly agreed that its implementation was complex (McKie et al. 2021). Researches identified numerous factors that may influence implementation success. The most reliable one was company's culture, which is directly reflected on employees' engagement and commitment. In fact, poor knowledge regarding Lean Manufacturing tools and principles leads the workforce to high resistance to change by fear to lose their job or not being able to cope with working methods change, not only by shopfloor operators, but from the top management as well. The lack of necessary resources for implementation support and training must also be considered (Salonitisa and Tsinopoulosb

2016). In addition to that, other issues faced by companies while implementing lean manufacturing was the absence of a specific strategy taking into consideration cost and lead time, as well as unclear roles and responsibilities, not knowing what to expect and how lean tools and practices could support daily work (Lodgaard and al. 2016).
However, LM philosophy, being focused on enhancing companies' performance, has many advantages, among which we can quote developing key performance indicators, the establishment of best practices, standardization to ensure continuous improvement and therefore survive internal constraints (Salonitisa and Tsinopoulosb 2016) and better flow management within the value stream (Lodgaard et al. 2016). LM also presents a practical problem-solving approach, supports improvement sustainability through the Kaizen mindset, and focuses on waste elimination, visual management for skills monitoring and all employees' participation on a daily basis (McKie et al. 2021).

Based on Lean 4.0 implementation phases presented in section 3.2, we can presume that these risks can be identified in the third and fourth phases while selecting and analysing lean and industry 4.0 elements. In addition to that, due to lack of studies regarding lean 4.0 risks and opportunities and since this concept represents the digitalization of lean manufacturing tools and principles, we can consider that same risks identified in I4.0 implementation can be reflected in Lean 4.0 systems.
To validate/reject this hypothesis, a case study is presented in the next section.

4. Modeling of A Case Study: Smart Production Line

To analyse the risk and opportunities of Lean 4.0 implementation, we selected some I4.0 technologies and combined them with lean manufacturing tools to constitute a smart production line. Its modelling is presented in this section using Unified Modelling Language (UML), a standard modelling language representing accurate word elements by classes, subclasses and objects, which helps modelling systems in an object-oriented vision. (Gallab and al. 2017).
The production system is composed of intelligent machines using Andon 4.0 as an alert system. The principal is to establish a direct communication between the machines and the maintenance operator, so that he can be aware of the machine's condition in real-time. To better understand this system, a sequence diagram was adopted as it helps to describe interactions between the different objects of the system considering the temporal dimension (Gallab, and al 2019). The result is shown in figure 5.

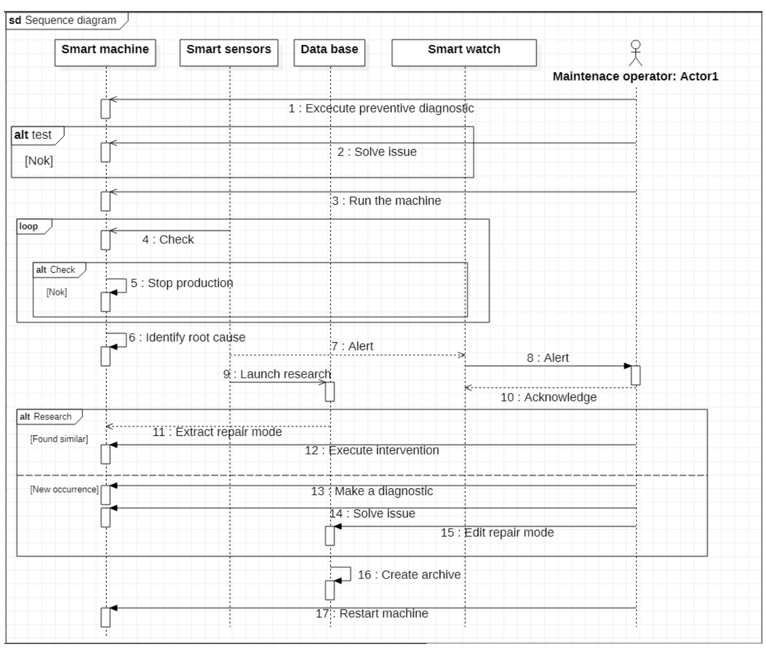

Figure 5. Sequence diagram describing the sequenced exchanges within the smart production line.

Figure 5 presents the chronological sequencing of this system's functions. In case of abnormality, the concerned machine stops producing according to Jidoka concept, and identify the issue using smart sensors, then refers to the database for historical occurrence. At the same time, a notification is sent to the maintenance department using a smartwatch connected to the machine via the Internet of things. Once the notification is received, the operator must confirm reception and go to the concerned machine. If it is the first occurrence of the issue, a diagnostic must be ensured, and once the problem is found, and the intervention is done, the operator must edit a detailed report and save it in the database for future usage. Otherwise, the machine extracts the needed intervention instructions and display them to be followed by the operator. Once it is done, an archive is automatically created, the database is updated, and the machine is restarted to go back to production.

Following the purpose of this paper and based on the proposed system, an analysis was held in order to define the different risks that may represent a barrier to the implementation of the system, especially from a technical point of view, and, in return, the opportunities it presents from an industrial and economic point of view. The tool used for this analysis is SWOT matrix. SWOT stands for the short form of four words; Strength, Weaknesses, Opportunities, and Threats, and is a 1960s-1970s popular technique to identify the internal strengths and weaknesses and external opportunities and threats of a system (Bakhtari and al, 2020). Results are represented in Figure 6.

Figure 6. SWOT analysis of the smart system.

From an economic, social, industrial and cultural point of view, we were able to analyse the possible roadblocks that may occur while implementing the smart production line system. Indeed, many risks are to be considered, mainly the high investment needed considering the cost of I4.0 equipment and training sessions. Regarding the technical aspect, since abnormalities detection depends on smart sensors, the risk of their non-function must be considered. Another weakness of this system relies on maintenance operator dependence on the smartwatch.

Regarding the threats, data is our first concern. Risk of hacking is highly present if an adequate cyber-security system is not implemented. Furthermore, this concept brings radical changes to the traditional ones, which may not be accepted by the employees or society, and may not encourage innovation policy support.

Nevertheless, several positive aspects of the smart production system resulted from the analysis: this new concept helps increase production costs by reducing resources and lead times using autonomous and flexible systems helping with maintenance activities thanks to real-time man-machine and machine-machine communication, which leads to an effective supervision and downtime decrease by preventing stoppages. It is an excellent opportunity to enhance the company's digital maturity, quality, productivity and performance, but also to create new business models and customized products and services to cope with customer demand fluctuation.

5. Conclusion

Based on the research held in the context of this paper, we can state that Lean Production is a people and organization-oriented approach, while I4.0 is a technology-oriented one enabling a fluid information and material flows along the value chain. But the target remains the same: less costs with higher performance. Researchers studying the integration of these two paradigms has found many complementarities, and stated that, on one hand, continuous improvement practices establishment and LM practices preliminary implementation in the company makes I4.0 technologies adoption more accessible, and on the other hand, I4.0 technologies enhance Lean manufacturing efficiency. Indeed, the case study proposed is a consistent example of Lean 4.0 application.

This study can serve as a support to companies willing to implement Lean 4.0 concept. Eventually, results of the SWOT analysis have shown several treats to Lean 4.0 adoption such as cyber-security, social awareness, lack of financial support and lack of skills, but many opportunities as well. We are now talking about autonomous and flexible systems enabling the customization of products and services for higher competitiveness within the industrial firms and higher customer satisfaction due to quality increase and lead time decrease.

In terms of perspectives, government and private sectors collaboration within the education sector is primordial. More programs and funds regarding Industry 4.0 technologies are highly needed to instore innovation culture within our society and encourage employers to engage more in the development of Industry 4.0. On the other hand, due to the lack of Lean 4.0 risk and opportunities studies, the analysis was based on authors' personal knowledge and experience. In response to this, the next step is to prepare a survey in order to evaluate the barriers faced by companies while implementing lean 4.0, or the treats that stopped them from adopting this new concept. Finally, research must be held to study the possibility to overcome the weaknesses and threats identified during our analysis.

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