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Applying a process-centric approach to the digitalization of operations in manufacturing companies: a case study

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Abstract

This research aims to explore how digital technology can enhance productivity in manufacturing firms through the application of lean methodology and Industry 4.0. While previous studies have been primarily theoretical, digital technologies have the potential to improve efficiency in lean organizations. The research develops a practical and effective digitalization framework for manufacturing firms to improve operational efficiency. The proposed framework recommends a step-by-step approach to implementing digital technologies and fostering a culture of digital innovation. The framework will be tested in a real-world manufacturing setting to provide industry practitioners with empirical evidence to support and guide its implementation. The study first focuses on the literature review of Lean Manufacturing, Industry 4.0, and their connection. The methodology adopted for the research is then discussed, followed by the case study. The study concludes that a culture of digital innovation is critical for digitalization success. The study recommends that companies adopt the proposed framework to increase operational efficiency, reduce waste, and gain a competitive advantage. This study provides a practical framework for manufacturing firms to implement digital technologies and improve operational efficiency. The proposed framework is designed to be adaptable and can be customized to meet specific organizational needs. The study highlights the importance of a digital innovation culture and recommends a step-by-step approach to implementing digital technologies in manufacturing firms.

Keywords: Digitalization; Industry 4.0; Lean

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1. Introduction

The adoption of digitalization has brought numerous benefits to individuals and businesses, revolutionizing how we conduct business, work, and communicate. However, like any significant change, it also comes with potential risks that must be considered. One of the most significant risks is abandoning a digital project, resulting in wasted time, effort, and resources. Many companies have invested heavily in digitalization but have yet to see a return [1].

Nowadays, more and more companies are asking themselves how it is possible to survive in a globally competitive market, achieving and maintaining a competitive advantage with respect to competitors. In this context, where the pressure coming from this global competition is high, strategic operational goals that manufacturing companies are pursuing are related to the execution of all the operations having the lowest cost possible, reaching flexibility and reliability, and focusing at the same time on the continuous improvement of internal practices [2]. Many companies adopt and implement the Lean Manufacturing (LM) philosophy to enhance their operations and achieve higher efficiency. Indeed, according to Ohno, whom is today considered the father of the Toyota Production System (TPS), operational efficiency can be reached through the elimination of seven wastes ("Muda" in Japanese) arising in manufacturing companies [3]. The LM philosophy, then, looks at the whole manufacturing process to identify and reduce activities that could generate waste, having the final goal of eliminating all the nonvalue-adding activities performed. Companies are also investing in reshaping their operations to cope with the competition. In this sense, companies undergo a reengineering process to enhance flexibility and integrate several processes.

Digitalization automates processes, reduces manual labor, and reduces errors, increasing productivity, efficiency, and profitability. E-commerce opens new revenue streams and business models for retailers. However, digitalization risks must be considered by businesses. To stay caught up, small and medium-sized businesses must keep up with technological advances and afford expensive digital technologies [4]. Many manufacturing companies are reshaping their core functions to improve efficiency and connectivity in response to external changes [5]. Manufacturing companies are using digital technologies to adapt to the internal complexity of their competitive environment [6]. Industry 4.0 (I4.0), or the Fourth Industrial Revolution, is adopting digital technologies within companies, changing how they operate. By undergoing a digital transformation, companies can become more agile and resilient in a high-cost environment [7]. However, even if companies are combining both to pursue their objectives and even if there is evidence of the fact that digital technologies seem to stabilize the benefits coming from the implementation of the LM approach, there is still no clarity on the impact that the joint implementation of the two has on the performance of companies. Moreover, a good example of how companies can embrace a digitalization process with lean bundles to increase operational efficiency is still missing.

Considering the integration between Industry 4.0 and the Lean approach. Notably, Lean philosophy aligns with the autonomous principles of Industry 4.0, exemplified by the concept of "autonomation." The autonomous nature of Industry 4.0 finds a precursor in the Lean approach emphasis on automating value-adding processes. This connection signifies the Lean approach as a foundational precursor to Industry 4.0.

Wang et al. [8] and others emphasize how Lean-based processes play a facilitative role in implementing Industry 4.0, while Kolberg and Zühlke [9] and Dombrowski et al. [10] highlight the importance of Lean process orientation in effectively integrating Industry 4.0 autonomation and information exchange, mitigating integration risks. The significance of standardized processes, as underscored by Butollo et al. [11], lies in error detection and synchronization, critical for seamless process execution. Additionally, Tortorella and Fettermann [12] affirm Lean's positive impact on Industry 4.0 adoption.

Scholars like Erol et al. [13] and Mayr et al. [14] underscore Lean's fundamental importance in Industry 4.0 endeavors. Research by Rossini et al. [15] and practical insights from Pagliosa et al. [16] further solidify the connection between Lean Philosophy and Industry 4.0, with Lean practices demonstrating practicality in facilitating Industry 4.0 adoption. The essential role of Value Stream Mapping (VSM) in identifying improvement opportunities, highlighted by Pagliosa et al. [16], underscores the symbiotic relationship between Lean and Industry 4.0. Last of all, the integration of Industry 4.0 and the Lean approach establishes a substantial foundation, where Lean serves as both a precursor and a facilitator for Industry 4.0 adoption. The alignment of principles between these paradigms underscores their potential synergy in enhancing operational efficiency and innovation in modern manufacturing contexts.

Given this context, this work aims to study how companies are approaching the digitalization of their operations and provide a framework that organizations could adopt during their journey toward innovation. To address this point, a case study has been selected and analyzed to be used as a reference for defining this process-centric research.

This paper is organized as follows. First, the literature review provides a comprehensive account of how Lean is implemented in corporate and multinational organizations. Next, the methodology and discussion section put forth an analytical framework that can be used to examine Lean practices in such organizations. Finally, the paper concludes with a summary of findings and recommendations for future research.

2. Literature Review

This section aims to furnish a comprehensive summary of the present research on Industry 4.0 and the Lean methodology. The focus will be on the advantages and difficulties linked with these approaches, along with their potential impact on the overall functioning of businesses. Additionally, the subsequent segment will offer an account of the current state of the literature regarding the combined consequences of both these methods.

2.1. Industry 4.0

Integrating Lean Production and Industry 4.0 can offer a competitive advantage to manufacturing companies. According to Rossini et al. 2022, Lean Automation can improve productivity, reduce waste, and enhance product quality [17]. Similarly, integrating Lean Supply Chain Management and Industry 4.0 can lead to a more efficient and effective supply chain, enabling companies to respond to changing customer demands and market conditions with agility and speed [18]. This was highlighted in a Rossini et al. 2023 article in the International Journal of Lean Six Sigma, which also noted that implementing Lean principles in IT SMEs can enhance their efficiency and competitiveness and prepare them for the challenges and opportunities of Industry 4.0 [19].

Digital technologies are increasingly being incorporated into today's business operational procedures to boost productivity and ensure continued relevance in the market. Industry 4.0 refers to the current fourth revolution in manufacturing, made possible by the emergence of the Internet of Things (IoT) and the creation of interconnected machine networks [20]. Integrating these technologies into manufacturing operations is commonly referred to as Industry 4.0. The primary objective of this new industrial revolution is to use newly available digital capabilities to achieve technological breakthroughs, rethink innovation processes, and digitalize organizational processes and those throughout the supply chain [21].

Although implementing cutting-edge technologies is an undeniable prerequisite for the fourth industrial revolution, the precise meaning of the term "Industry 4.0" is still debatable. Zong [22], Vaidya [23], and Shafiq [24] have each proposed a distinctive interpretation of the term "definition." However, the literature on Industry 4.0 describes it most commonly as an umbrella term for a group of technological advancements that aim to increase an organization’s digitalization levels [25]. Ruessmann [26], Gilchrist [27], and Wang [28] have identified nine primary technology fields as inherent to the sphere of Industry 4.0 and as enablers for the digital transformation of the manufacturing world. Even though there is no single definition of Industry 4.0, these nine technology fields have been identified as inherent to the sphere of Industry 4.0.

The adoption of lean practices enables the elimination of non-value-adding activities, and similarly, the implementation of digital technologies revolutionizes the operations of manufacturing companies. This transformation facilitates the improvement of results through enhanced agility and flexibility and a boost in operational efficiency by reducing waste. The availability of various digital technologies highlights the potential for innovation and digitalization within the manufacturing sector. Therefore, the manufacturing industry has ample room for growth and development in digital technologies [20].

There needs to be more than just implementing technology for manufacturing companies to successfully undergo digital transformation. Managers must act by implementing effective management strategies and business models. Simply adopting digital technologies is insufficient to reap the benefits; companies must also initiate an organizational transformation and establish a new internal ecosystem that prioritizes innovation [29].

Moreover, before implementing new technologies, it is important to consider each company's specific conditions and requirements. It is essential to ensure that all new emerging technologies are integrated smoothly with existing

systems to maximize their benefits and ensure proper coordination among all systems [30]. In essence, a combination of strategic planning, organizational transformation, and technological integration is necessary for manufacturing companies to undergo digital transformation successfully.

2.2. Lean Approach

According to the research that was carried out, it has been discovered that both the Lean methodology and Industry 4.0 have the same overarching objective, which is to increase the operational efficiency of businesses. Nevertheless, additional research is required to investigate the connection between the factors enabling operational efficiency. Additionally, combining Lean Manufacturing with Industry 4.0 may help businesses achieve higher performance levels [31], [32]. The advantages of lean methodologies could be improved using digital technologies [33], [34]. In addition, businesses that have already implemented Lean practices will find it simpler to integrate the technologies of Industry 4.0 into their operations [34], [35]. Nevertheless, research on the connection between Lean and Industry 4.0 in various businesses reveals that mature Lean approaches might not have an equivalent digitalization status. Because of this, the way digital technologies can support the benefits of lean transformation is not yet clear, and a well-defined method is required to quantify the impact that they have on one another [36].

In addition, there is not currently a framework to guide businesses through digitally transforming their operations. During their journey toward innovation, businesses can benefit from access to a general framework like the one developed because of this research.

3. Methodology

Case study methodology serves as a versatile approach aimed at comprehensively grasping the intricacies of human complexities within a specific setting. This method entails the systematic collection of data from various sources, facilitating the exploration of a particular phenomenon or scenario. Diverse research techniques such as interviews, observations, and document analysis can be employed to conduct case studies. By concentrating on a singular instance or a small set of instances, case studies enable researchers to meticulously scrutinize the finer details and subtleties of the subject under investigation. Particularly valuable within the realm of occupational science research, this methodology empowers researchers to delve into the experiences, viewpoints, and interactions of individuals within their occupational environments. Through its provision of detailed and extensive data, case study methodology contributes to the advancement of both theory and practice within the field of occupational science [37].

In this research, we use a case study methodology to investigate a phenomenon in its real-life setting. This method involves conducting an empirical investigation and thoroughly examining a few cases. We gather and analyze various types of data to comprehensively understand the case. By utilizing the case study methodology, we can obtain a versatile and thorough strategy for comprehending the intricacies of this phenomenon.

3.1. Case Study

Yin [38] describes case study methodology as an empirical inquiry that examines a phenomenon in its real-life context. Case studies investigate complex phenomena from multiple angles [38]. The method examines a single or few cases to study a phenomenon, event, or activity. To understand the case, the case study methodology collects and analyzes interviews, documents, observations, and artifacts. Triangulation, which uses multiple sources of evidence to confirm findings and improve study reliability and validity, is also used.

Depending on the research questions and objectives, case studies can be exploratory, descriptive, or explanatory, according to Yin [38]. Exploratory case studies are used for broad, open-ended research questions to gain a preliminary understanding of the phenomenon. Descriptive case studies are used when research questions are more specific, and the investigator wants to describe the phenomenon. The investigator uses explanatory case studies to explain causal research questions. Finally, case studies allow researchers to analyze a phenomenon's context and interrelationships.

3.2. The Cases

This research investigates ways companies can digitalize business processes while adhering to lean principles. A case study of a multinational corporation currently undergoing digital transformation is the foundation for this research. Over almost a year, the Merchandise Planning & Inventory Management (MPIM) department of the company. was observed as it worked on various new product development initiatives. The findings of this study will be determined after observing various innovation projects that the company has carried out. The analyses that were carried out focused on reconfiguring three fundamental processes vital to the operation of a business in the apparel industry.

The observations on the processes described earlier allowed for deriving the displayed results. The main goal behind the existence of Jump'in in the company. is to bring digital transformation within the company's operations, developing web applications that simplify the daily tasks that colleagues need to perform. To reach this goal, the team is designing and developing so-called AIO (All-In-One) tools that allow users to execute their tasks directly on the tools. Three projects the team is following will be presented, and an overview will be provided on the business processes to be improved on the technologies used and how the team operates while developing new digital tools. The methodology adopted by the team will be derived, which could be used by other companies that desire to innovate in their business operations.

3.2.1. Item Master (IM).

The Item Master tool was developed by Jump'in in 2021 and launched in 2022 to simplify the order-taking process between the sales team and customers. It can also be used as a "self-service" platform by other Business stakeholders (Sales, CS/OTC, Merchandise, Planning, etc.) to download and visualize several key pieces of information regarding the products offered by the company. Before the introduction of the tool, orders were managed mainly using Excel files containing the assortment available to the customer and desired quantities. With the introduction of the tool, sales teams can now access a user-friendly application where they can download an order sheet containing all the product information needed to be sent to the customer. The export of the order sheet can be done through the tool quickly, considering the Planning Group (PG)5 associated with the customer, the season of interest, and the brand of the products in the proposed assortment.

Additionally, users can decide if they want to include in the Excel file size matrix for each product, displaying then more visually the sizes available for each PC96. The Item Master (IM) The roadmap for the Item Master tool was defined and discussed with software developers, who were able to give insights about the time needed to develop the enhancements. The two most relevant requests for the business were the possibility of showing the price associated with a certain month of delivery and the possibility of uploading the same order for multiple shops. The two enhancements developed for SAP were the possibility to upload the same order for multiple shops and the discovery of the new features the business requested. The two enhancements were realized in two months due to the technical complexity and the part-time developer's previous knowledge of the tool.

3.2.2. Pricing tool (or Pricing Module – PM).

Jump'in developed the Pricing Tool to simplify setting prices for the European assortment of products, considering different countries, typologies, markups, and conversion rates. It was essential to reduce the workload of the merchandising team. The Jump'in team developed a new pricing tool to simplify the status of the process, following all steps required in product management to reach the development of a completely new tool. The team also defined a roadmap for developing the new tool with the help of the leadership. The roadmap is defined in an approximative way, considering the availability of resources, the timing of different phases, and the delivery date given for the tool.

It is important to collaborate with software developers to estimate the time needed to code the application. Jump'in started the innovation process to bring a new Pricing Tool to life, involving meetings with key users, flowcharts, brainstorming, and mock-ups to show the final users what the application should look like. The mock-ups were used to define the behavior expected by the tool, validate the first proposal, and collaborate with key users to reshape the mock-ups and define features. A document with the requirements of the new tool was created. The technical requirements are essential for software and systems development processes and should be set clearly to guide developers while coding.

They should also include flowcharts to help developers read complex parts of the text. Jump'in organized several meetings to review the application requirements and answer questions. During these calls, problems emerged in defining the elements to be included and the logic the tool should follow. Features were prioritized to provide the highest value to the business. Jump'in implemented a way of working (WOW) to provide value through multiple iterations of tools.

Developers supported them by answering questions, organizing meetings, and setting deadlines. Demos were organized between developers and key users to provide updates and clarify doubts. Jump'in developed a new tool in five months, surpassing the expected deadline of three months. The delay was due to technical complexity and a lack of developers, but the development time was short and acceptable compared to the project's value.

3.2.3. Addition Good Request Tool (AGR).

The LSA region requested a tool to carry out the Additional Good Request process, which presents a high complexity and is important for increasing sales. Jump'in focused on developing the new application and the tools and methodology used during the innovation process. The team conducted one-to-one meetings with the people involved in the European AGR process to under-stand how it is carried out locally and compare it to the one conducted in LSA. Flowcharts were used to map the flow of tasks and information. The team conducted interviews to understand the pain points of the people involved with AGR, build documentation, and present a solution implemented in Europe for the AGR process.

They brainstormed on a possible solution to the main problems and built mock-ups for a new tool. The collaboration between Jump'in and LSA colleagues was essential for developing the new AGR tool, enabling them to understand the logic and data needed to apply it. Additionally, a call with the LSA colleagues was held to validate the proposed solution. The team worked on the mock-ups of the application to update them and revise some of the pages. The project will be resumed, and a new roadmap will be defined to conclude the development of the AGR tool.

4. Framework and Discussion

From the conducted observations, it has been feasible to comprehend that the reengineering process for implementing digital solutions in businesses occurs in three primary stages, namely the pre-project, in-project, and post-project phases.

4.1. Pre-Project phase

During the initial phase of the innovation process, the team that oversees the project will concentrate their efforts on evaluating of the time and resources that will be required to carry out the procedure and to present the business with a new digital tool. In this stage, the Operations manager, Product manager, and software developers work together in close collaboration to evaluate the business request that will be implemented and provide an estimation of three primary points: (i) the number of developers that will be required to fulfill the request, (ii) the expected delivery time for the project, and (iii) the expected budget that will be allocated.

When all the necessary resources have been identified, the next step is to create a roadmap to approximate the timeline along which the various activities will be carried out. The tasks that are outlined in the roadmap are the ones that make it possible to develop a new product, beginning with the recognition of a requirement posed by the company and culminating in the distribution of the instrument. Using Gantt charts, the roadmap provides an overview of the following steps and their associated timelines: (i) Discovery sessions; (ii) Development phase; and (iii) Testing and Launch. In conclusion, the evaluation of the required resources and the internal organization of the team are the two primary focuses of the first phase of the project.

Based on the knowledge gained during the observations, the Pre-Project phase can take one to three weeks of work for a single project. The time required is directly proportional to the number of technical challenges that must be overcome while determining the required resources. In this first stage of the innovation process, the goal of the roadmap that will be defined is to provide an estimation of the amount of time needed for the reengineering of the business process, as well as to guide the team through the various tasks that will need to be carried out. Nevertheless,

the planning done during this Pre-project phase is not final, and it can be modified while the project is being carried out to accommodate the various requirements and priorities that come up during the process.

4.2. In-Project phase

Company digital transformation begins in this second phase. The innovation team is currently focused on understanding the business process and business needs, ideating and designing a digital solution, and implementing it to improve a business process. The roadmap for the innovation process is followed by three main phases: Ideation, development, and tool launch.

During solution ideation, the team must first understand the process to be improved, and the business needs to be met while reshaping the process and introducing a new digital tool. The team uses "Discovery sessions" with the business to map the business process. After this, the team can brainstorm how the new application should solve the business problem. The tool's appearance and features are mocked up here. The team can begin development after understanding the business process and conceiving a solution. Technical requirements and tool coding comprise solution development. After the Product manager and team find a solution, the second phase begins with technical requirements, which list all the tool's expected functions. Developers will code the app after the requirements are finalized.

Finally, during testing and launch, the team performs functional testing to evaluate the new application's performance, find and fix bugs, and ensure that it meets business needs. The business can use the new tool after testing. The In-Project phase is the heart of an innovation process, and the team focuses on it. According to analyses, the second tool development phase takes two to six months, depending on the technical challenges of coding features and connecting to other tools.

4.3. Post-Project phase

After the tool has been handed over to the organization, the final stage of the innovation process begins. This is the post-Project phase, where the team focuses on promoting the newly developed application and analyzing its performance in the future. The investigation shows that this phase starts immediately after the tool’s launch and continues throughout its lifecycle. However, the team pays more attention to promoting the tool in the first few months after launch, which suggests that this phase lasts for about a year. This is because the attention given to promoting the tool increases over time.

4.4. Results

This research proposes a framework for companies to reshape their business processes while introducing new digital tools. The results obtained in the framework can be adapted to the specificity of each case, allowing each team to use it as a reference to build their own way of working. Studies previously conducted demonstrate how the adoption of lean practices and the digitalization of processes promoted by Industry 4.0 is gaining strategic importance for companies to gain a competitive advantage in their competitive environment. However, some gaps in the literature can be found here: the impact that the joint implementation of digital technologies and lean practices needs to be clearly quantified, and there needs to be a defined approach to guide companies through their digitalization process. This research contributed to advancing the current literature by proposing a framework that lean companies could follow to digitalize their operations.

The effectiveness of the innovation model presented in this case study has also been assessed based on available data, showing that the reengineering of the order-taking process, with the introduction of a new digital tool, allowed the company to eliminate some non-value adding activities, leading to a saving of 2100 hours The adoption rate of this framework is evidence of its ability to provide the company with digital tools having a good market fit and answering the necessities of users. Different surveys conducted within the MPIM department have revealed that 74,7% of the users are highly satisfied with the applications offered, and 81,1% would be “extremely disappointed” if the tools were stopped. Moreover, none of the interviewees declared to prefer the old ways of working with respect to the new digital applications proposed. These results highlight the positive impact that the adoption of the method, and the

delivery of new web applications through it, has on the business users and the performance of the company. To ensure the implementation of the method is effective and provides the expected results, some recommendations can be provided according to the analysis of the case study.

The most important details in this text are the importance of proper internal organization, constant communication between team members, collaboration with a strong data team, and resistance that could be encountered while implementing new digital solutions within an organization. To bring digital innovation within the processes of a company while keeping a lean and agile way of working, it is essential for the team to have a proper internal organization, follow the principles behind the lean philosophy, and communicate with a strong data team. Additionally, collaboration with a strong data team is at the base of the success of the implementation of new digital tools. Finally, some management actions should be implemented to support the implementation of new digital tools within the business processes and enhance its efficiency level.

The convergence of Lean Manufacturing and Industry 4.0 represents a notable trend shaping the manufacturing landscape. This combination bridges the time-tested methods of Lean Production with the groundbreaking potential of Industry 4.0 tools. The outcomes of this investigation emphasize the symbiotic interplay between these paradigms. The study's revelations showcase how the fusion of Lean's efficiency-centric practices and Industry 4.0's data-driven insights can yield enhanced operational efficiency, waste reduction, and streamlined processes. The paper's case study exemplifies how this harmonized approach yielded amplified production capacity, shortened lead times, and elevated customer satisfaction. Organizations adeptly navigating the details of contemporary manufacturing strategically leverage a holistic strategy that synergistically integrates technological innovation and process enhancement, optimally tapping into the combined potency of Lean and Industry 4.0.

5. Conclusion

This research delves into the advantages and challenges of integrating Industry 4.0 and the Lean methodology in manufacturing companies. The case study highlights the benefits of Lean Automation and Lean Supply Chain Management, along with the advantages of digital technologies in manufacturing operations. However, the research also points out the lack of a clear definition of Industry 4.0 and the importance of effective management strategies and business models to successfully implement digital transformation. Additionally, the case study recognizes the potential benefits of combining Lean Manufacturing with Industry 4.0 while acknowledging that some Lean approaches may not have the same level of digitalization. Lastly, the research proposes a framework for companies to incorporate new digital tools into their operations while reshaping their business processes.

This paper has investigated the way companies are tackling their innovation journey in the context of a case study, introducing a model to face the changes required by organizations and bring innovation within operations. The framework proposed allows for driving the digital transformation of companies, providing a fast and adaptable method to carry out the reengineering of processes, and digitalizing them. The model proposed approaches the digital transformation of a company through three different phases: first, the innovation team needs to define the expected time and resources needed, then the reshaping of a business process to introduce a new digital tool is performed, and the designed application is developed. The proposed model allows companies to improve their operational efficiency by reshaping the way operations are carried out, eliminating non-value-adding activities, and developing new digital tools that can answer the necessities of the business and constitute a good market fit for the company itself. This research describes a model for the digital transformation of operations within companies, but it has limitations.

The results have been derived from observations conducted on the innovations projects of a single, large company, and research conducted on a larger set of case studies could lead to more precise considerations on the way companies operating in different sectors and having different sizes can improve their processes. Additionally, a technology-based approach is still missing, and further analyses and examples are needed to better estimate the benefits given by the application of the proposed approach. Finally, further analyses and examples are needed to add details to what has been proposed and to better define the developing approach to be followed. To conclude, this paper provided a general framework to drive digital transformation within companies, a framework that can be used as a reference and that still must be adapted to the specificities of each case.

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