

Driving lean practices to improve procurement in supply chains through Industry 4.0

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Abstract. This study examines the pivotal function of lean practices in optimizing procurement processes across supply chains through the implementation of Industry 4.0 (I4.0) technologies. It addresses the inefficiencies and high costs associated with traditional procurement methods. The objective is to develop a model that integrates these approaches in order to revolutionize procurement strategies, based on a comprehensive review of the relevant literature. The findings of this study offer significant insights for organizations striving to enhance the efficiency of their procurement operations within the context of the contemporary business environment, characterized by rapid changes and competition.

Keywords: Lean, I4.0, procurement.

1 Introduction

The procurement stage of the supply chain is of crucial importance, as it is the starting point for its success and the guiding thread for the smooth running of the various processes within the supply chain. Hence the need to strengthen this stage. On the other hand, lean manufacturing has demonstrated greater efficiency in production [1], and more specifically, lean has improved the functioning of the entire supply chain, and it certainly will prove to be the case, if digitalization is added to the Lean method. I4.0 technologies, such as data analytics, artificial intelligence, and the Internet of Things (IoT), are transforming traditional manufacturing processes by providing automation, real-time data insights and predictive analytics for better decision-making [2]. It's noteworthy that digital transformation is a roadmap to excellence for the organization, includes a number of components, such as tools that help to automate operations, and the technological instruments designed to increase an organization's competitiveness [3].

The main research questions of this paper are as follows:

- Do I4.0 technologies impact Lean practices to streamline procurement in a supply chain?

- How can procurement processes be transformed through the implementation of I4.0 technologies and Lean practices?

To answer these questions, the paper outlines the importance of Lean practices and I4.0 for procurement in supply chains, and the need to optimize and improve efficiency in contemporary business environments. After an exhaustive literature review on I4.0 and lean practices, this paper will present a general framework on the implementation of I4.0 and how it could be used to transform procurement processes by also using lean practices. While identifying the key ideas, challenges, and opportunities related to leveraging lean practices to improve procurement in supply chains through I4.0.

2 Literature Review

2.1 Lean Practices Used to Streamline Procurement

The concept of ‘lean manufacturing’ has been defined by the use of terms like multi-skilling, cooperative work preparation, and flow studies (scheduling, planning, etc.)[4]. Lean production’s primary goals are waste reduction and improved product competitiveness through the application of cost-cutting and quality-improvement techniques [5]. A number of core lean practices are frequently employed in order to facilitate the optimization of procurement procedures. One common lean tool, value stream mapping (VSM), is a technique that enables the visualization and analysis of a process in order to identify and remove non-value-added activities, thereby streamlining operations [6]. For instance the study carried out by [7] provides an example of how the (VSM) approach can be used to visually portray and rationalize activities inside a physical enterprise. The approach entails the differentiation between Value-Adding (VA) and Non-Value-Adding (NVA) processes, facilitating the identification of inventory accumulation and the calculation of lead times. The Just-in-Time (JIT) system is also important to discuss. JIT aims to lower inventory costs by coordinating material purchases with production schedules. This procedure minimizes waste and lowers storage costs by ensuring that items are delivered precisely when needed [8].

In addition, the idea of Kaizen, or continual improvement, is something to think about. The Kaizen technique encourages staff members at all organizational levels to actively participate in the ongoing improvement of operational procedures and infrastructure. The approach encourages the use of little, gradual changes that, when added together, result in major breakthroughs [9]. The study conducted by G. [1] aimed to conduct an empirical inquiry into the relationships between the use of lean methodologies. The findings indicated that the relationship between the practices might not consistently yield synergistic outcomes. Specifically, there were instances where concurrent implementation of certain practices led to conflicting outcomes, thereby impeding the potential benefits associated with these practices.

2.2 I4.0 Technologies Used to Streamline Procurement

The advent of Industry 4.0 (I4.0) technologies has ushered in a new era of automation, real-time data insights, and advanced analytics in the realm of procurement processes.

The key Industry 4.0 technologies employed to streamline the procurement process include: The Internet of Things (IoT), which facilitates the real-time tracking and surveillance of materials and products, the interconnection of sensors and devices via the Internet facilitates the continuous acquisition and examination of data, thereby enhancing the visibility of procurement operations and the quality of decision-making processes [10]. Furthermore, artificial intelligence (AI) which has the potential to enhance decision-making processes through the utilization of predictive analytics, thereby facilitating more accurate demand forecasting and inventory optimization. The application of machine learning algorithms to historical data enables the prediction of future trends, thereby reducing the uncertainty inherent in the procurement process [11]. Also referred to as "Digital Twins," these are virtual replicas of physical assets, processes, and systems. Such systems permit real-time monitoring and simulation, thereby facilitating the optimization of procurement processes through predictive analytics and scenario planning [12].

Moreover, blockchain technology offers a secure and transparent framework for transactions and procurement, as it operates through a decentralized ledger that logs all transactions, thereby safeguarding data accuracy and reducing the likelihood of fraud [13]; [14]. Lastly, predictive analytics tools utilize statistical algorithms and machine learning techniques to forecast future events. In the context of procurement, these tools facilitate demand forecasting, risk assessment, and decision optimization, thereby enabling the formulation of more efficient and proactive procurement strategies [13].

2.3 Bibliographic Analysis of Lean Practices and I4.0 Technologies

The combination of lean manufacturing tools and I4.0 concepts will help to transform industrial processes in a supply chain, and I4.0 will provide technological tools to facilitate this transformation [4]. The research work of [4] has demonstrated the possibility of automating many tasks within the manufacturing industry to incorporate I4.0 concepts. Multi-functional, flexible value chains demand that players and systems are interconnected throughout the value creation process and therefore need a higher level of digitalization [15]. With increasing volumes of data emerging from interconnected production resources, [16] propose to develop different models to support the use of digital technologies in lean production systems.

As far as infrastructure is concerned, it must be designed to adapt to any change because advanced technologies come at a high cost, both in terms of the cost of materials and the complexity of implementation [17]. The implementation of lean and intelligent concepts is making a significant impact on logistics performance, while autonomous logistics systems have yet to be fully implemented and exploited [18]. Today, the trademark I4.0 defines the discussion on the revolutionary development of digitalization while at the same time improving productivity, flexibility, and customer focus [2].

The procurement phase is essential in the supply chain, as it has an impact on the overall efficiency and profitability of operations [19]. Indeed, there are some effective procurement practices that can improve relations with suppliers and streamline pro-

cesses, such as optimizing procurement decisions, reducing costs, and minimizing the risks associated with supply disruptions. In a nutshell, these practices can be further improved by integrating lean methods and digitalization (I4.0). [20] underlined the relevance of digital technologies in modern procurement processes, highlighting the role of e-procurement systems, automation, and data analysis in increasing the transparency and efficiency of procurement. In summary, the extant literature indicates that while lean practices are primarily concerned with enhancing efficiency and reducing waste, I4.0 technologies facilitate more effective decision-making and automation, thereby contributing to a more streamlined procurement process.

3 Research methodology

The aim of this research is to ascertain whether the implementation of Industry 4.0 (I4.0) technologies affects the efficiency of lean practices in the procurement process within supply chains. A systematic literature review methodology is used in this paper to collect and analyze pertinent research papers on the contribution of lean practices to improving procurement along supply chains using I4.0 technologies. Scopus and Web of Science databases are used as database selection tools to capture scientific papers on lean practices, supply chains, procurement, and I4.0 technologies, and the key words ‘lean manufacturing’, ‘lean’, ‘procurement’, ‘sourcing’, ‘supply chain’ and ‘industry 4.0’ are used to pinpoint relevant literature reviews. Research works focused on lean principles, procurement strategies, supply chain optimization, and I4.0 applications are among the inclusion criteria, with full emphasis on papers written in English. Papers that do not pertain to the subject of procurement or supply chain management, as well as studies that do not incorporate lean practices or the fourth industrial revolution (I4.0) technologies, are excluded from consideration. Additionally, publications that are not in the English language are not eligible for inclusion. In addition to the synthesis of the collected data, in order to determine the challenges, opportunities, and key ideas related to the integration of Lean practices and I4.0 in procurement processes within the supply chain.

The systematic review entailed the identification of pertinent literature pertaining to the integration of lean practices and I4.0 technologies. This was followed by a comprehensive examination of the selected papers, wherein the full texts were carefully reviewed to ascertain their alignment with the established inclusion criteria. Subsequently, papers that offered substantial insights into the convergence of lean practices and I4.0 technologies in the domain of procurement were selected. Finally, the papers were categorized into three distinct groups. The categories were as follows: Category 1 (Lean practices), Category 2 (I4.0 technologies), and Category 3 (combining Lean practices and I4.0 technologies), as follows:

- **Category 1:** Papers Treating Lean Practices: Papers on Lean Practices The findings should be summarized in a manner that highlights the benefits of lean practices in the context of procurement, including, but not limited to, the reduction of waste, improvements in efficiency, and cost savings.

- **Category 2:** Papers Treating I4.0 Technologies: Provide a summary of the findings that highlight the potential for I4.0 technologies, including the Internet of Things (IoT), artificial intelligence (AI), and blockchain, to bring about transformative changes in the field of procurement.
- **Category 3:** Papers Combining Lean Practices and I4.0 Technologies: Provide a summary of the findings that demonstrate the synergistic benefits of integrating lean practices with Industry 4.0 technologies in procurement processes.

The objective of the performance analysis of the procurement process, based on findings from each category, was to ascertain whether I4.0 technologies have the potential to enhance lean practices. A matrix (Table 1) was constructed to visually represent the impact of specific I4.0 technologies on lean practices, thereby ensuring robust findings and offering useful insights for organizations aiming to develop more effective procurement strategies.

4 General framework

Waste prevention, continuous improvement, and value stream mapping are among the principles of the Lean method, which aims to reduce lead times in manufacturing processes and improve operational efficiency. The procurement process involves a set of activities, from the acquisition and management of resources and essential services to the organization's functioning.

Table 1 below provides a summary of key opportunities and practices that procurement managers can implement in order to enhance the procurement process through the application of lean principles and Industry 4.0 (I4.0) technologies. The data presented in Table 1 has been derived from a comprehensive analysis of current literature and case studies that highlight successful integrations of lean methodologies and advanced technologies within procurement functions. The table presents a detailed overview of the specific lean practices that are complemented by the corresponding I4.0 technologies. This enables procurement managers to gain a comprehensive understanding of the synergies between these two distinct but complementary approaches. By employing this framework, managers can establish a hierarchy of initiatives based on their organizational goals and the suitability of the outlined strategies for their specific procurement challenges.

Tableau 1. Challenges, key ideas, opportunities for procurement integrating Lean and 4.0 tools

Description	Reference	Main terms	Areas of application	
			L	I.
			ean	4.0

	Description	Reference	Main terms	Areas of application	
				L ean	I. 4.0
Chal- lenges	Integrating Lean practices and Industry 4.0 into procurement processes can meet opposition from staff used to traditional methods, which requires appropriate change management strategies to deal with this challenge.	[21];	Resistance to Change	■	■
	Combining lean principles with Industry 4.0 technologies may present challenges in terms of aligning data from different sources and achieving interoperability among systems.	[22]; [23]	Data Integration Complexity	■	
	Bridging the skills gap within procurement practitioners to use advanced technologies such as AI, IoT, and blockchain effectively across lean practices and Industry 4.0.	[23]; [24]	Skill Gaps	■	■
	Ensure the integrity and confidentiality of data, and protect against cyber threats. And managing the cyber security risk arising from the digitalization of procurement processes	[25];	Cyber security Risks		■

Key ideas	Description	Reference	Main terms	Areas of application	
				Lean	4.0
	Digital twin technology can improve procurement processes through virtual replicas of physical assets, predictive analytics, and simulation to support better decision-making.	[26]; [27]	Digital Twin Adoption	■	
	Fostering a culture of continuous improvement founded on lean principles as part of Industry 4.0 can drive responsiveness, innovation, and agility in supply operations, thereby promoting a competitive advantage in the marketplace.	[28]	Continuous Improvement Culture	■	
	Embed smart contracts driven by blockchain technology so as to automate procurement transactions, enhance transparency, and strengthen trust between supply chain partners.	[29]	Smart Contracts Implementation	■	
	The use of predictive analysis tools for forecasting demand, assessing potential risks, and optimizing procurement decisions on the basis of trend analysis and data-driven information.	[30]	Predictive Analytics Utilization	■ ■	

	Description	Reference	Main terms	Areas of application	
				L ean	I. 4.0
Oppor- tunities	Lean practices and Industry 4.0 embedded in procurement processes present opportunities to enhance global efficiency, and rationalize operations thanks to data-driven decision making and automation.	[5]; [23]	Enhanced Efficiency		■
	The ability to make proactive decisions and optimize procurement activities is thanks to Industry 4.0, since it enables real-time monitoring of these activities.	[22] ;[31]	Real-time Monitoring		■
	Industry 4.0 can increase supply chain visibility, thereby enabling demand forecasting, real-time stock tracking, and supplier performance assessment.	[32];[33]	Supply Chain Visi- bility		■
	Lean principles integrated with Industry 4.0 can drive cost reductions by optimizing inventory control, effective resource allocation, and demand-driven procurement.	[34]	Cost Re- duction		■

The model presented in Figure 1 below summarizes table 1. It integrates principles from Industry 4.0 and the Lean methodology with the aim of enhancing procurement processes. The model incorporates several key components, including the adoption of digital twins, the establishment of a culture of continuous improvement, the implementation of smart contracts, and the utilization of predictive analytics. The model has been designed with a view to enhancing efficiency, facilitating real-time monitoring, improving supply chain visibility, and achieving cost reduction. It also seeks to address a number of other challenges, including resistance to change, data integration complexity, skill gaps, and cybersecurity risks.

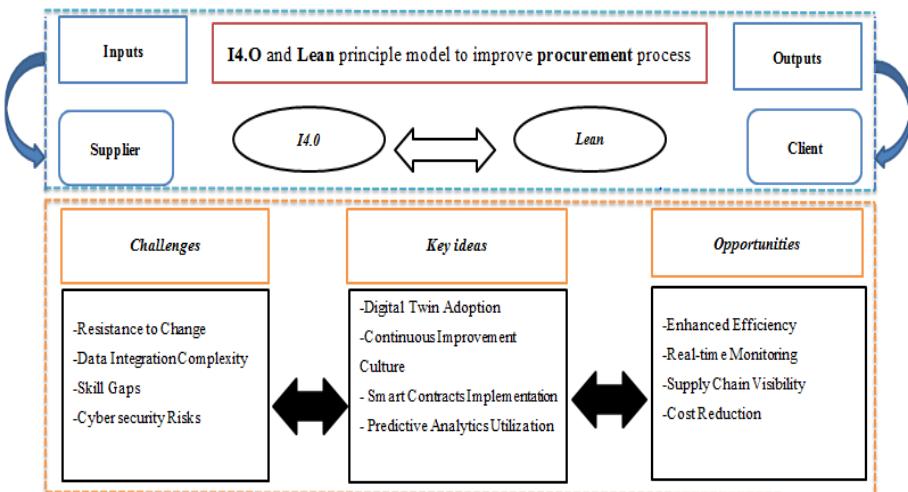


Fig. 1. Challenges, Key ideas, and opportunities beyond the integration of Lean and I4.0 in procurement process

4.1 Discussion

The proposed framework emphasizes the vital necessity for the integration of lean practices and Industry 4.0 technologies in order to enhance the efficacy of procurement processes within the context of supply chains. Table 1 identifies significant challenges, including resistance to change, data integration complexity, skill gaps, and cybersecurity risks, as well as potential opportunities, such as enhanced efficiency, real-time monitoring, supply chain visibility, and cost reduction. The model illustrated in Figure 1 illustrates the effective combination of these principles to optimize procurement strategies.

As an illustration, the implementation of digital twin technology can markedly enhance procurement decisions by furnishing virtual replications of physical assets for more optimal decision-making through predictive analytics and simulations. Likewise, encouraging a culture of continuous improvement based on the principles of Lean within the context of Industry 4.0 can facilitate innovation and agility, thereby conferring a competitive advantage on companies in the marketplace. Nevertheless, the implementation of these technologies necessitates the surmounting of considerable

challenges, including the assurance of robust cybersecurity measures and the bridging of skill gaps among procurement practitioners.

Future research should investigate the potential impact of emerging technologies, such as blockchain, on the optimization of procurement processes within the context of Industry 4.0 and lean practices. This may facilitate a deeper understanding of the potential for enhancing transparency, automation, and trust in supply chain transactions.

5 Conclusion

The objective of this paper is to propose an integrated model that incorporates both Lean principles and I4.0 technologies with the aim of improving the efficiency of procurement processes. Through the effective addressing of challenges and the strategic leveraging of opportunities, the model strives to enhance process performance and establish a resilient framework for decision-making. This approach will assist organizations in attaining enhanced efficiency, responsiveness, and cost savings in their procurement operations, in alignment with the demands of a rapidly evolving business landscape. It is recommended that future research be directed toward the development of strategies for skill development, cybersecurity, and continuous improvement, with a view toward further refining and implementing the proposed framework.

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