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Lean Six Sigma Implementation and Sustainability: An Investigation into Moroccan Manufacturing Firms

Implementación de Lean Six Sigma y sostenibilidad: una investigación sobre empresas manufactureras marroquíes

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Abstract

Goal: The purpose of this paper is to explore the implementation level of Lean Six Sigma (LSS) within manufacturing companies in Morocco. It examines the LSS tools used by these industries and their impact on sustainable performance. Design/Methodology/Approach: Data were collected through semi-structured interviews with 20 participants from industrial companies and analyzed using NVivo 10 software. Results: The results indicated that both Lean and Six Sigma approaches are used; however, Lean tools are predominant. The most used LSS tools include 5S, VSM, Ishikawa, standardized work, DMAIC, Kanban, and visual management. Interviewees perceived that effective implementation of LSS tools positively influences sustainable performance, with particular improvements noted in the economic pillar. Limitations of the investigation: The potential for biased responses due to the subjective nature of interviews and the lack of generalizability of findings beyond the specific context of Moroccan manufacturing companieslimitation of the study is the potential for biased responses due to the subjective nature of interviews and the lack of generalizability of findings beyond the specific context of Moroccan manufacturing companies. Practical implications: This study offers practical guidance to manufacturing companies in Morocco, helping them to select appropriate Lean Six Sigma tools, prioritize improvement initiatives, cultivate a culture of continuous improvement, benchmark against industry standards and, ultimately, improve sustainable performance results. Originality / Value: Most studies dedicated to investigating the impact of LSS on sustainability has have been conducted in developed countries. Therefore, the originality of this work is in to trying to exploringe those concepts in a developing country like Morocco.

***Keywords*:** Lean, Six Sigma, LSS, Sustainability.

Resumen

Objetivo: El objetivo de este artículo es explorar el nivel de implementación de Lean Six Sigma (LSS) en las empresas manufactureras de Marruecos. Examina las herramientas LSS utilizadas por estas industrias y su impacto en el desempeño sustentable. Diseño/Metodología/Enfoque: Los datos se recopilaron a través de entrevistas semiestructuradas con 20 participantes de empresas industriales y se analizaron utilizando el software NVivo 10. Resultados: Los resultados indicaron que se utilizan tanto los enfoques Lean como Six Sigma; sin embargo, las herramientas Lean son predominantes. Las herramientas LSS más utilizadas incluyen 5S, VSM, Ishikawa, trabajo estandarizado, DMAIC, Kanban y gestión visual. Los entrevistados percibieron que la implementación efectiva de las herramientas LSS influye positivamente en el desempeño sustentable, con mejoras particulares observadas en el pilar económico. Limitaciones de la investigación: La posibilidad de respuestas sesgadas debido a la naturaleza subjetiva de las entrevistas y la falta de generalización de los hallazgos más allá del contexto específico de las empresas manufactureras marroquíes. Implicaciones prácticas: Este estudio ofrece una guía práctica para las empresas manufactureras en Marruecos, ayudándolas a seleccionar herramientas Lean Six Sigma adecuadas, priorizar iniciativas de mejora, cultivar una cultura de mejora continua, comparar con los estándares de la industria y, en última instancia, mejorar los resultados de desempeño sustentable. Originalidad / Valor: La mayoría de los estudios dedicados a investigar el impacto de LSS en la sustentabilidad se han realizado en países desarrollados. Por lo tanto, la originalidad de este trabajo radica en tratar de explorar esos conceptos en un país en desarrollo como Marruecos.

Palabras claves: Lean, Six Sigma, LSS, Sustentabilidad.

Introduction

Because industrial processes can have profound effects on ecosystems, natural resources, and people, the manufacturing industries are highly concerned about sustainable development (Neri et al., 2021; Hebaz et al., 2022; Wankel & Stachowicz-Stanusch, 2020). These industries need to remain competitive in an increasingly globalized market, which requires not only gaining more market share and making profits but also considering social and environmental issues to satisfy the requirements of all stakeholders throughout the company's supply chain, from the first supplier to the last customer, therefore fulfilling sustainability goals. Thus, this is one of the reasons that drives them to look for new approaches such as Lean Six Sigma (AitHammou & Oulfarsi, 2022). Lean management is mostly concerned with eliminating waste and identifying operations that do not add value to the product. To better meet customer needs, lean companies focus on decreasing production cycles by simplifying their operations and using limited resources better (Do Rosário Cabrita et al., 2015). Six Sigma, on the other hand, focuses on identifying and reducing process variations through the identification of the root causes behind the problems that disrupt the production process, the measurement of the extent of these problems, the analysis through various tools, then the implementation of possible improvements and most importantly the maintenance and control of the results obtained (Sujova et al., 2016). Despite their success and the positive results of applying these two methods separately, Lean and Six Sigma each have their own limitations. Thus, the Lean Six Sigma (LSS) approach was the result of their integration, combining the benefits of Lean and Six Sigma to reduce waste and variation at the same time, thus leading to a continuous improvement of productivity, performance, and quality to provide greater customer value (Do Rosário Cabrita et al., 2015; Singh & Rathi, 2019).

It is certain that this field of research on the use of lean and Six Sigma tools and their integration with sustainability concerns has already been the subject of a significant number of studies. Several researchers have addressed the importance of the implementation of LSS tools to improve the sustainable performance of

manufacturing companies, resulting in financial profits, employees' satisfaction, health and safety, as well as waste elimination and energy efficiency (Fatemi & Franchetti, 2016; Kalkar & Chitanand, 2018). However, the studies that have presented an approach that considers the use of LSS tools with the economic, social, and environmental dimensions simultaneously are not deemed to be sufficient (De Freitas et al., 2017; Caiado et al., 2019; AitHammou et al., 2022). Moreover, there is still a scarcity of empirical studies in the literature investigating which LSS tools are most effective in achieving sustainable performance goals within the manufacturing context, especially when it comes to their effect on social aspects and also their use in developing countries like Morocco (Cherrafi et al., 2016; Belhadi et al., 2020). Thus, the purpose of this study is to (i) discover the level of use of the LSS approach in Moroccan manufacturing companies, (ii) identify the main LSS practices and tools used by these companies, and (iii) determine the awareness level of manufacturing practitioners about the concept of sustainability and if the use of LSS tools help them to improve their sustainable performance. This paper begins with a literature review presenting the LSS concept and its relationship with sustainable performance. Then, the methodology used is presented, followed by the results obtained and discussion. Finally, the last section of this paper is devoted to the conclusion.

Literature review

Lean six sigma

The definition of lean approach is mainly based on the concept of added value. Thus, lean manufacturing aims to examine all the activities in the production process of the company to determine the level of added value of each of these activities for both the final product or service and the customer. Then, non-value-added activities are to be eliminated because they are considered wasteful (Ratnayake & Chaudry, 2017). Overproduction, overprocessing, inventory, waiting times, transportation, motion, and defective outputs are all examples of the seven types of waste known as "mudas" in the Japanese language (Cherrafi et al., 2018). Lean provides a variety of tools to facilitate the identification of the seven distinct categories of waste, such as value stream mapping (VSM), 5S, Pareto analysis,

kaizen events, total productive maintenance (TPM), standardized work and visual management (Cherrafi et al., 2016). Numerous organizations have adopted lean manufacturing as a strategy because of its capacity to enhance manufacturing efficiency and its ability to improve quality at low production costs by emphasizing waste elimination (Iyede et al., 2018). While Lean manufacturing is focused on waste minimization, the Six Sigma methodology is implemented by companies to reduce process variation, decrease defect rates, increase customer satisfaction, and decrease overall costs using statistical tools. The success of this methodology is conditioned by the completion of the DMAIC structured framework (define, measure, analyze, improve, and control) (Moya et al., 2019; Narottam et al., 2020).

Initially used separately, Lean and Six Sigma have been combined because of their completeness. Customer satisfaction through operational excellence and continuous improvement are their common objectives. Companies often start by using Lean before launching projects with Six Sigma tools. As experience is gained in these projects, organizations become more reflexive in their choice of tools. According to Salah et al. (2010), the two strategies, Lean and Six Sigma, focus on specific aspects of organizational performance. Thus, efficiency can be negatively affected in a highly competitive environment when any of these programs are implemented alone. Therefore, it is important for Lean companies to integrate more data into decision-making and use methodologies promoting a more scientific approach to quality. Six Sigma companies should also integrate the lean culture through training for all employees to eliminate all types of waste. Assarlind et al. (2013) also consider that Lean and SS are complementary. Based on the case study they conducted, it was concluded that the implementation of Lean, after Six Sigma, considerably improved the performance of the concerned organization. Moreover, Alhuraish et al. (2017) have conducted a study on 33 industries in France to compare the performance of companies using lean management and Six Sigma, lean management only, or some Six Sigma tools only. They have found that the two approaches work together to enhance the financial performance, operational performance and innovation performance of companies.

Lean six sigma and manufacturing sustainability

The term “sustainability” is used to describe an unlimited method of development, which seeks to maximize the value for human beings while also minimizing negative impacts on the environment (Duran et al., 2015). According to Zimek and Baumgartner (2017), company’s sustainable performance is how well it balances profit with responsibility to the environment and society. Thus, various measurements are used to evaluate and assess the effects of these factors. The social dimension considers the welfare of individuals and groups, encompassing issues such as access to education and employment opportunities, as well as issues of health and safety. The environmental dimension is concerned with how human actions affect the planet’s natural resources, as well as issues of energy efficiency, pollution, and environmental degradation, and the economic dimension discusses methods for increasing business success and profits while minimizing costs and maximizing efficiency (Erdil et al., 2018). Because of the paradigm shift in our society to focus on the effects of economic activity, sustainability has emerged as one of the key objectives of manufacturing organizations. As a result, these organizations must now demonstrate a strong commitment to the environment and society in their actions (Ben Ruben et al., 2020). Recently, due to factors such as increasing competitiveness in all sectors, climate change, growing consumer demands, and increasingly rigorous regulations, especially concerning polluting industries, companies are constantly seeking new strategies to satisfy all stakeholders. Thus, LSS was one of the approaches investigated in several studies to assess its compatibility and results in improving the company’s profits and employees’ well-being while protecting the environment. In this regard, the study of Cherrafi et al. (2016) confirms that there is a synergy between LSS and sustainability, as they share an interest in waste reduction with a strong commitment to continuous improvement, taking into consideration supply chain relationships, employee involvement, and customer satisfaction. However, they have argued that there is a lack of an integrated measurement system to assess LSS and sustainability performance from social, environmental, and economic perspectives. In addition, the relationship between LSS implementation and social performance has not been fully explored in

academic research. Several researchers have tried to identify which of the wide range of LSS tools can be used to improve companies' sustainable performance. As a synthesis, we have compiled a table (Table 1) with 18 studies that have presented LSS tools for sustainability improvement, with a classification of these tools according to their frequency of citation. However, few articles have studied the impact of the integration of lean and Six Sigma tools on the three aspects of sustainable performance at the same time (Cherrafi et al., 2016; Fatemi & Franchetti, 2016; Ratnayake & Chaudry, 2017; Erdil et al., 2018; Kalkar & Chitanand, 2018). To provide an overview of the most important studies that have investigated the relationship between the LSS approach and sustainable performance outcomes, Table 1 presents the aspects of sustainability covered by each of these studies (Ec: economic, So: social, Ev: environmental), as well as their main contributions.

Tabla 1 Major contributions of the main studies on the integration of LSS with sustainable performance goals.

Authors	Sustainability			Main contribution
	Ec	So	Ev	
Banawi and Bilec (2014)			✓	Reducing waste as a result of integrating Lean, Green, and Six Sigma.
Kumar et al. (2015)	✓	✓	✓	The integration of LSS and sustainability concepts is very important for meeting economic, social, and environmental challenges. However, the impact on costs is negative.
Cherrafi et al. (2016)	✓	✓	✓	Improved health and safety, employee commitment and morale, team spirit, reduced waste, lower costs and higher profits.
Cherrafi et al. (2016)	✓		✓	Value Stream Mapping (VSM) is used to identify environmental waste, the 5S technique to improve waste management, and cellular production to reduce energy consumption.

Authors	Sustainability			Main contribution
	Ec	So	Ev	
Kowang et al. (2016)	✓	✓	✓	The identification of five key factors for achieving LSS sustainability goals: continuous improvement culture, innovation culture, team management approach, employees' level of LSS knowledge and communication.
Sagnak and Kazancoglu (2016)			✓	Six Sigma overcomes the limitations of Lean and Green methods to improve environmental performance.
De Freitas and Costa (2017)	✓	✓	✓	A strong tendency for LSS to improve economic sustainability, especially in terms of cost reduction and quality improvement. The majority of identified impacts have a neutral effect on the environment. However, most of the impacts identified have a negative or neutral effect on social performance.
De Freitas et al. (2017)	✓	✓	✓	Strong correlation between LSS and the three dimensions of sustainable performance.
Powell et al. (2017)			✓	LSS reduces environmental waste at both corporate and supply chain levels.
Ratnayake and Chaudry (2017)	✓	✓	✓	Value Stream Mapping (VSM) is a tool for improving various aspects of sustainable performance.
Chugani et al. (2017)			✓	Lean and Six Sigma both have a positive impact on the environment, particularly in terms of efficient use of resources, climate protection and energy savings.
Walter et al. (2018)	✓	✓	✓	The 5S and Kaizen tools have been identified as the most effective for reducing the environmental and social impacts of industrial companies.
Ben Ruben et al. (2018)			✓	Integrating the LSS approach with environmental strategies is a powerful tool for reducing environmental impacts.
Erdil et al. (2018)	✓	✓	✓	Economic sustainability is the result of improved environmental performance.

Authors	Sustainability			Main contribution
	Ec	So	Ev	
Kalkar and Chitanand (2018)	✓	✓	✓	The “Sustainability Goal Tree” concept is used in LSS projects to achieve sustainable development results.
Caiado et al. (2019)	✓		✓	Organizations that adopt Lean Management and Six Sigma generally improve the efficiency of their use of natural resources and reduce energy costs and environmental impacts.
Sony et al. (2020)		✓	✓	LSS has a positive impact on several social and environmental aspects.
Khan et al. (2020)	✓	✓	✓	Integrating Green, Lean, and Six Sigma approaches enables us to gain a competitive advantage in terms of sustainable performance.
Ben Ruben et al. (2020)	✓	✓	✓	There is a strong correlation between LSS and sustainable production, contributing to improved organizational performance. Indeed, the LSS strategy complements sustainability initiatives by providing benefits relating to resource consumption. Consequently, the integration of LSS and sustainability helps the company to achieve sustainable operational benefits.
Ali et al. (2020)			✓	The three strategies of Lean, Six Sigma and environmental sustainability have a positive impact on the environmental performance of SMEs, by reducing waste and variation in production processes.
Kaswan and Rathi (2020)	✓	✓	✓	The SIPOC and Environmental Value Stream Mapping (EVSM) tools have proved to be the most widely used in the DMAIC method. These tools not only increase productivity but also reduce negative environmental impacts.
Parmar and Desai (2020)	✓	✓	✓	The Lean Six Sigma approach can improve all three dimensions of sustainability. However, the social dimension has been the least studied in previous studies.

Authors	Sustainability			Main contribution
	Ec	So	Ev	
Belhadi et al. (2020)			✓	LSS efforts have a partial mediating effect on the relationship between Big Data analytics capabilities and environmental performance.
Farrukh et al. (2021)			✓	LSS tools help to define and solve environmental problems.
Mundra and Mishra (2021)	✓	✓	✓	The direct impact of integrating LSS tools with Agile tools on economic progress, and indirect impact on social and environmental aspects.
Gaikwad and Sunnapwar (2021)	✓	✓	✓	To achieve positive results, project selection must be based on customer demand, environmental concerns and socio-economic needs.
Ahmad and Khan (2022)			✓	Combined with an environmental strategy, the LSS approach is capable of meeting environmental protection goals.
Yadav and Gahlot (2022)	✓	✓	✓	The integrated use of Green and Lean methods within a structured Six Sigma framework enables small and medium enterprises to improve their sustainability.
Walter et al. (2023)	✓	✓	✓	Combining sustainability with LSS has the potential to enhance the advantages delivered to companies. However, the majority of existing Sustianable-LSS frameworks primarily rely on conventional LSS methodologies and incorporate a few sustainability-focused key performance indicators.

Source: The authors themselves.

Methodologies and Data

This research paper is based on a qualitative exploratory study that provides an in-depth and rich investigation (Yin, 2016). Therefore, to identify the Lean Six Sigma tools used in the context of Moroccan industries, as well as the perception of these companies towards the concept of sustainability and the role played by LSS tools in improving this concept, we have chosen semi-structured interviews as a data

collection tool, using an interview guide. The strength of this instrument is that it is carefully planned to ensure that all the topics from the interview guide are covered while maintaining focus on the interviewee's thoughts and experiences (Keegan, 2009). This study uses both purposive and snowball sampling. Thus, semi-structured interviews were conducted with 20 managers from different companies in the Moroccan industrial sector who work with Lean and Six Sigma methods. Initially, the participants were selected intentionally based on their expertise in the Lean and Six Sigma tools. Then, since it was difficult to identify more people working with Lean and Six Sigma methods, we asked participants to suggest other people with similar backgrounds from other industries (Creswell, 2015).

The interview guide used in this study has four main sections. The first section contains questions related to general information about the participant and the company they belong to, such as the type of industry in which the company operates, the position occupied, and the number of years of work experience. This section is very important to justify whether the person is qualified to participate in the interview. The second section contains questions regarding the implementation of Lean and Six Sigma tools in the company, such as the type of tools used, the frequency of use of these tools, and the benefits resulting from the implementation of these approaches. The third section contains questions related to the three aspects of sustainable performance, namely the economic, social, and environmental aspects. The objective is to know the level of importance given by the company to the concept of sustainability through the activities performed, as well as the existence of indicators dedicated to the evaluation of the company’s results in terms of sustainable performance. In the last section, the questions concern the determination of the possible effects of LSS practices on sustainable performance and the identification of the sustainability dimension that is likely to be most positively affected using LSS tools. The interviews were conducted in the language in which the interviewees felt comfortable expressing themselves to ensure the validity of the qualitative research. Prior to each interview, we ensured the anonymity of all interviewees to guarantee their freedom of expression, which allowed them to authorize the voice recording of the interview. In this context, Rowley (2012)

highlights the importance of ethical considerations in conducting interviews, such as obtaining informed consent from participants, maintaining confidentiality, and protecting sensitive information. The pilot study was then performed with three participants, as shown by Azalanzazllay et al. (2020). A period of 30 to 40 min was estimated for the interviews, but there were some interviews that went beyond this time frame because the participants wanted to give more details, which allowed us to enrich our practical knowledge about the topic. It was planned that the interviews would be conducted face to face, but since this study was conducted between 8 January and 16 February 2022, a period during which the Omicron wave, a variant of COVID-19, reached its peak in Morocco, we were obliged to switch to phone interviews to respect the health regulations imposed. After the transcription of the 20 interviews, the data were imported into NVivo 10 software to perform the thematic analysis. This software allowed us to code the data into blocks of information and helped us identify the different themes. The steps and processes of qualitative data analysis from Laureani and Antony (2017) were as follows: (1) familiarizing yourself with the data; (2) generating initial codes; (3) searching for themes; (4) reviewing themes; (5) defining and naming themes; and (6) producing the report. As a result, four themes were generated, which will be discussed in detail in the next section.

After transcribing the 20 semi-structured interviews, the data was imported into NVivo 10 software for thematic analysis. These interviews enabled us to collect a considerable amount of data. Based on the principle of confidentiality and to respect the anonymity of the interviewees as they requested, we assigned each participant a Greek alphabet code. Our coding process began by identifying open codes. These are NVivo nodes, where we used participants' words to identify and label meaningful concepts. After initial coding by assigning codes to the relevant text extracts, categorization involves clustering these similar or related codes into broader, thematic categories. Then, we carefully assessed the relevance of the codes emerging from the qualitative analysis. To do this, we carried out an in-depth review of the coded text extracts for each category identified during the categorization process. We ensured that each coded extract matched the corresponding theme, making sure that the content expressed in these extracts was

indeed representative of the underlying topic, and we assigned all the categories to the themes that grouped them. Finally, the four main themes obtained are presented and discussed in the section below.

Results and discussion

The main objective of this qualitative study is to explore the use of LSS practices in Moroccan industries and identify the perceived impact on sustainable performance. By examining the results of this study in relation to the Moroccan industrial context, we aim to provide valuable information on the degree of application of Lean and Six Sigma approaches, the tools most widely used in the Moroccan industrial context, the importance attached to the concept of sustainable development by these industries, as well as the perceived impact of Lean and Six Sigma, approaches on performance: economic, social and environmental.

Thus, we have conducted 20 interviews with professionals in various positions within different industrial companies in Morocco. Table 2 provides general information on the profile of the participants in this survey.

Table 2. Profile of the interviewees.

N°	Respondent code	Gender	Experience (years)	Position	Industry
1	AA	M	6	Process engineer	Aeronautics
2	SD	M	6	Continuous Improvement Engineer, LSS Green Belt	Microelectronics
3	RC	M	27	Quality Monitoring Manager	Food industry
4	AG	M	10	Quality Manager	Automotive
5	MB	F	9	Quality Assurance and Regulatory Affairs Specialist	Pharmaceuticals
6	MM	M	15	Quality Manager	Automotive
7	AH	M	6	Lean Manufacturing Engineer	Automotive

N°	Respondent code	Gender	Experience (years)	Position	Industry
8	BK	M	7	Manufacturing and Process Engineer	Automotive
9	OY	M	10	Plant manager	Electric
10	MA	M	18	Quality Manager	Automotive
11	HG	M	9	Continuous Improvement Manager	Automotive
12	SA	F	4	Project Quality Leader	Automotive
13	HK	M	4	Performance Engineer	Mining industry
14	YE	M	7	Industrial Performance Coordinator	Food industry
15	SM	F	9	Performance and Lean Manufacturing Manager	Pharmaceuticals
16	HB	M	4	Methods and Evolution Management Engineer	Aeronautics
17	MC	M	10	Project Manager, LSS Green belt	Aeronautics
18	OM	M	18	Head Pharmacist and Quality Manager	Pharmaceuticals
19	SK	M	19	Production and Operational Excellence Manager, LSS Green belt	Aeronautics
20	YJ	M	11	Lean Manufacturing Manager	Automotive

Source: The authors themselves.

Comparison between the use of lean and six sigma

We asked the respondents whether they use lean, six sigma or a combination of both. We also tried to make a comparison between the approaches that are most used and to understand the reasons behind them. As a result, among the 20 interviewees, 18 said that use both approaches. The following responses clarify this:

A combination of both is applied. These methods are complementary. Six Sigma is mainly a statistical approach that allows us to reduce variability. On the other hand, Lean is about material flow and optimization by eliminating all kinds of waste. (MA)

Moving from lean to Lean Six Sigma is, in my opinion, a logical continuity within an entity that wants to be agile and proactive. (SM)

We use a combination of both and have been doing so for 10 years. The use of Lean could be the first phase of the implementation of a continuous improvement approach; if we only aim to eliminate waste without considering the variability of the process, then the LSS comes as a complement to remove variability problems in the process with quantitative tools… The advantages of this integration are enormous, as Lean management focuses on waste and LSS focuses on the elimination of variability, which allows us to have the output of the process products that are compliant and free of defects. (SK)

Although the interviewees have indicated that both approaches are often used, it was pointed out among some of them that lean tools are more common. This is due to several reasons, as reported by (MC):

Lean is easier to implement: “Lean is the easiest approach to be assimilated by all the colleges of the company, to be implemented in all the sectors and processes”.

Lean results are faster than Six Sigma: “Six Sigma remains of course beneficial but requires more time to gather enough representative data to measure,

analyze and improve the studied process and finally to control and maintain the obtained results".

Lean is used systematically, whereas Six Sigma is used in specific projects and workshops:

"Mainly, Lean management is frequently used through daily production routines; there are also monthly meetings of individual performance in terms of continuous improvement, as well as annual workshops to define new challenges oriented "a better Lean management". However, Six Sigma remains a restricted methodology for support services and is practiced during half-yearly projects (DMAIC) and occasional projects to address process deviations."

Lean six sigma tools

The interviewees mentioned that more than 50 LSS tools were used, but they were not of the same importance. Table 3 summarizes the tools that were cited the most used by the participants. Thus, it has been considered that 5S, Value Stream Mapping, Ishikawa, standardized work, DMAIC method, pull production, visual management, and mistake proofing (Poka-yoke) are the most used ones, emphasizing that some tools such as 5S and work standardization are the most basic and common LSS tools:

We started with some classic workshops on 5S and work standardization. Employees had to understand that continuous improvement starts with a good organization of the workplace through standardized work and practices. (HG)

These findings are consistent with those of prior studies that have highlighted the most powerful LSS tools, especially when it is about a context where it is intended to improve the company's sustainable performance. Banawi and Bilec (2014) have proposed a framework that includes several of these tools, following the steps of the DMAIC approach and using the VSM to identify waste throughout the process, as well as the cause-and-effect diagram (Ishikawa) and the Pareto analysis to eliminate and reduce these sources of waste previously identified. Thus, these tools have

been effective in reducing waste in the process studied. Ben Ruben et al. (2018) have also focused on identifying the most used LSS tools within the industrial sector through a systematic literature review of 70 articles. As a result, they have developed a generic framework to successfully implement the LSS approach while specifying the tools to be used in each of the DMAIC steps. These are essentially tools used to analyze and identify the root causes of the problems, such as Pareto analysis, cause-and-effect diagram, and five why analysis. Cherrafi et al. (2016) have presented a framework to guide companies in the integration and effective implementation of Lean, Six Sigma, and green approaches to improve their sustainable performance. This framework, which was tested in four companies in Morocco, included a variety of tools, including 5S, kaizen, VSM, Kanban, TPM, SMED, Poka-yoke, visual management, standardized work, and other analysis tools such as Five Why, Pareto charts and cause-and-effect diagram.

Table 3. The most used LSS tools by the interviewees.

	AA	SD	RC	AG	MB	MM	AH	BK	OY	MA	HG	SA	HK	YE	SM	HB	MC	OM	SK	YJ
5S	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓
VSM	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓		✓		✓	✓	✓	✓	✓
Ishikawa	✓				✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	
Standardized work	✓	✓	✓	✓	✓		✓	✓			✓		✓	✓	✓		✓			
DMAIC		✓				✓		✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	
Kanban	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓						✓			
Visual management	✓		✓	✓	✓		✓	✓	✓		✓	✓	✓		✓					
Poka yoke	✓	✓		✓	✓	✓	✓	✓	✓			✓	✓				✓			
SMED	✓	✓					✓	✓			✓	✓	✓	✓					✓	✓
5 why analysis	✓									✓	✓	✓	✓	✓	✓		✓		✓	
PDCA	✓				✓			✓				✓	✓		✓	✓	✓			
FMEA	✓					✓	✓		✓				✓				✓	✓		✓
JIT		✓				✓	✓	✓	✓						✓	✓			✓	
Pareto analysis			✓			✓		✓	✓	✓					✓		✓			
TPM	✓	✓						✓			✓		✓							✓
Waste removal	✓						✓			✓			✓				✓			✓

	AA	SD	RC	AG	MB	MM	AH	BK	OY	MA	HG	SA	HK	YE	SM	HB	MC	OM	SK	YJ
Kaizen events		✓					✓								✓		✓		✓	✓

Source: The authors themselves.

When asked about the frequency of use of these tools and how they choose the most relevant ones, many interviewees have stated that LSS tools are used depending on the need, and it is also necessary to have a purpose behind using them.

Honestly, I can tell you that it depends on the need. It can be monthly, twice a year, or sometimes daily; it depends on the need… For example, we use the DMAIC approach for any optimization project, and it is mostly used in case of complex problems. On the other hand, if it is a simple problem, we use the PDCA method, which is faster. So, it depends on the nature of the problem. (HK)

It depends on the needs and the practices, too. When you tell me SMED, I'll tell you that it's always used. When you talk about visual management, I'll tell you that it's implemented once and for all, requiring updates. Kanban is also used as a working method. (BK)

I remember that we once decided to launch a VSM project because it was a new tool we had never used, without a clear vision and objective behind its use. So, it was an exercise for the sake of doing an exercise, but without any results. (HG)

This is in line with the results of the study of Cherrafi et al. (2016), which highlighted the importance of the proper selection of LSS tools to be used. It is a big mistake to think that simply introducing such tools would lead companies to successful implementation. However, these tools must be carefully selected and tailored to the organization in place.

In addition, several interviewees have highlighted that it is important to ensure a combination of both lean and Six Sigma approaches, as the Six Sigma approach

provides the overall framework and structure, while the lean approach provides the tools to be used in each step of this framework:

In this process improvement initiative, there is always a hard part and a soft part. The hard part is the tools, but these tools need a methodology to be applied; it is the soft part that defines the approach. For me, there is no lean tool that can be used independently of a context. The benefit of integrating the two parts is to structure the continuous improvement approach in each context; in other words, this integration will allow us to know where to start, what steps to follow, and in which step we need to use each tool. In short, the tools give you the technical background to tackle part of the implementation of a continuous improvement project, while the methodology gives you the general framework and allows you to structure the project. I am saying this out of experience because we have failed in the realization of several projects because of the lack of a framework before starting the project or because of ignoring certain steps or generalizing before making sure and measuring the constraints. (HG)

These methods can be used separately because they are two different concepts: Lean focuses on the elimination of mudas, and Six Sigma focuses on process improvement and defect removal. But their combination gives more relevant results. (HB)

This is supported by the previous studies that have highlighted the importance of integrating lean and Six Sigma together to have better results, and this using the DMAIC method as a general framework for the application of LSS, then the identification of the appropriate tools to be used based on the requirements of each step. After having conducted a case study on a Portuguese industrial company, Do Rosário Cabrita et al. (2015) have found that the adoption of a systematic methodology (step by step) is essential for the success of the continuous improvement process in manufacturing companies, hence the importance of the DMAIC method to organize LSS adoption. This has consequently allowed a 50% reduction in the level of stock, a 10% increase in the level of machine availability,

and a 15% improvement in the production capacity, as well as significant financial savings for the company and its customers.

Moreover, some interviewees have indicated that they use their own company-specific tools, depending on their culture, context, and strategy. Most of them have requested that these tools remain confidential.

We use a group-specific vocabulary that may be different from what is known. Most of the tools used by our group are confidential because they are exclusive and should not be mentioned please. (YE)

At the beginning, we started with tools proposed by the group, but later, based on our own experience, we proposed reforms and modifications according to our context. (HG)

This is also the case for a Swedish manufacturing company that has been studied by Assarlind et al. (2013). This company has developed its own lean-inspired improvement program which they call the “company production system”.

The importance given to the concept of sustainable performance

Regarding the assessment of the concept of sustainability within companies, the interviewees were asked: “Is sustainability important for your organization?”. The majority of respondents have confirmed that their companies value this concept highly, trying to balance the three aspects: economic, social, and environmental. Therefore, they highlighted several actions carried out by their companies to develop sustainability, especially regarding social and environmental aspects. Table 4 summarizes the main initiatives taken by these companies:

Tabla 4. Sustainability initiatives.

Social actions	Regular employee surveys	A survey is organized every couple of years with the employees, allowing to deal with all aspects such as working conditions, employee satisfaction, ergonomics at work, transportation, lunchroom, etc. (MA) Surveys are organized to measure employee satisfaction in order to

		implement appropriate social actions. (AG) Annual interviews and also an individual development review are conducted, which allows us to know the objectives of each employee and to plan his or her career in the future based on these objectives. (RC)
	Working conditions improvement	We also make sure to receive feedback from the operators; do they have any difficulties or problems? Of course, our first objective is to improve the company's performance, but not at the expense of the operator's well-being. This is also evident in the great support from the HR department and from the company's management in general, in order to improve the working conditions of operators. (HG) Of course, we aim for excellence and performance, but we also take into consideration the well-being of our employees; hence we have recently launched a campaign to guarantee a favourable environment to achieve this excellence and performance. (SK)
Environnemental actions	Collaboration with partners to protect the environment	Our environmental policy is communicated to our suppliers so that they can take it into consideration in order to protect the environment. For example, when buying a new machine, we have requirements regarding noise level, energy consumption and water consumption. (BK)
	Environmental certifications	We are also planning to become ISO 50001 certified, a project that I am managing myself. (MA) For the environmental side, we have launched a project for ISO 14001 certification. (HG) We are also working on a project to adopt the ISO 45000 standard. (AG)
	Solar panels implementation	We have implemented solar panels for the moment, and of course we have targets for each year, to finally reach the general target by 2025. (YE) We will soon implement photovoltaic panels at our three factories. (MA)
	Clean energy use	We mainly aim to preserve natural resources and optimize the use of

		clean energy. In fact, we have a clean energy ratio of about 80% to 90% per year. (HK) We have a target of 100% renewable and clean energy by 2025. (YE)
	Elimination of products and hazardous substances that may harm the environment	For the environmental dimension, generally, we do not have products and substances that can harm the environment. (AA) We also give importance to waste management and recycling, even if, in our case, we do not really generate dangerous or hazardous materials given our high standards of quality. (HG)

Source: The authors themselves.

Lean six sigma and sustainable performance improvements

In terms of the relationship between the LSS approach and sustainability, most respondents considered the adoption of LSS tools to have a positive and significant impact on improving the three pillars of sustainable performance. However, the effect is different on each dimension, and this depends mainly on the measures used to determine it.

Economic performance

Among the interviewees, 11 have seen the economic aspect as being the most improved using LSS tools. This is reflected in the improvement of several economic indicators, such as cost reduction, profit increase, profitability improvement, turnover increase, and market share increase, as well as the improvement of the company's image and competitive position.

An example of a "just do it" action is eliminating an intermediate stock between two stations, which has already allowed us to save 2 million MAD. We had a Kanban of D-2, i.e., the initial station is 2 days ahead of the next station; the initial station produces and stocks the product, then after 1 or 2 days, the next station risks finding non-conformities, which leads to a lot of losses. So, we brought the stations closer together, eliminated the intermediate stock, avoided non-conformities, and consequently freed up space within the factory (MM).

By improving our processes, providing a well-controlled deadline, and providing products that meet the requirements, we ensure better financial gain and a good image in the market with all these advantages (turnover, EBIT, market share, etc.) (MC).

It is mainly the economic dimension because if you succeed in reducing the level of waste, and if all the operators work in the same way, you will have fewer losses and more profitability (AG).

When we say parameter stability, this means material optimization, which obviously impacts costs and the company's margin since we are consuming just the necessary material (OY).

Of course it does! It allows us to become more competitive and increase customer satisfaction, improving the company's profitability (SM).

Indeed, the use of tools such as pull production allows for the optimization of space. As a result, manufacturing companies that implement these practices efficiently show better economic performance (Hofer et al., 2012; Lwiki et al., 2013; Cherrafi et al., 2016). However, the study by Hofer et al. (2012) has highlighted that the implementation of some lean practices increases inventory levels, particularly in the beginning, which leads to higher costs and lower financial results. Therefore, it takes time for these practices to contribute to inventory reduction and, subsequently, to enhanced financial outcomes.

Environmental performance

According to several respondents, the environmental dimension is positively affected by LSS practices, although it is less important to economic performance. This effect is measured through the decrease of several indicators such as energy consumption, waste generation, negative impacts on the environment, resource consumption, and CO_2 emissions.

These tools allow, as I said, to increase the production capacity without having to acquire new machines. Consequently, this reduces energy consumption and CO2 emissions. (SD)

LSS tools also allow the reduction of waste, raw material consumption, and resources in general, which is obviously in favor of environmental protection. (MC)

This is consistent with the results of several studies. According to Larson and Greenwood (2004), lean tools positively improve resource productivity by reducing the amount of energy, water, and raw materials used, thus minimizing the negative environmental impact of production activities. Using a workplace organization tool like 5S enables the maintenance of a clean workplace, which enhances the elimination of waste and the inappropriate use of raw materials (Belhadi et al., 2018). In addition, environmental wastes in industrial processes can be identified and reduced or eliminated with the help of analytical tools like the 5 Whys, Pareto chart, and cause and effect diagrams (Cherrafi et al., 2016). The use of Six Sigma tools also reduces defects, minimizes energy and resource requirements, and thus reduces waste (Fliedner, 2008). However, three interviewees stated that LSS has no impact on the environment according to their experiences. LSS is a structured, data-driven approach that eliminates sources of variation and waste. It is certainly beneficial, but reducing environmental waste is not its primary goal (Ahmad & Khan, 2022).

Social performance

The improvement of the social side through LSS tools is also tracked using a variety of measurements such as improvement of working conditions, employee motivation, health and safety, employee empowerment, employee participation and teamwork, employee productivity, and reduction of workplace accidents.

Before starting the implementation of lean in the company, I can assure you that people are frustrated at the beginning because they expect an increase in workload. So, as a project leader, it is necessary to try to convince people in a tangible way, not only through words but also by improving their daily environment.

Then people start to trust you and be convinced that the objective of lean is not only to improve profitability but also to be human. It aims to improve the daily working conditions, encouraging people to adhere more and more to this approach. (SM)

The benefit of LSS is everywhere. The employees who apply these methods certainly gain; they will have a listening mindset instead of an attacking mindset, they will be able to understand each other and communicate effectively, they will also collaborate to achieve the goals, and the effect of this appears globally in the plant and allows the employees to have more confidence in their competence, and it also allows them to evolve and have better recognition within the company. (MM)

If the work is well standardized and all the tools are well implemented, it helps to minimize work accidents. (AG)

According to several studies conducted in this regard, it has been found that using visual management and 5S tools provides a clean and tidy factory, improving employees' productivity, safety, and well-being (Piercy & Rich, 2015). Six Sigma also decreases potential accidents, resulting in safer and healthier working conditions for employees (Cherrafi et al., 2016).

However, for a few respondents, this improvement in the social side is only an indirect result of the implementation of LSS tools.

For me, LSS is about reducing variability, especially on the process side. So, reducing variability means stabilizing the process, and stable processes mean more control and less effort, i.e., achieving the same objective with fewer resources and more professionalism. So, in this sense, the use of LSS tools has a strong contribution to improving the work environment, work processes, and work methods as well. (OY)

Conclusion

The objective of this study was to explore the level of implementation of the LSS approach, specifically the LSS tools used within manufacturing companies in

an emerging country such as Morocco, and to discover the level of importance that these companies give to the concept of sustainability, as well as the investigation of the link that exists between LSS tools and the improvement of sustainable performance. Thus, through semi-structured interviews with 20 LSS practitioners, they have agreed that the integration of Lean and Six Sigma tools is more effective and leads to greater results, as the Six Sigma approach provides the overall framework and structure, while the Lean approach provides the tools to be used in each step of this framework. However, the use of Lean tools by these companies is more common since they are easier to implement and used daily, whereas Six Sigma is used in specific projects and workshops. Concerning the tools used, we have identified more than 50 LSS tools; the most frequent ones are: 5S, Value Stream Mapping, Ishikawa, standardized work, DMAIC method, Kanban, visual management, and mistake proofing (Poka-yoke). Moreover, the concept of sustainability is highly valued by most of the companies to which the interviewees belong. In this regard, several initiatives have been taken, especially to promote social and environmental aspects. This study also highlights the positive link between LSS and the improvement of companies' sustainable performance. Nevertheless, it was found that the economic dimension is the most enhanced by this continuous improvement strategy, and this through several measurements such as cost reduction, profit increase, profitability improvement, turnover increase, market share increase, as well as the improvement of the company's image and its competitive position. This strategy also allows the improvement of the environmental dimension by reducing energy consumption, waste generation, negative impacts on the environment, resource consumption, and CO_2 emissions. Finally, the social dimension is also improved by LSS tools, according to the interviewees, but some of them consider this impact to be indirect.

This qualitative exploratory study on the impact of LSS on sustainable performance can have significant theoretical and managerial implications. It can enhance our understanding of how LSS practices affect sustainability and provide actionable insights for Moroccan organizations looking to integrate LSS principles into their sustainability strategies.

Regarding the limitations of this study, we noticed that the interviewees did not have enough knowledge about sustainable performance indicators. Due to the large size of the companies, other departments are involved in measuring these indicators. Moreover, the focus of LSS projects is generally on cost, quality, and deadlines. Sustainable development is not considered as a primary objective. Thus, the findings of this study highlight the need for more research to investigate the link between LSS and sustainability. The next step will be to expand our results by conducting a quantitative study to generate more generalizable results.

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