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Original Article

Lean tools for sustainability in organizations: an analysis by levels of knowledge and agreement by common sense

Ferramentas lean para a sustentabilidade nas organizações: uma análise por níveis de conhecimento e concordância por senso comum

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ABSTRACT

Purpose: Investigate the differential perceptions of distinct groups, both with and without knowledge of lean and sustainability, and compare them with the responses of Toyota experts, aiming to identify the agreements and divergences in the evaluations of lean manufacturing tools concerning the three pillars of sustainability: social, environmental, and economic.

Methodology: A literature review involving 131 articles was conducted, resulting in the identification of 40 lean manufacturing tools described as having an impact on sustainability. This was followed by exploratory research, employing a self-administered online questionnaire and comparing results between groups to identify convergent responses.

Findings: The findings demonstrate that all groups provided identical responses for 26.4% of the possible answers. Specifically focusing on the group of experts, an increase to 8.3% in unique responses was observed. In the non-expert group, only 0.6% of responses specific to this group and Toyota were added.

Practical implications: Gaining an understanding of lean tools that impact sustainability represents a valuable outcome. However, identifying which perspectives align with Toyota's opens new avenues for discussion and research.

Originality/Value: Much of the research explores the implementation of lean tools based on the views of experts alone. Yet, no studies have been found comparing the influence of the dissemination of these tools through common sense, thereby allowing for responses that are equivalent to Toyota's.

Keywords: Lean; Common sense; Toyota; Toyota Production System

RESUMO

Objetivo: Investigar as percepções diferenciais de grupos distintos, com e sem conhecimento sobre lean e sustentabilidade, e compará-las com as respostas de especialistas da Toyota, visando identificar a concordância e as divergências nas avaliações de ferramentas de manufatura enxuta em relação aos três pilares da sustentabilidade: social, ambiental e econômico.
Metodologia: Realizou-se uma pesquisa bibliográfica envolvendo 131 artigos que resultaram em 40 ferramentas da manufatura enxuta descritas como impactantes para a sustentabilidade, seguida de uma pesquisa exploratória, utilizando um questionário on-line autoaplicável, comparando-se posteriormente os resultados entre grupos para identificar as respostas convergentes.
Resultados: Os resultados demonstram que todos os grupos têm respostas idênticas em 26,4% das respostas possíveis. Ao focar exclusivamente nos especialistas, observa-se um acréscimo de 8,3% particulares a esse grupo e análogos ao benchmarking. Já na categoria de não especialistas adicionam-se apenas 0,6% de variáveis que são específicas entre esse grupo e a Toyota.
Implicações práticas: A compreensão das ferramentas *lean* com impacto para sustentabilidade por si só já é um resultado profícuo, mas identificar quais são as visões alinhadas com a Toyota abre novas discussões e oportunidades de pesquisa
Originalidade/valor: A maioria das pesquisas investiga a implementação das ferramentas *lean* com base na visão dos especialistas, porém, não identificaram-se estudos que comparem a influência da divulgação dessas ferramentas pelo senso comum, permitindo assim respostas equiparadas com a da Toyota.

Palavras-chave: *Lean*; Senso comum; Toyota; Sistema Toyota de Produção

1 INTRODUCTION

The search for superior performance, combined with environmental initiatives, equips companies with the necessary conditions to sustain a uniform and continuous improvement in their competitive performance. Moreover, this approach also allows for operational versatility to respond quickly to volatile markets, a strategy increasingly sought after by companies aiming to outperform competitors in the current global economic scenario (Alves & Alves, 2015).

A highly competitive and constantly evolving environment exerts significant pressure on companies to adopt sustainable practices (Abualfaraa et al., 2020). In this context, the primary aim of lean manufacturing is to reduce or eliminate waste, also known as 'muda,' thereby improving quality, reducing manufacturing time, and cutting costs (Chen et al., 2020; García-Alcaraz et al., 2021). Lean thinking, as a management philosophy, focuses on minimizing waste and enhancing customer value (Antonelli et al., 2024).

Therefore, the deployment of lean manufacturing tools in production processes is vital for the economic, environmental, and social sustainability of companies (Figueroa et al., 2023). Sustainable actions are necessary for business maintenance (Hudy et al., 2023). The growing awareness of operational impacts on sustainability and government pressure to lower emission rates have compelled industries to adopt sustainable methods, such as green lean six sigma (Kaswan et al., 2023). Thus, efficient manufacturing, coupled with environmental initiatives, offers companies favorable conditions for maintaining uniform and continuous improvement in competitive performance (Alves & Alves, 2015).

Various studies have indicated that lean manufacturing supports the sustainable performance of organizations (Naeemah & Wong, 2023). Considering this scenario, it is logical to investigate the impact, as perceived by respondents with varying levels of knowledge, of lean tools cited in literature as influencing sustainability. Consequently, this article addresses the following research questions: To what extent do the benefits produced by lean tools and approaches impact the sustainability of organizations, according to different levels of knowledge? Is there a difference in perception based on knowledge levels, or does a "group knowledge" phenomenon tend to align responses with those of experts? Guided by these questions, this research aims to investigate the differentiated perceptions of various groups, including those with knowledge of lean and sustainability as well as those without. Additionally, it seeks to compare these perceptions with the responses of Toyota experts, aiming to identify both the agreements and divergences in the evaluations of lean manufacturing tools concerning the three pillars of sustainability: social, environmental, and economic. This objective is closely aligned with the research problem, which explores how perceptions across different knowledge levels influence the assessment of the impacts of lean tools on the sustainability of organizations.

This study is justified by the need to further explore the relationship between lean manufacturing and sustainability. Despite growing awareness of the need for sustainable production practices, the implementation rate seems relatively slow (Maginnis et al., 2017). For this reason, assessing sustainability performance in manufacturing processes and proposing strategies for sustainable growth is crucial

(Hudy et al., 2023). Moreover, no studies have been found comparing different levels of knowledge regarding the impact of lean tools on sustainability.

The survey is limited to respondents from Brazil and focuses on analyzing interactions between lean manufacturing and sustainability, concentrating on a selection of lean manufacturing tools. In this sense, this article›s main contribution is to correlate 40 lean manufacturing tools with their effects on the social, environmental, and economic dimensions from the perspective of 210 respondents. These findings are compared with the foundational reference of the lean concept by Toyota, whose influence continues to shape global efficiency, quality, and sustainability strategies.

The structure of this article is as follows: This section presents the introduction, followed by the methodology and analytical framework, the results and discussion, and, lastly, this study's limitations and future research directions.

2 LITERATURE REVIEW

2.1. Lean Manufacturing and Lean Tools

Lean manufacturing is a management philosophy that incorporates a variety of strategies (Mohd et al., 2024), emphasizing principles such as customer value, continuous flow, pull production, and the pursuit of perfection (Liker, 2004). According to Henao and Sarache (2023), lean emerged as a response to the challenges imposed by traditional mass production paradigms, particularly in Japan's post-war context.

Lean production, which focuses on waste elimination, is recognized as a crucial instrument for promoting sustainability and competitiveness within organizations (Elattar et al., 2020). Lean manufacturing (LM) provides techniques and innovations for lean activities in industries, specifically targeting the elimination of eight types of waste in the production system (Silva & Sousa, 2024).

Demaj and Mehillaj (2023) expand on this concept by stating that lean manufacturing's central principle is the effective application of tools and practices aimed at reducing wasteful activities while maintaining or enhancing the quality delivered to customers. By focusing on waste reduction, lean promotes continuous improvement, enhances manufacturing performance, and optimizes material utilization, enabling modern companies to meet customer demands for high-quality, customized products with shorter lead times and more competitive prices (Lin et al., 2024). The core motivation of the lean methodology is to identify what adds value from the customer's perspective, minimizing the time between order and delivery (Silva et al., 2011).

Gatell and Avella (2024) argue that this philosophy, originating from the Toyota Production System and initially viewed as a toolkit for waste reduction, has evolved into a culture imbued with values, principles, and behaviors that encourage continuous improvement and waste elimination across all organizational levels. This culture of continuous improvement is closely linked to sustainability (Pampanelli et al., 2014).

Moreover, integrating green, lean, and six sigma approaches is deemed necessary for balancing operational efficiency with environmental and social responsibilities (Caiado et al., 2018). There is also evidence suggesting that lean, six sigma, and green methodologies positively impact the economic, social, and environmental performance of organizations (Cherrafi et al., 2017). Various tools facilitate the integration of lean with sustainability. For instance, Khair et al. (2024) analyzed the flow of the aircraft maintenance process using methods such as PDCA (plan-do-check-act), problem identification and corrective action, and value stream mapping (VSM), all aligned with a sustainability system.

Tenera et al. (2019) explored potential synergies for sustainability achieved through integrating lean thinking with continuous improvement methods, six sigma, the theory of constraints, 5S, value stream mapping, and SMED (single minute exchange of die). Fitriadi and Ayob (2024) combined continuous improvement, VSM, and sustainability indicators in the shipyard industry, while Verma et al. (2021) employed six sigma and VSM to assess energy use and waste reduction. Ishijima et al. (2020) introduced 5S, Kaizen and TQM (total quality management) approaches in five Egyptian public hospitals, contributing to improved working environments.

Díaz-Reza et al. (2024) demonstrated the significant role of 5S methodologies, total productive maintenance, quick changeover, and one-piece flow, showing their positive effects on social sustainability. Figueroa et al. (2023) used a structural equation model to illustrate the relationship between lean tools, such as Kaizen, Gemba, VSM, and key performance indicators (KPIs), in driving sustainability. Naeemah and Wong (2022) identified 7S, SMED, six sigma, Poka-Yoke, VSM, visual management, cellular layout, Kaizen, Kanban, and JIT (Just in Time) as the top ten lean production tools with a positive impact on the three aspects of sustainability.

Antonelli et al. (2024) employed Ishikawa diagrams, value stream mapping, and cognitive maps to minimize barriers to the inclusion of workers with disabilities, increasing their involvement in tasks and promoting their well-being. Thus, lean tools can go beyond operational efficiency, serving social goals such as inclusion and improving employee conditions (Åhlström, 2004).

Pushug et al. (2024) applied practices like Pareto and Ishikawa diagrams, 5S, Poka-Yoke, SMED, personnel training, and process standardization through Lean Six Sigma's DMAIC (define, measure, analyze, improve and control) methodology, reducing downtime and fostering sustainable business practices over time. García-Alcaraz et al. (2021) found that 5S significantly affects SMED and continuous flow, with SMED being crucial for maintaining a continuous production line flow and essential for economic sustainability due to reduced changeover times. Camones-Caballero et al. (2024) integrated tools such as 5S, autonomous maintenance, standardized processes, and PDCA as mechanisms to support sustainability. García-Alcaraz et al. (2021a) demonstrated the integration of visual management, Poka-Yoke, and Andon, highlighting their direct effect on economic sustainability.

Gandhi and Thanki (2024) presented several benefits of lean practices for sustainability. For instance, with JIT (Just in Time), suppliers can provide raw materials promptly and on short notice, reducing inventory. Kaizen, in addition to decreasing the area used, also reduces energy consumption by implementing new technologies. Lean six sigma helps retain workers for longer periods, increasing production and reducing turnover. According to Mittal and Shameem (2024), Just in Time is the most advantageous lean tool for promoting sustainable growth in companies, generating substantial savings in storage costs, minimizing transportation, delays, overproduction, and defects, and strengthening supplier relationships, leading to profitability and better customer service.

2.2. Sustainable practices for organization performance

The pressure from various stakeholders has driven companies to adopt more sustainable practices, fueled by growing concerns over energy costs, environmental degradation, and demands for social and environmental responsibility (Henao & Sarache, 2023; Ferrazzi et al., 2024). In this context, marked by a competitive and constantly changing market, the incorporation of sustainability-oriented strategies is not only a response to external demands but also a way to ensure long-term economic viability (Abualfaraa et al., 2020). Sustainability, therefore, emerges as a priority for organizations worldwide, reflecting the increasing expectations of stakeholders regarding the adoption of environmentally responsible practices (Hammami & Othmani, 2024).

To achieve superior organizational performance, companies have been integrating social, economic, and environmental aspects into their operations and processes (Guodong et al., 2022). This movement aims not only to reduce the negative impacts of their activities but also to align with global trends that value sustainable business practices (Ferreira & Gerolamo, 2016). As competitiveness shifts towards sustainability principles, practices such as lean management have stood out for promoting efficiency and waste reduction, becoming essential to tackling contemporary challenges (Saraswati et al., 2024; Abreu et al., 2024).

The relationship between lean and sustainability is particularly relevant, as both share the goal of eliminating waste and optimizing processes. Lean practices have proven effective in enhancing the three dimensions of sustainability—social, environmental, and economic—reinforcing their applicability as a strategy for achieving sustainable organizational performance (Lizarelli et al., 2024). Through this approach, companies can minimize environmental impacts while simultaneously reducing costs and improving productivity (Zhang et al., 2020).

Within the lean context, Green Supply Chain Management (GSCM) represents a key element in sustainable performance, positively influencing both the social and environmental aspects of organizations. Initiatives such as green purchasing and logistics directly contribute to reducing environmental impacts, while cooperation with customers strengthens social performance (Khan et al., 2024). For this approach to be successful, companies must carefully manage the interactions between the internal and external aspects of GSCM, ensuring efficient integration of operations and the mitigation of environmental impacts (Feng et al., 2024).

Beyond operational practices, the role of leadership is crucial for the success of sustainability strategies. Green transformational leadership, combined with sustainable human resource management practices, can positively influence organizational performance by fostering a culture that values environmental and social principles (Nakra & Kashyap, 2024; Yang et al., 2024). Green Human Resource Management stands out as a facilitator for the adoption of sustainable innovations and organizational transformation, contributing to a positive impact across social, economic, and environmental dimensions (Zihan & Makhbul, 2024).

Simultaneously, Total Quality Management (TQM) offers a complementary approach, providing a competitive advantage by enhancing environmental sustainability and improving customer satisfaction (Jabi et al., 2024). Top management support is a critical factor in this process, as it directly influences organizational performance and the successful adoption of sustainable practices (Qureshi et al., 2022).

Employee training is an essential tool for fostering an organizational culture oriented towards sustainability. Intensive training programs not only increase engagement and understanding of lean practices but also help reduce safety violations and strengthen work ethics (Yuik et al., 2020; Caffaro et al., 2022).

These efforts are fundamental in developing competencies that support social and environmental practices in the workplace, contributing to more sustainable organizational performance (Lizarelli et al., 2023; Sun et al., 2024).

In the context of lean practices, Kaizen emerges as an effective approach for continuous improvement, enabling waste reduction and value stream optimization. Implementing Kaizen in operations results in significant benefits, such as reducing environmental emissions, water consumption, and operational costs, while also integrating eco-design practices and circular economy principles (Costa et al., 2024). This focus on continuous improvement is essential for meeting stakeholder expectations regarding social, economic, and environmental responsibility (Opoku et al., 2024).

In conclusion, adopting lean and sustainable practices goes beyond seeking operational efficiency, representing an integrated strategy that strengthens companies' competitiveness and meets global demands for sustainability. The combination of transformational leadership, quality management, and continuous training creates a solid foundation for sustainable performance, ensuring that companies can proactively respond to external pressures and market changes.

3 METHODOLOGY

This study was conducted in three stages: (1) conducting a literature review, a crucial step in the research process; (2) administering a survey through an online questionnaire; (3) performing a comparative analysis of knowledge levels, as detailed below.

To refine the search for relevant articles and tools, a systematic approach was adopted. Initially, the inclusion criteria were clearly defined, focusing on peer-reviewed articles published in English that addressed the intersection of lean and sustainability. The search strategy involved utilizing Boolean operators to expand and narrow the results, allowing for a comprehensive collection of literature. Additionally, a detailed analysis of the abstracts and keywords of the identified articles was conducted to ensure they aligned with the study's objectives. This rigorous selection process led to a more focused set of relevant publications.

Subsequently, the review also involved cross-referencing citations and examining the bibliographies of the selected articles. This step ensured that seminal works and recent contributions to the field were not overlooked. Furthermore, the identified tools were categorized based on their relevance and applicability to sustainability practices within the lean framework. By systematically organizing this information, the study not only established a robust theoretical foundation but also identified gaps in the existing literature that warranted further exploration, such as the one considered in the present research described as the general objective.

The literature review established a theoretical foundation on the topic (Gil, 2010), utilizing articles from the Web of Science database. The search used the keywords "lean" and "sustainability" in the title field, was restricted to English-language articles and to those classified as document type, yielding 131 published articles. Two articles were excluded: one due to the keyword "lean" coinciding with the term lean outside the intended context, and the other because the full text was not accessible. The review identified 40 tools, further substantiated by additional literature.

The analysis was broadened with exploratory research aimed at generating further knowledge on the subject (Vergara, 2016). A self-administered online questionnaire was employed for this purpose, which, according to Vieira (2009), involves respondents completing the questionnaire themselves, utilizing questions based on a Likert scale (1-5).

The survey, conducted on the Google Forms platform, was available from December 2023 to July 2024. After a pilot test and subsequent adjustments, it was distributed to a sample of undergraduate and postgraduate students and professionals across various fields via email and LinkedIn connections. The survey garnered 210 valid responses. Upon data examination, the results were organized by tools and knowledge levels, further stratifying the frequency, median, and dispersion (quartiles) of each tool across three dimensions, as Likert-scale data are ordinal, allowing only for non-parametric tests (Schriesheim & Castro, 1996). Table 1 summarizes the stages of the research methodology.

Table 1 – Search tools

Data base	Literature review	Tools identified	Research	Dimensions	Levels of knowledge
Literature review			**Exploratory research**		
Web of Science (n = 131)	Literature review for theoretical background	5S 6 sigmas Agile RCA (Root cause analysis) Andon Benchmarking Brainstorming Statistical process control (SPC) Continuous Improvement (CI) DFMEA/FMEA (Failure Mode and Effects Analysis) Spaghetti diagram DMAIC Customer involvement Continuous flow Visual management *Jidoka* Just in time Kaizen Kanban *Karakuri* KPI (key performance indicator) Cellular layout Lean leadership Lean supply chain (LSC) Milk run *Muda* OEE (Overall Equipment Effectiveness) Pareto PDCA Poka-Yoke Product design SMED/quick changeover *Takt* time Top management commitment TPM (Total Productive Maintenance) TQM SW (Standardized work) Employee training Safety improvement program VSM	Pilot test Survey questionnaire with 210 valid respondents	Social Environmental Economic	Comparison of group responses Toyota (n = 4) Lean x sustainability expert (n = 142) Lean expert (n = 168) Sustainability expert (n = 163) Non-expert of sustainability. (n = 47) Non-expert in lean (n = 42) Non-experts in both areas (n = 21)

Source: The authors (2024)

The study compared results across groups based on their level of knowledge to investigate the following hypotheses:

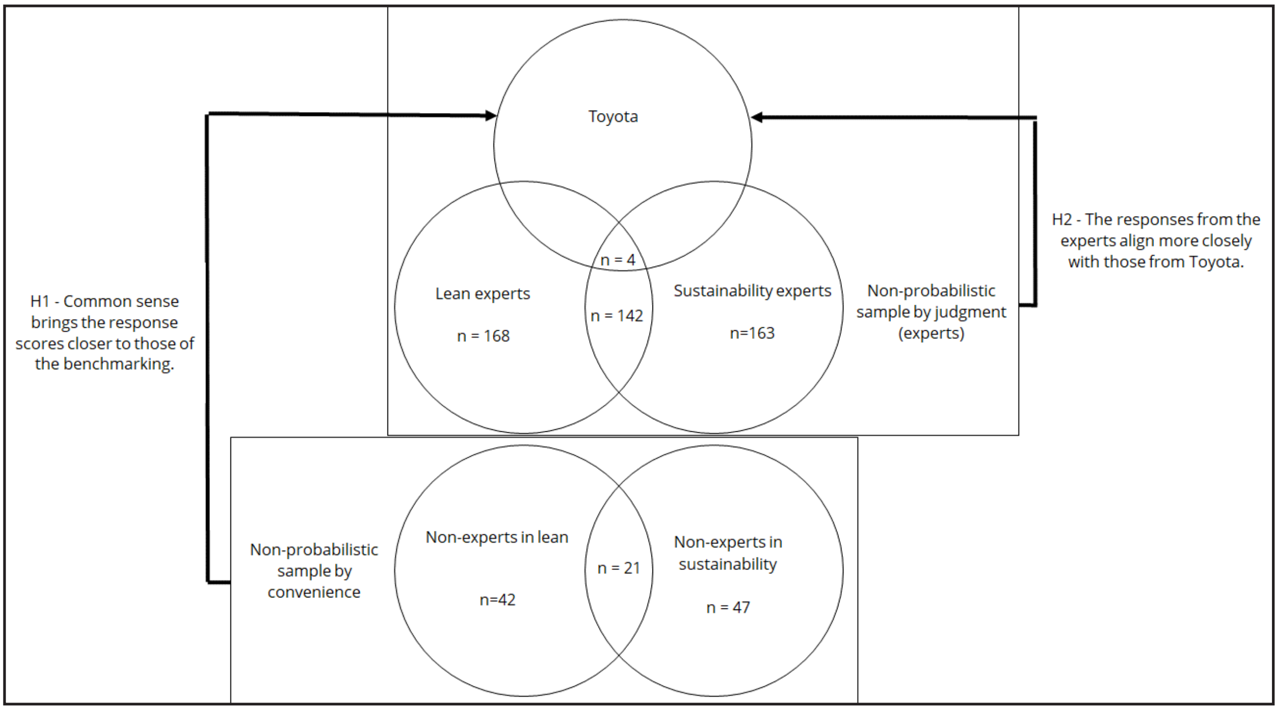
H1: There are tools that, by leveraging the widespread understanding of the lean philosophy, allow for identical responses to benchmarking compared to other respondents.

H2: Experts' responses are more similar in quantity to those of non-experts than previously assumed.

These hypotheses stem from the theory that the collective insights and judgments of non-expert groups can achieve outcomes that are as good as, or even better than, those of experts (Wagner & Back, 2008). The extensive dissemination of lean tools over years may lead respondents to align more closely with Toyota's answers, given that common sense is complemented by tacit knowledge— a blend of personal experience and social interaction (Zhao, 2009). The Toyota Production System is already well-known and implemented in the production sector (Valamede & Akkari, 2020). In the context of H2, which pertains to experts or judgment sampling, this approach is deemed suitable when individuals are selected based on their qualifications according to specific criteria and the pertinence of their information (Ferreira et al., 2009).

The survey targeted participants fitting the study's profile of interest. To ensure a qualified sample, it included a question on the respondent's level of knowledge regarding lean and sustainability. To be considered an expert, one needed to have both practical and theoretical understanding of these philosophies. Among the respondents from Toyota, all declared themselves experts in both fields, contributing to the 142 individuals with this designation. Focusing solely on lean culture, 168 respondents were classified as experts and 42 as non-experts. Comparable ratios were observed in the sustainability domain, with 163 identifying as experts and 47 lacking comprehensive knowledge on the application of sustainability principles. Approximately 10% of participants felt unqualified as experts in these areas, possessing only theoretical knowledge or no experience with the tools, as illustrated in Figure 1.

Figure 1 – Sample distribution



Source: The authors (2024)

4 RESULTS

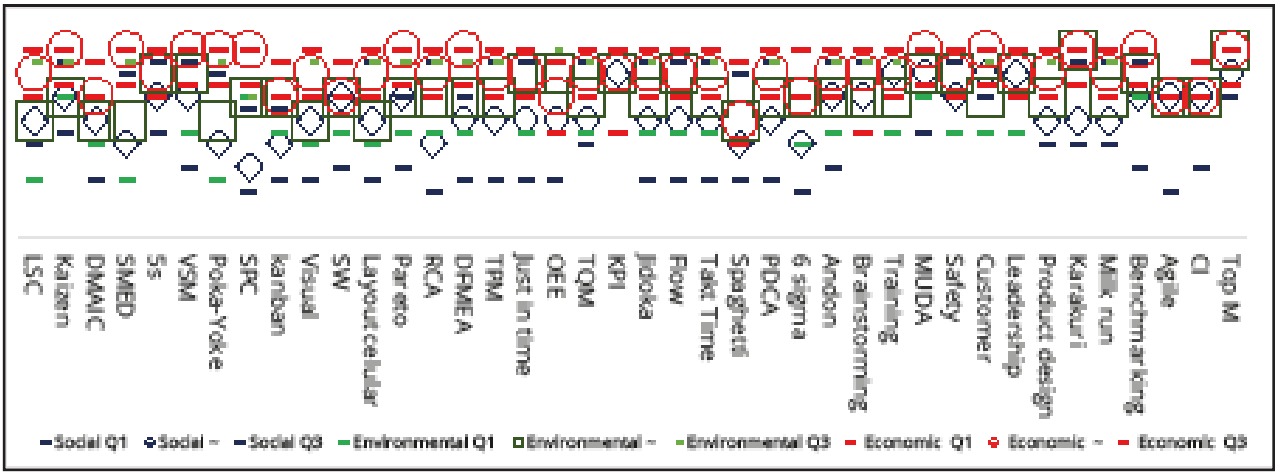
This section analyzes the results obtained from a survey, comparing the responses regarding 40 selected techniques across different levels of knowledge. Initially, the focus is on Toyota, often cited as a benchmark for lean concepts due to its innovative and successful lean production principles application, encompassing waste reduction and process optimization. Toyota's success in these principles has not only markedly enhanced its productivity and quality but also exerted a substantial influence on the automotive and other industrial sectors, establishing a global standard for operational efficiency. Therefore, Toyota serves as a reference model for studying and applying lean practices, indispensable for any analysis of the state of the art in this field.

4.1. Toyota

Toyota's experts identified 14 tools as highly beneficial for sustainability, with a median score of 5.00. Among these, 12 tools fall under the economic pillar: Kaizen, SMED, VSM, Poka-Yoke, SPC (Statistical Process Control), Pareto, FMEA, customer involvement, *Karakuri*, benchmarking, *muda*, and top management. Two others, *Karakuri* and top management, pertain to the environmental pillar. None of the tools in the social pillar received the highest median score. The top value was 4.50, awarded to tools such as KPI, training, *muda*, customer involvement, leadership, and top management.

Exploring the Toyota experts' responses, it is evident that the economic pillar consistently receives higher scores. Beyond the 12 tools with a median of 5.00, an additional 20 tools are rated with a value of 4.50, seven with a value of 4.00, and one with a value of 3.50. The environmental pillar saw 5% of tools scoring 5.00, 25% at 4.50, 52.5% at 4.00, and 17.5% at 3.50. Conversely, the social pillar revealed a considerably lower impact perception, with no tool achieving a 5.00 score, six evaluated at 4.50, 11 at 4.00, the majority (n = 16) at 3.50, six at 3.00, and one at 2.50. These data points are illustrated in Figure 2.

Figure 2 – Comparison of responses from the sample of Toyota representatives



Source: The authors (2024)

The tools demonstrated significant variability in terms of social impact, with medians ranging from 2.50 to 4.50. The tools identified as having a high social impact include top management, leadership, customer involvement, *muda* and training, and KPI. Notably, *Karakuri* and top management emerged as the leading tools in the environmental area, while in the economic sector, 10 tools received top scores.

An examination of the dispersion of results for the social pillar revealed Root cause analysis (RCA) with the largest range (2.75), and several tools, notably agile, 6 sigmas, and SPC, had a minimum first quartile (Q1) value of 2.00. In the highest quartile, the lowest values belonged to SPC and Kanban (3.75).

The variation in environmental results was narrower than that in social impact, suggesting a more uniform application of the tools' environmental practices. The maximum variation observed was 2.50 for the lean supply chain (LSC), SMED, and Poka-Yoke tools, which also had the lowest Q1 value (2.25). Additionally, another 12 tools scored a third quartile (Q3) of 5. SPC and agile were notable for their consistency, achieving identical scores across the three variables analyzed.

The economic impact of the tools was generally high, with the agile tool recording a Q3 value of 4.00, and the remainder scoring between 4.75 and 5.00. The greatest amplitude found was 1.75, noted in three tools (KPI, spaghetti diagram, and brainstorming). The lowest position measure was assigned to the spaghetti diagram tool, while the top management tool excelled in all dimensions, exhibiting both a high median and low dispersion. This indicates a robust correlation between Toyota's leadership and its outcomes. Conversely, the spaghetti diagram tool was perceived as offering the lowest benefits across the three pillars, and SPC had the lowest median score.

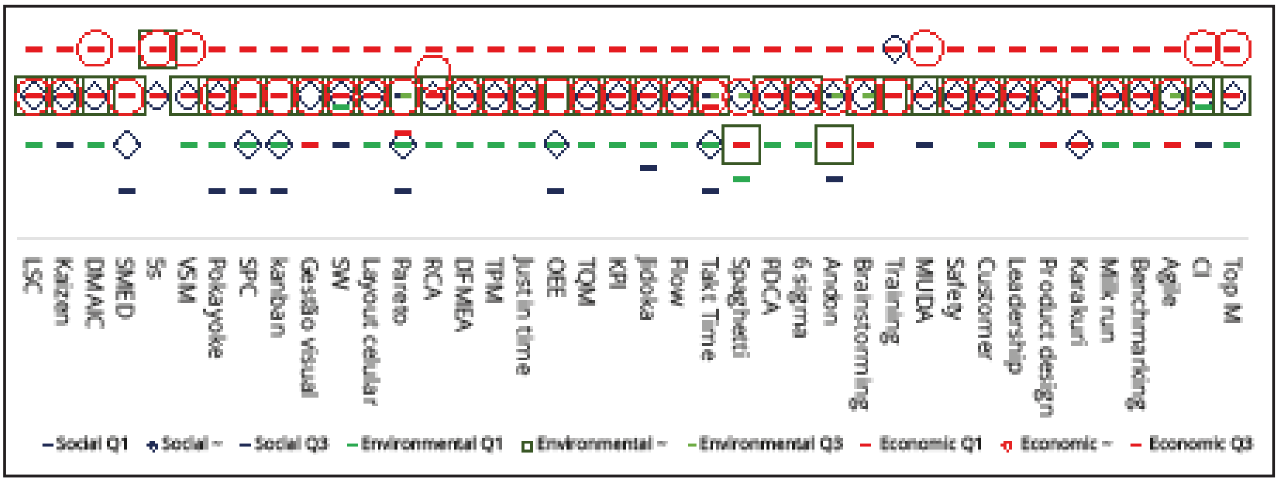
4.2. Analysis by level of knowledge

Understanding how different levels of knowledge assess the methodology's tools reveals the perspectives on lean and sustainability from both experts and non-experts in these fields, allowing for a comprehensive and balanced understanding of the integration of these practices.

4.2.1. Lean and sustainability experts

Experts with knowledge in both lean and sustainability numbered 142 participants, with their responses illustrated in Figure 3.

Figure 3 – Comparison of responses from the sample of lean and sustainability experts



Source: The authors (2024)

The median score predominantly remains at 4.00, including 32 in the social pillar, 37 in the environmental pillar, and 33 in the economic pillar. Within the social pillar, seven tools received a score of 3.00, and two tools in the environmental pillar scored the same. The highest scores were recorded once in the social pillar and once in the environmental pillar with the training and 5S tools, respectively, while in the economic pillar, six tools reached this peak.

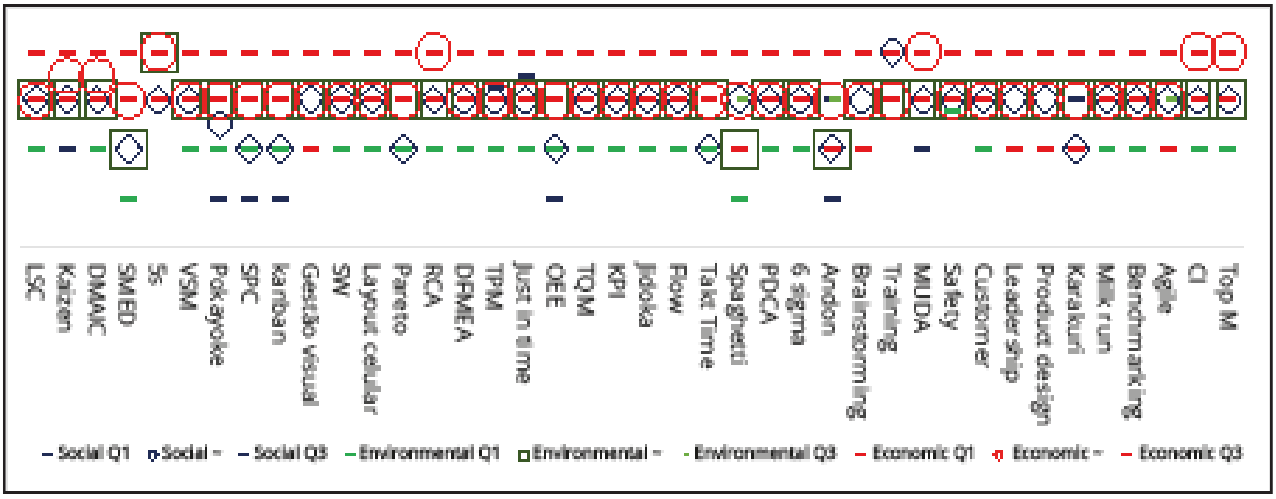
Regarding dispersion, seven tools in the social pillar recorded a first quartile (Q1) at the minimum value of 2.00 and a third quartile (Q3) at the lowest value of 4.00. Additionally, 23 tools achieved an upper quartile score of five. The environmental pillar's lowest quartile score was for the spaghetti diagram tool at 2.25, and a Q3 score of 5.00 was noted 29 times, with the remainder scoring 4.00. The dispersion of economic results showed lower variability for most tools, indicating effective and consistent application across different organizations.

As for Q1, the minimum score of 3.00 occurred seven times, and the maximum score of 4.00 appeared 31 times. The 5S tool stood out, with median scores of 4.00 for the social pillar and 5.00 for both the environmental and economic pillars.

4.2.2. Lean experts

with specialized knowledge included 168 respondents. Their responses, as depicted in Figure 4, show medians ranging from 3.00 to 5.00, with a higher frequency of 4.00 scores across all pillars.

Figure 4 – Comparison of responses from the sample of lean experts



Source: The authors (2024)

Considering the medians of the economic pillar of the tools, they were assessed as more significant than those of the social and environmental pillars, with values frequently ranging between 4.00 and 5.00. The economic pillar received one score of 5.00, three scores of 3.00, and the remainder were rated at 4.00. The social pillar had the highest frequency of 3.00 scores, with eight occurrences, 3.50 and 5.00 only once, and all other evaluations yielded a median of 4.00.

When considering all three pillars, the tool that stood out the most was 5S, achieving a score of 4.00 in the social pillar and the highest scores in the remaining categories. However, the SMED and Andon tools received the lowest evaluations across all three pillars. Regarding the variation, five tools showed a range of 2.00 across all pillars (visual management, spaghetti diagram, brainstorming, leadership, product design).

In the social pillar, all tools that scored 2.00 in Q1 achieved 4.00 in Q3 and a median of 3.00, except for Poka-Yoke, which had a median of 3.50. For the environmental pillar, the lowest scores in Q1 were recorded for the spaghetti diagram and SMED tools (2.00), and Q3 showed a value of 4.00. The economic pillar exhibited minimal variability, with eight tools scoring 3.00 and 32 scoring 4.00 in Q1, and in the top quartile, all tools were rated with the maximum score. The 5S Tool is the standout, boasting two median scores of 5.00 and one of 4.00 (social), as well as consistency in the quartile scores, ranging from 4.00 to 5.00.

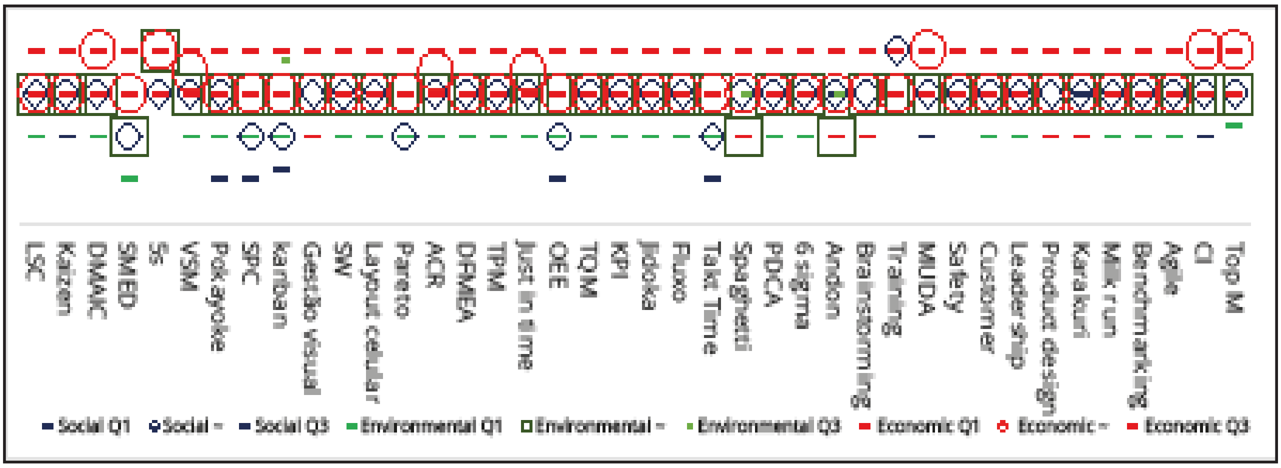
4.2.3. Experts in sustainability

A total of 163 respondents identified themselves as knowledgeable about sustainability, evaluating 23 tools with a score of 4.00 on the position measure (~) across the three pillars. Regarding medians with the lowest score (3.00), none were in the economic pillar, three were in the environmental pillar, and six were in the social pillar. Of the seven scores of 5.00, 28.5% were equally distributed between the social and environmental pillars, with the remaining 71.5% in the economic pillar, which also had three scores of 4.50.

Considering the dispersion of scores in the social pillar, quartile 1 had four scores of 4.00, 30 scores of 3.00, one score of 2.25, and five scores of 2.00, while in the upper quartile, the scores were concentrated at 4.00 (12) and 5.00 (28). In Q1 of the environmental pillar, six scores were 4.00, one was 3.25, and 32 were 3.00, with the lowest score (2.00) recorded for the SMED tool; in Q3, there were 31 scores of 5.00, one of 4.75, and eight of 4.00.

In the economic pillar, all scores in the upper quartile were 5.00, with six at 3.00 and the rest at 4.00 in the lower quartile. 5S stands out with medians of 4.00 and 5.00 and low dispersion; for the lowest scores, SMED was notable. The distribution of results is presented in Figure 5.

Figure 5 – Comparison of responses from the sample of sustainability experts



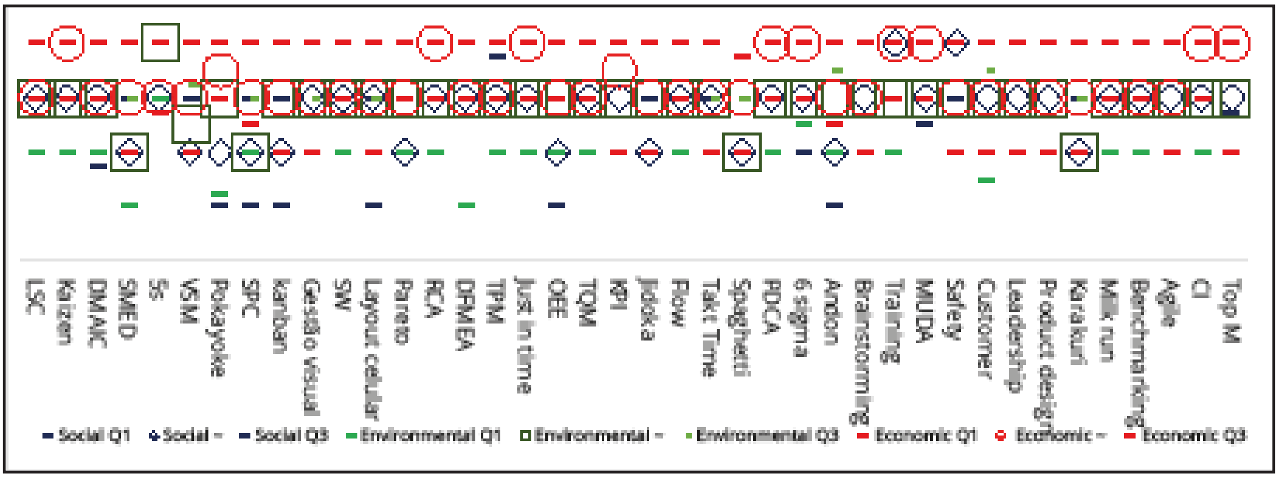
Source: The authors (2024)

4.2.4. Non-experts in sustainability

Of the respondents, only 47 declared themselves non-experts in sustainability. Analyzing the median scores across the pillars, the maximum range observed was 2.00 per tool. The most common median score was 4.00, representing the most typical value across all pillars. In the social pillar, the training and safety tools were notable, achieving scores of 5.00.

Similarly, in the environmental pillar, 5s scored 5.00; in the economic pillar, CI, top management, training, *muda*, PDCA, 6 sigmas, just in time, RCA and Kaizen all stood out. In addition to the frequent 4.00 scores, median scores of 3.00 were prevalent in the social pillar, accounting for 27.5% of the tools, and 10% in the environmental pillar. The environmental pillar also had a score of 3.50, while the economic pillar included two scores of 4.50. Figure 6 offers a comprehensive overview of these results.

Figure 6 – Comparison of responses from the sample of non-experts in sustainability



Source: The authors (2024)

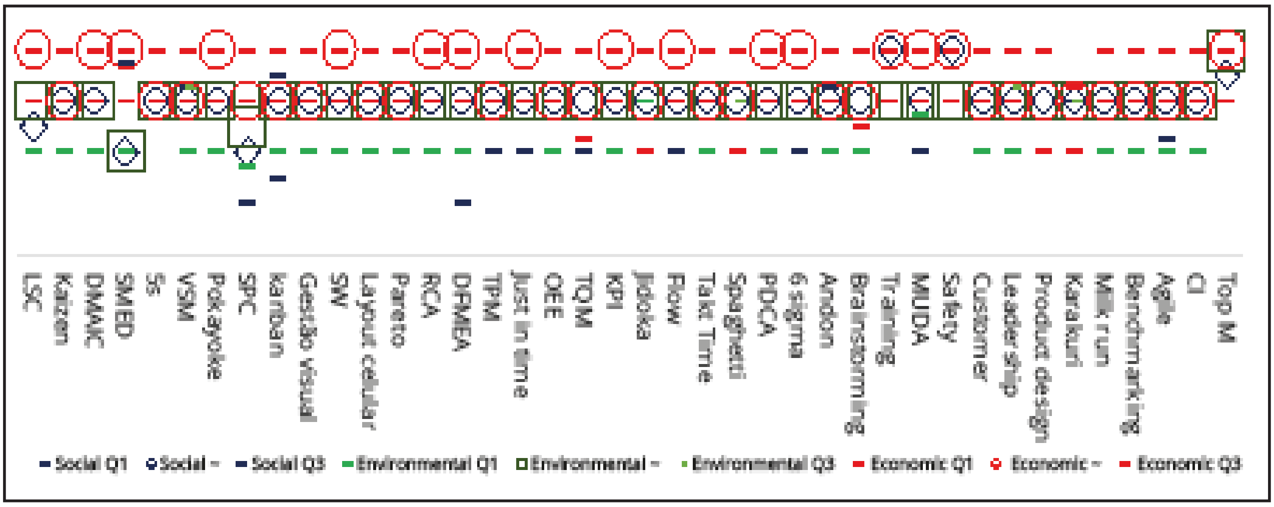
The variability in distributions indicates that in the lower quartile of the social pillar, 20% of the tools received a score of 2.00, while 65% scored 3.00. Additionally, a score of 4.00 was recorded three times, and scores of 2.75, 3.50, and 3.75 were each noted once. In the third quartile (Q3), 62.5% of tools achieved the maximum score of 5.00; a score of 4.00 was seen 13 times, and 4.75 was recorded twice.

Within the environmental pillar, 5% of tools received a score of 2.00 in the first quartile (Q1), whereas 70% achieved a score of 5.00 in Q3. In the economic pillar, the 5.00 score was predominant in Q3, with 97.5% of tools, and in Q1, 42.5% of tools received the lowest observed score of 3.00. Training emerged as the predominant technique, scoring 5.00 in both the social and economic pillars and 4.00 in the environmental pillar. Conversely, *Karakuri*, spaghetti diagrams, SPC, and SMED were identified as the tools with the lowest median scores according to non-experts.

4.2.5. Non-experts in lean

Of the 42 surveyed individuals who reported having no in-depth knowledge of lean manufacturing and self-identified as non-experts in lean, the data were presented in Figure 7.

Figure 7 – Comparison of responses from the sample of non-experts in lean



Source: The authors (2024)

In this study, the top management tool was highly rated, receiving scores of 4.50 in the social pillar and 5.00 in the others. Training and safety were also notable, achieving top marks in the social and economic pillars, and a score of 4.00 in the environmental pillar, underscoring their significance for this sample.

The economic pillar includes another 13 tools each with a score of 5.00. The lowest scores were observed for the SMED tools, with a score of 3.00 in both the social and environmental pillars, and SPC, with scores of 3.00 in the social and 3.50 in the environmental pillars, respectively. Most tools had a median score of 4.00, occurring 95 times across all three pillars. Generally, the range of the tool scores in the first and third quartiles within the pillars was between 1.00 and 2.00, except for the FMEA tool, which exhibited the greatest variance in the social pillar (Q1 = 2.00, Q3 = 5.00), indicating the evaluators' diverse opinions. Seven tools (top management, safety, training, takt time, cellular layout, Pareto, and 5S) displayed evaluations with closer scores and, consequently, lower variation.

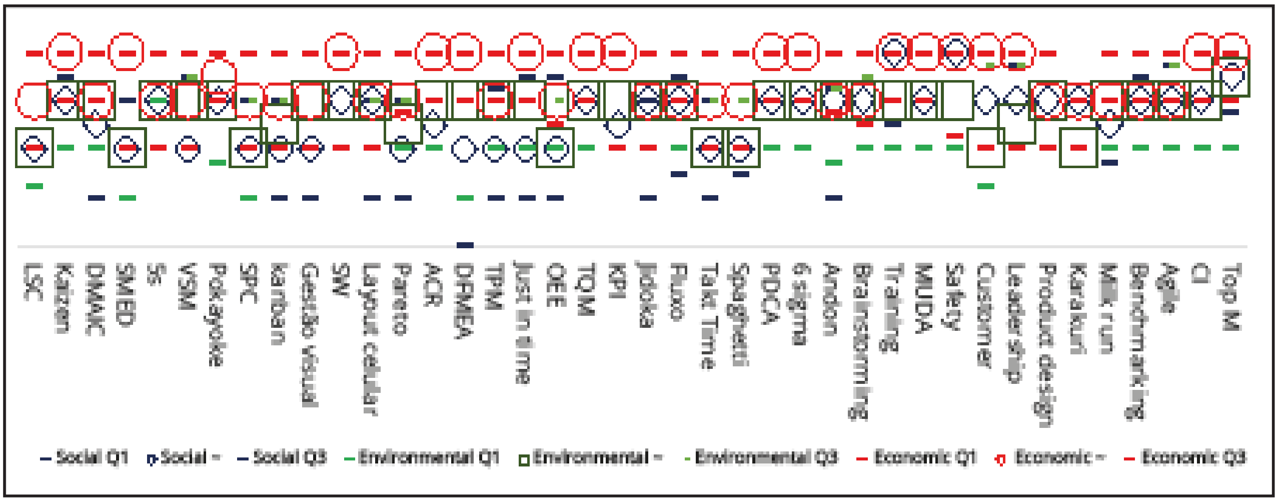
4.2.6. Non-experts in both areas

10% of interviewees (n = 21) identified as having no experience in either field after reviewing the qualification criteria for selecting experts. These participants deemed the median score for thirteen tools (lean supply chain, SMED, VSM, SPC, Kanban, visual management, Pareto, DFMEA, TPM, just in time, OEE, spaghetti diagram, and *takt* time) as 3-Medium impact in the social pillar. In the environmental pillar, eight tools received this median score.

The highest scores (5.00) were recorded in the social pillar for two tools, and in the economic pillar for Kaizen, SMED, standardized work, RCA, DFMEA, just in time, TQM, KPI, PDCA, 6 sigma, training, change, safety, customer involvement, continuous improvement, and top management. A broad quartile analysis range (value of 3.00) was noted for social (DMAIC, visual management, DFMEA) and environmental (SMED and DFMEA) pillars. This group also reported the lowest Q1 scores, with a score of 1.00 for the DFMEA tool.

Training and safety emerged as the most significant tools, with top scores in the social and economic pillars and 4.00 in the environmental pillar. The tools with the lowest median scores included lean supply chain, SPC, OEE, *tak*t time, and spaghetti diagram, with scores of 3.00 in the social and environmental pillars and 4.00 in the economic pillar. A graphical summary of the data is presented in Figure 8.

Figure 8 – Comparison of responses from the sample of non-experts



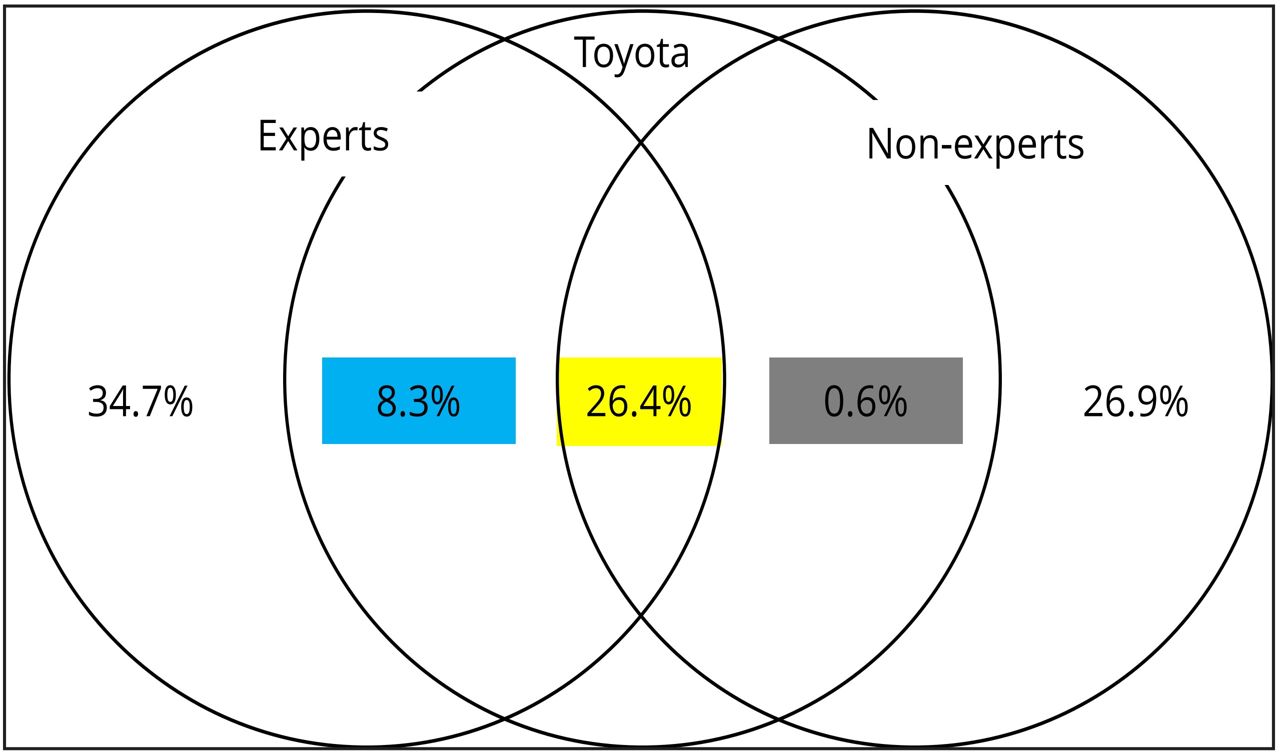
Source: The authors (2024)

5 DISCUSSION OF THE RESULTS

The analysis of the data collected throughout the study is presented, offering a comparative view of the variables analyzed between the expert and non-expert groups. In these groups, identical answers were observed in 26.4% of the cases, with nine tools showing agreement in one variable. Eleven techniques shared two characteristics that matched across all answers compared with other groups; 16 tools had three variables in common; and four tools achieved identical scores across four variables analyzed.

Examining the experts alone, the concordance with Toyota's scores is 34.7%, of which 8.3% are unique to this group. Among the non-experts, the number of tools in agreement is lower, with only 0.6% of variables being unique to this group and Toyota. The graphical comparison is depicted in Figure 9, and a detailed analysis of the tools follows.

Figure 9 – Response agreement



Source: The authors (2024)

To visually express the concordance of scores between respondents and the manufacturer, Table 2 is presented. This table shows the equivalence of the answers with Toyota's, marked with an "x" in their respective cells. The color-coding is as follows: a yellow background indicates variables that coincide across all observed results for both expert and non-expert groups; a blue background denotes variables where only the expert group's responses match the manufacturer's; and a dark gray background is used for variables where only the non-expert group's responses align with the benchmarking.

Azevedo et al. (2012) discussed how supplier collaboration and the implementation of a green supply chain can enhance resource efficiency, promote the recycling and reuse of materials, reduce lead times, stock levels, scrap generation, energy consumption, and minimize the production of solid and liquid waste. The tool LSC demonstrates that all groups share the same view of Toyota in Q1 of the social pillar and Q3 of the economic pillar. The experts uniquely identified correspondences in Q3 for the social pillar and Q1 for the economic pillar.

Morell-Santandreu et al. (2020) highlighted that Kaizen, or continuous improvement, is a strategic approach to identify and eliminate non-value-adding activities in processes. In terms of the social and environmental pillars, the company matched Toyota's median score, a similarity also observed in the economic pillar's upper quartile. This alignment of variables is also evident in the brainstorming technique, crucial for Toyota to explore problems and identify opportunities for Kaizen. Moreover, Q1 of the environmental pillar was exclusively matched by the experts' group using the Kaizen tool.

Tasdemir and Gazo (2019) employed the DMAIC method to assert their objective of achieving profitability essential for sustainability. The DMAIC tool aligned with other groups in the bottom quartile for the environmental and economic pillars. The SMED tool aims to minimize setup times to enhance demand responsiveness, reflected in the social pillar's linear medians and in Q3 of the economic pillar.

Table 2 – Coincidence of the tools researched with Toyota

	Experts																											Non-experts																									
	Lean and Sustainability									Lean									Sustainability									Sustainability									Lean									Lean and Sustainability								
	Social			Environm			Economic			Social			Environm			Economic			Social			Environm			Economic			Social			Environm			Economic			Social			Environm			Economic			Social			Environm			Economic		
Tools	Q1	~	Q3	Q1	~	Q3	Q1	~	Q3	Q1	~	Q3	Q1	~	Q3	Q1	~	Q3	Q1	~	Q3	Q1	~	Q3	Q1	~	Q3	Q1	~	Q3	Q1	~	Q3	Q1	~	Q3	Q1	~	Q3	Q1	~	Q3	Q1	~	Q3	Q1	~	Q3	Q1	~	Q3	Q1	~	Q3
LSC	x		x				x		x	x		x				x		x	x		x				x		x	x						x		x	x	x					x		x	x			x					x
Kaizen		x		x	x				x		x		x	x				x		x		x	x				x		x			x			x	x		x			x				x		x			x			x	x
DMAIC				x			x							x			x							x			x							x			x	x						x			x					x		x			x	x	
SMED		x							x		x							x		x							x		x							x		x						x	x		x						x	x
5s		x		x		x	x		x		x		x		x	x		x		x		x		x	x		x		x		x		x			x		x		x		x	x		x		x		x		x			x
VSM		x				x		x	x		x				x			x		x				x			x									x		x							x									x
Pokayoke									x									x									x		x		x					x								x	x									x
SPC	x				x	x			x	x				x	x			x	x				x	x			x	x					x			x	x					x			x	x					x			x
kanban		x			x	x	x	x			x			x	x	x	x		x	x			x		x	x			x			x			x						x		x	x			x				x		x	
Gestão visual				x					x				x					x				x					x				x					x				x			x		x				x					x
SW		x			x		x	x			x			x		x	x			x			x		x	x			x			x		x	x			x			x		x				x			x				
Layout celular				x			x		x				x			x		x				x			x		x				x					x				x			x		x				x					x
Pareto			x		x				x			x		x				x			x		x				x			x		x				x		x	x		x				x			x						x
RCA					x		x	x	x					x		x		x					x		x	x	x					x		x		x					x		x		x					x		x		x
DFMEA					x				x					x				x					x				x			x		x				x					x			x	x			x		x			x	x
TPM					x		x		x					x		x		x					x		x		x			x		x		x		x				x	x		x		x					x		x		x
Just in time						x	x		x						x	x		x						x	x	x	x						x	x		x						x	x		x						x	x		x
OEE								x								x								x		x								x								x		x								x	
TQM	x				x		x		x	x				x		x		x	x				x		x		x	x				x		x		x	x			x	x				x	x				x		x		x
KPI			x			x			x			x			x			x			x			x			x			x			x			x		x	x			x			x			x			x			x
Jidoka					x		x		x					x		x		x					x		x		x					x				x					x				x					x				x
Flow						x	x		x						x	x		x						x	x		x						x	x		x						x	x		x						x	x		x
Takt Time					x				x					x		x		x					x		x		x					x				x					x		x		x									x
Spaghetti							x									x							x			x				x		x			x		x					x			x				x		x			x		
PDCA					x		x		x					x		x		x					x		x		x					x		x		x					x		x		x					x		x		x
6 sigma				x	x		x	x	x				x	x		x	x	x				x	x		x	x	x					x		x		x					x		x		x				x	x		x		x
Andon		x							x									x		x							x					x				x		x			x		x		x		x			x				x
Brainstorming		x			x				x		x			x				x		x			x				x		x			x				x		x			x				x		x			x				x
Training			x		x		x		x			x		x		x		x			x		x		x		x			x		x		x		x			x		x		x		x			x		x		x		x
MUDA			x	x		x		x	x			x	x		x		x	x			x	x		x		x	x			x	x		x		x	x			x			x		x	x			x			x		x	x
Safety	x	x				x	x		x	x	x				x	x		x	x	x				x	x		x	x					x			x	x					x	x		x						x			x
Customer			x		x				x			x		x				x			x		x				x			x		x				x			x		x				x			x			x		x	x
Leadership			x			x	x		x			x			x			x			x			x	x		x			x			x			x			x				x		x									x
Product design	x				x				x	x				x				x	x				x				x	x				x				x	x				x				x	x				x				x
Karakuri	x					x			x	x					x			x	x					x			x	x								x	x																	
Milk run	x				x		x		x	x				x		x		x	x				x		x		x	x				x		x		x	x				x		x		x		x			x		x		x
Benchmarking		x				x			x		x				x			x		x				x			x		x				x			x		x				x			x		x				x			x
Agile		x			x	x		x			x			x	x		x			x			x	x	x	x			x			x			x			x			x	x	x	x			x			x		x	x	
CI		x			x		x				x			x		x				x		x	x		x				x			x		x				x			x		x	x			x			x		x		
Top M			x			x		x	x			x			x		x	x	x		x			x		x	x			x			x		x	x	x	x	x		x	x		x	x		x	x			x		x	x

Source: The authors (2024)

Cherrafi et al. (2016) stated that the 5S system fosters a clean and organized work environment, decreases input consumption, and encourages proper disposal of production waste. The environmental pillar scored Q1 and Q3, aligning with the benchmark, as did Q3 for the economic pillar and the median for the social pillar. The experts' group also showed a unique alignment in Q1 of the economic pillar.

Santos et al. (2021) defined standardized work as a comprehensive system of documented descriptions that guide operators through specific task sequences in their activities. This technique aims to identify and formalize the best working methods. Toyota achieved a consensus on the median in the social and environmental pillars, and exclusively among experts in the median and Q1 of the economic pillar.

Cherrafi et al. (2016) emphasized that VSM is a critical tool for organizations to identify and mitigate production waste by focusing on resource use, waste management, and emissions. The only matching responses among respondents were observed in the upper quartile of the economic pillar. This was also true for systems aiming to prevent process errors, represented by the Poka-Yoke tool; *Takt*, which aligns production pace with demand, minimizing stock needs; Andon, crucial for identifying and eliminating unnecessary elements, thus reducing material use and waste; and leadership, a key component of lean manufacturing that fosters teams dedicated to continuous improvement.

Gatell and Avella (2024) noted that leadership is vital for lean production success. Analysis limited to the expert group found correspondences in the median of the social and Q3 of the environmental pillar for the VSM tool, in the environmental median for *Takt*, and in Q3 of the social and environmental pillars for leadership. The non-experts' group agreed only on the median of the environmental pillar for the Andon tool.

Vetter and Morrice (2019) argue that statistical process control uses statistical techniques to monitor production, ensuring it adheres to acceptable quality standards. According to their philosophy, Toyota shares its results with other groups, situating itself in the lower quartile for the social pillar and the upper quartile for other pillars. Two tools align with the median of the economic pillar across all groups: Overall Equipment Effectiveness (OEE), a benchmark indicator for measuring quality, productivity, and performance of processes; and Kanban, an information control system managing inventories, typically utilizing just-in-time cards or flags (Mohapatra et al., 2021).

These also align in the median values for the social and environmental pillars, and in the lower quartile for the economic pillar. Visual management, a core aspect of the lean management model, enhances safety and reduces errors by providing informative warnings or reminders (Kruskal et al., 2012). It draws identical values across groups in Q1 (environmental) and Q3 (economic), parallel to the variables of the cellular layout technique used by Toyota to increase production flexibility and meet varying demands, further matching the Q1 score of the economic pillar in the expert-only group. Pareto analysis and customer involvement stand out in the top quartile for both the social and economic pillars.

Awwad et al. (2022) acknowledges that customer interaction, supplier collaboration, and the adaptability for new products significantly influence sustainable product development. Kaswan (2023) highlights Pareto analysis's role in identifying primary causes of waste and inefficiencies within lean green contexts. This analysis is consistent among expert groups in the environmental pillar's median. RCA, TPM, PDCA, 6 Sigma, and Milk Run exhibit similar patterns across groups in economic pillar dispersion measures (Q1 and Q3) and the median for the environmental pillar.

The Deming cycle fosters a systematic approach for Toyota members to plan, execute, control, and act upon deviations, utilizing root cause analysis for problem investigation, including accident analysis (Adib et al., 2024). Similarly, 6 Sigma provides a statistical methodology to address complex problems, while TPM focuses on maintaining equipment availability to boost productivity and minimize breakdowns.

Bertagnolli et al. (2021) advocate for Milk Run's role in reducing logistics inefficiencies and environmental impact. Analysis of expert opinions shows 6 Sigma and Milk Run aligning in the Q1 environmental pillar and economic pillar's median. Respondents' views on FMEA and *Jidoka* mirror in the environmental pillar's median and economic pillar's Q3. *Jidoka*, or automation with a human touch, is vital for minimizing defective production (García-Alcaraz et al., 2021), whereas FMEA identifies potential defect causes in sustainable projects (Yadav & Gahlot, 2022).

Only *Jidoka* received identical scores from experts in the economic pillar's Q1. Just-in-Time and flow are compared favorably in the top quartile of the environmental and economic pillars, and in Q1 of the economic pillar. Azevedo et al. (2012) note that green and lean practices, such as just-in-sequence and direct point-of-use deliveries, reduce waste and enhance corporate image across economic, social, and environmental dimensions.

García-Alcaraz et al. (2021) describe continuous flow as an ideal state where products move directly from one production stage to the next, one at a time. Product design, focusing on durable, recyclable, or reusable products, aligns with total quality management (TQM) in the social pillar's Q1, environmental pillar's median, and economic pillar's Q3. Liu et al. (2022) state that quality management, including ISO 9001 certification and adherence to TQM policies, is crucial for sustainability. Expert analysis of TQM responses reveals additional alignment in the economic pillar's Q1.

Siegel et al. (2022) point out that selecting appropriate lean and sustainability indicators (KPIs) in projects is crucial for measuring the performance of the current state and allowing comparisons with future results across the environmental, social, and economic dimensions. In this context, all groups, including Toyota, positioned Q3 with top marks in the three studied pillars. Similarly, the spaghetti diagram, a visual representation of movements in a workplace that helps identify inefficiencies and reduce waste by reorganizing the layout to eliminate unnecessary movements, only showed equivalence in one variable: the lower quartile of the economic pillar. According to Oliveira and Lima (2023), the application of the spaghetti diagram aligns with the first quartile (Q1) of the environmental pillar, especially for the group of non-experts.

Lai et al. (2022) assert that training is fundamental to successfully implementing lean thinking. This principle correlates with the responses of other participants in four variables: Q3 of the social pillar, the median of the environmental pillar, and the two quartiles of the economic pillar. *Muda* and top management also aligned in four measures, coinciding in the upper quartile of the three pillars and the median of the economic pillar.

As observed by Qureshi et al. (2022), the proactive support of top management is crucial to ensure the effective implementation of various organizational performance measures, including waste elimination, with the *muda* tool showing exclusive agreement for the group of experts in the lower quartile of the environmental pillar.

An initiative aimed at improving occupational health and safety is crucial for reducing accident and injury rates in the workplace (Sajan & Shalij, 2017). Statistically, this technique (safety) is equivalent to the responses of other participants in the top quartile of the environmental and economic pillars. For the group of experts, this tool is also positioned in the lower quartile of the social and economic pillars while coinciding in the median of the social pillar.

The low-cost automation or *Karakuri* concept, used by Toyota, aligns with other groups in Q1 in the social pillar. For the experts, the values in the upper quartile are the same for the environmental pillar. Bertagnolli et al. (2021) indicate that *Karakuri* relies on natural forces, such as gravity, springs, or magnetism, to save resources and energy, strongly linking it to sustainability.

Toyota is often benchmarked against other companies for its successful application of the lean mentality methodology. Responses in this area are consistent in the median of the social pillar and Q3 of the environmental and economic pillars. Ramos et al. (2018) suggest that integrating lean and cleaner production through benchmarking enables the evaluation of management practices in people, processes, and practices from a sustainable perspective.

The analysis of agile techniques yields the same conclusions as other respondents in the medians of the three pillars. Focusing solely on the group of experts, the tool performs equally in the Q3 variable of the environmental pillar. Phillips (2003) emphasizes that this approach ensures companies focus on principal business dimensions in addition to short-term time and cost issues.

Lizarelli et al. (2023) highlighted that continuous improvement (CI) positively correlates with the three dimensions of sustainability and demonstrated how lean practices influence sustainability performance. In this context, the median of the social and environmental pillars and Q1 of the economic pillar show congruency between groups.

6 CONCLUSIONS

This study conducted an in-depth analysis of the perceptions of six groups, both with and without knowledge of lean and sustainability, critically comparing these perceptions with those of four Toyota experts, who represent the state of the art in lean practices. The analysis contextualized 40 lean manufacturing tools identified in the literature for their impact on sustainability, aiming to align the experts' views with the three pillars of sustainability: social, environmental, and economic.

As theoretical contributions, the research highlights the relevance of aligning lean management practices with sustainability, deepening the understanding of how techniques such as Kaizen and DMAIC can be integrated to promote operational efficiency and waste reduction. The analyses of the agreements between the responses of expert and non-expert groups regarding the studied tools not only corroborate the findings of Azevedo et al. (2012) and Morell-Santandreu et al. (2020) but also expand the literature by presenting a comparative model that can be used as a reference for future investigations. This theoretical contribution is essential for underpinning new research that explores the intersection of sustainability and continuous improvement practices.

The overall research objective was successfully achieved, as the investigation provided a detailed understanding of the differing perceptions among groups with various levels of knowledge about lean and sustainability. Comparing the responses from the Toyota experts with those from the other groups allowed for the identification of convergences and divergences in the evaluations of lean tools, as planned. Additionally, the study thoroughly explored the three dimensions of sustainability, analyzing how each tool was perceived in terms of social, environmental, and economic impact, thus fulfilling the aim of assessing variations and possible alignments in perceptions across different groups.

Regarding practical contributions, the results obtained provide clear guidelines for the implementation of lean tools in companies with the aim of achieving greater sustainability. The alignment observed between the expert groups and Toyota highlights the effectiveness of techniques such as 5S and TPM in creating more efficient and sustainable work environments. These findings have direct implications for managers seeking to adopt cleaner production practices, suggesting that training and awareness about the importance of each tool are essential to maximize operational and environmental benefits. Thus, the research offers a practical guide for integrating lean principles and sustainability into business operations.

The study analyzed 210 questionnaire responses, addressing the research hypotheses and meeting the proposed objectives. Hypothesis H1, which aimed to determine whether the widespread dissemination of the lean philosophy over the decades resulted in uniform benchmarking responses across all groups, showed that 26.4% of the responses matched. Nine tools showed agreement in one variable (such as VSM, Poka-Yoke, and Kanban), eleven tools showed coincidences in two variables, and sixteen tools displayed alignment in three variables. Four tools had coincidences in all four variables (5S, senior management, training, and muda).

Hypothesis H2, which examined whether experts' responses were more aligned with Toyota's perspectives than those of non-experts, was confirmed. Experts showed a 34.7% alignment with Toyota, compared to only 0.6% for non-experts. These findings indicate a clear convergence in the experts' perceptions, suggesting that experienced professionals tend to share views that are more closely aligned with Toyota's practices and guidelines.

The conclusions underscore significant contributions to lean and sustainability practices, providing evidence that alignment between perceptions is stronger among experts, which can guide the development of training and education in lean practices. Additionally, the results suggest that some tools, such as senior management and muda, tend to be more highly valued in relation to the three pillars of sustainability, while others, such as the spaghetti diagram, are less emphasized.

For future research, it is recommended to explore the reasons behind the differing perceptions between groups with and without knowledge of lean and sustainability through qualitative studies, such as interviews or focus groups. This approach could enhance the understanding of how education and experience influence evaluations of lean tools concerning the three pillars of sustainability. Expanding the range of tools analyzed and including various sectors, such as manufacturing, services, and healthcare, are also suggested to assess how perceptions differ across industrial contexts.

It is also important to investigate the role of organizational culture and business environment in the adoption of lean practices and their relationship with sustainability. Comparative studies between companies with different cultures may reveal replicable and successful approaches. Conducting longitudinal studies would allow tracking changes in perceptions over time, especially following organizational changes or training.

Finally, it is recommended to examine the interactions between lean practices and the United Nations Sustainable Development Goals (SDGs) and to develop assessment models that integrate lean and sustainability, helping organizations measure their progress in a cohesive and systematic way.

CONFLICT OF INTEREST

The authors have stated that there is no conflict of interest.

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1. Definition of research problem	√	√			
2. Development of hypotheses or research questions (empirical studies)	√	√			
3. Development of theoretical propositions (theoretical work)	√	√			
4. Theoretical foundation / Literature review	√	√	√	√	√
5. Definition of methodological procedures	√	√			
6. Data collection	√				
7. Statistical analysis	√				
8. Analysis and interpretation of data	√	√	√		
9. Critical revision of the manuscript	√	√	√	√	
10. Manuscript writing	√	√	√	√	√
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