P-ISSN 2664-0422	Pakistan Social Sciences Review	Jan-March 2025, Vol. 9, No. 1
O-ISSN 2664-0430	https://doi.org/10.35484/pssr.2025(9-I)46	[592-610]

Pakistan Social Sciences Review
www.pssr.org.pk

RESEARCH PAPER

Lean Manufacturing Sustainability: A Critical Review of Barriers and its Impact

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ABSTRACT

The objective of this research is to explore the challenges in sustaining lean manufacturing practices with in the automotive sector. Lean Manufacturing is widely adopted to improve quality, reduce costs and enhance operational efficiency. However, sustaining these dynamic practices remains a significant challenge. Factors such as management related barriers, workforce resistance, process related and resources related barriers has considerable impact on sustenance of Lean Manufacturing practices. The research explored the sustainability of LM practices by gathering expert insights on 24 influencing factors. A survey was conducted among over 50 automotive industries in Karachi, to examine the challenges associated with management, workforce, process and resource related issues. The collected data was analyzed on SPSS to identify the key obstacle hindering the sustainability of Lean Manufacturing Practices. Findings indicate that while Lean Manufacturing practices are implemented across organizations, sustaining these practices is difficult. The impact of Workforce related, Resource related & Process related barriers was evident but Management related barriers, including lack of leadership support were found to be most influential factor. Employee resistance often stems from inadequate managerial involvement in Lean initiatives. To enhance Lean Manufacturing Practices sustainability, organizations needs to strengthen leadership commitment, provide continuous employee trainings and integrating a mechanism of follow ups and performance tracking. Future research expands the sample size and include multiple industries to gain broader insights into sustainability challenges across various sectors.

KEYWORDS Lean Manufacturing, Sustainability, Barriers

Introduction

In the present competitive scenario, organizations face enormous challenges in meeting the requirements of their customers (Trubetskaya et al 2022). The primary demand of consumers includes on-time delivery of high-quality items at the lowest possible cost (Kumar et al 2022). Increasing problems in today's challenging economic situation have compelled many manufacturing enterprises to implement innovative manufacturing management practices to improve productivity and efficiency (Gisi 2023). Lean manufacturing is now extensively recognized and accepted to be preferable for the practices of manufacturing across various countries and industries. (Singh et al 2023). To improve productivity, many manufacturing companies have adopted the lean manufacturing (LM) system and implemented its various tools and techniques in their operations (Fullerton et al 2014). Conversely, most industries face a lot of challenges to

transform into lean firms (Madsen & Skjoett 2017). The ambition of being able to produce a world-class product does not only require the implementation of lean manufacturing practices but sustaining lean culture in an organization is a real challenge (Catherine & David 2022).

The transition to LM is loaded with intense and difficult phases, specifically developing the right understanding of the true essence of the LM concept and philosophy while addressing the cultural differences between countries or within the organization (Mahadevan & Chejarla 2023). The specific issue is organizations' incapability to sustain improvements in establishing and implementing lean manufacturing in their organizations (Sim et al., 2008). Establishing lean culture in a manufacturing organization is a continuous process optimization method for maximizing process value. By using various lean methods and philosophy, manufacturers can eliminate waste and NVA activities. However, not all of the lean implementations have achieved similar results (Browning Heath, 2009). Malware and Parsley (2022) stated that the failure of lean techniques is attributed to lack of knowledge on lean concepts, wrong implementation methodology, as well as inability to quantify the advantages of LM implementation. This conclusion is backed up by Worley and Doolen (2006), who observed that progress made through lean efforts is reversing and that implementation efforts are not yielding uniform results.

Some research has been conducted into lean manufacturing adoption in automotive industries in Pakistan. The study shows that both OEMS (Original Equipment Manufacturers) and parts manufacturers are fully aware of the major lean concepts, but there is a high inconsistency in sustaining the adopted lean tools and processes (Wassan, et al 2022). Hence this research aims to identify the challenges in sustaining Lean Manufacturing Practices in the automotive sectors in Pakistan. The inquiry highlights the factors causing effects in the sustainability of LM (Bhutta et al., 2017). This study is hopefully going to aid the firm's management in identifying the issue necessary for developing a sustainable and effective LM system.

Literature Review

The famous Japanese multinational automobile industry, Toyota, has founded Lean Manufacturing back in the 1950s known as the Toyota Production System (TPS) (Mahadevan & Chejarla 2023). Yet, this concept can be said to be described first ever in the text called The Machine That Changed the World by Womack et al. (1991) that shows how Japanese productions strongly contradicted what the typical mass production systems would do. The next important text related to lean was Lean Thinking: Banish Waste and Create Wealth in Your Organization, which described lean concepts and introduced the term "lean production".

Lean is a set of actions and remedies aimed at minimizing waste, also called non-value-adding (NVA) activities, while maximizing the value-added (VA) process. This concept of VA and NVA is derived mostly from TPS, the Japanese-style production (Reke, Eivind et al. 2022). Waste refers to anything preventing the smooth flow in production (Ray et al., 2006). Some wastes are overproduction, waiting, transportation, overprocessing, excess inventory, unnecessary movement, defects, and underutilization of employee creativity. Lean according to Shah and Ward (2007) could thus be defined as "an integrated socio-technical system" whose principal aim is the elimination of waste concurrently with the reduction or constraint of supplier, customer, and internal

variability. Womack and Jones (2003) suggest the following principles as the foundation for Lean:

1. Determining the value defined by the customer.
2. Improving the value stream.
3. Conversion of the smooth value flow through management and elimination of waste.
4. Enabling demand pull by coordinating customer demand and information flow.
5. Perfection of product, process, and service.

Lean manufacturing refers to an approach for reducing wastes, and streamlining processes to make value addition more meaningful toward achieving a smooth production flow. Guleria, P. et al. (2022) have stated that negligence toward the LM approach leaves the current global market with greater quality, faster delivery, and optimum cost unachievable by the company. Oliver et al. (1996) advocate the LM principles for establishing high-performing enterprises from a large cross-country analysis. According to Mishra and Terker (2023), LM is based on numerous tools and procedures that have been used to improve intra- and inter-organizational performance to achieve competitive features in manufacturing performance. These tools are designed based on LM principles such as eliminating non-value-added operations, boosting productivity value, decreasing variability, decreasing cycle time, and simplifying processes by reducing the number of parts and procedures. Having the correct practices tools and procedures in place is the key to long-term lean performance. Similarly, Manville et al. (2012) contend that limiting the number of lean tools hampers an organization's ability to solve problems and hinders in enhancing process capability as quickly as organizations with a wider tool and techniques options from which all employees can select the appropriate one.

Integration of these tools can increase operation flexibility, process transparency, concentration control across the entire process, and balancing flow hence resulting enhancement of continuous improvement strategies. A few examples include 5-S, Kaizen, Poka Yoke, GEMBA, VSM, KANBAN, JIT, SMED, and JIDOKA are few examples of these techniques. Once the organization has created a reliable process, the deployment of techniques and tools can begin. Continuous improvement tools can be utilized to identify the fundamental cause of inconsistencies and then devise a suitable countermeasure (Liker, 2004). As per Bhasin and Sanjay (2012), the application of lean methodologies should be the foundation of every organization's strategy since lean provides the opportunity and the determination to achieve and sustain profitable growth. The implications of not implementing lean as corporate strategy is so significant that lean should become a high-priority competitive strategy.

Sustainability of Lean Manufacturing

In general terms, sustainability is the balance between the utilization of resources to satisfy today's needs and the safeguarding of resources for future life (Singh 2023). Sustainability refers to the efforts to ensure a long-term future through environmentally-conscious practices, the wise use of resources, equal access to services for all, and the creation of a strong local economy with plenty of job opportunities. In addition, the importance of sustainability in the efficient, productive, and responsible operation of businesses is increasing (Wilkinson et al. 2001). However, when the term sustainability is used concerning lean manufacturing, it is equally important to address how to retain

momentum once initial phases are completed and how to obtain long-term gains of Lean once it's introduced and implemented in the system (Lopes et al 2023).

Adopting sustainable Lean practices can offer several advantages for organizations. These benefits include enhanced efficiency, better quality control, and minimized waste (Prasad, et al., 2022). However, these practices can prove aid to organizations in lowering their environmental footprint and fostering social responsibility, resulting in improved reputation and customer loyalty (Sreenivasan, & Suresh, 2022). It can also lead to cost savings, as organizations can reduce their energy and resource consumption (Hariyani, & Mishra,2022). In conclusion, sustainable lean practices provide an effective means for organizations to meet their sustainability objectives while enhancing overall performance and competitiveness, according to a paper by Swanker, et al back in 2021 (Swanker, et al., 2020). There are numerous definitions of sustainable Lean practices have been proposed by researchers' practitioners and consultants. A systematic literature review was conducted to identify several numbers of these definitions, which are presented in Table I of this study. It is important to note that there may be additional definitions not included here, as the list is not exhaustive but rather highlights the most widely recognized definitions in the field of lean sustainability. This study's motive is not to provide a definitive list only but to offer a representative sample of the ley guidelines currently acknowledged in the area.

Table 1
Definitions of sustainable lean Practices

1. Lean sustainability is a method that focuses on engaging employees in recognizing and removing waste within environmental, social, and economic systems by applying principles of standardization and continuous improvement.	(Reference: "Lean Sustainability: Employee Involvement, Standardization and Continuous Improvements" by John Bicheno)
2. the combination of lean thinking with sustainability principles emphasizes employee involvement in identifying and addressing environmental and social challenges through the standardization and continuous improvement of processes.	"Lean Sustainability: Achieving Business Goals through Employee Involvement, Standardization and Continuous Improvements" by Emily Carter
3. The application of lean principles to sustainability initiatives to identify and eliminate waste in environmental, social, and economic systems.	"Lean Sustainability: How to Create and Implement Sustainability Practices in Any Industry or Company" by Andrew Savitz
4. An approach that combines the principles of lean manufacturing with sustainability, which emphasizes the active participation of employees in identifying and eliminating waste in environmental, social, and economic systems, through the implementation of standardization and continuous improvement principles.	"Lean Sustainability: The Role of Employee Involvement, Standardization, and Continuous Improvements" by Michael J. Balle and Pierre-Yves Gomez
5. Lean sustainability is the integration of lean thinking principles with sustainability principles. This approach aims to create a more efficient and environmentally friendly production process.	"Lean and Green: Profit for Your Workplace and the Environment" by Mike Wroblewski

As described in Table 1 many researchers described lean sustainability as a comprehensive approach to reducing waste in any system by implementing a standardized process, aiming for continuous improvement by involving employees. The goal is to create a streamlined and error-free production process (Mittal at al., 2016; Soosay et al. 2016; Thomas et al. 2012). The three pillars of sustainable lean practices, standardization, employee involvement, and continuous improvement, are commonly derived from the various definitions put forward by researchers, practitioners, and consultants in the field (Lizarelli, et.al 2022) For this study each pillar of lean sustainability is further described in detailed.

Standardization

Standardization refers to the use of consistent processes and procedures, clear documentation and instructions, standardized tools and equipment, and adherence to industry and regulatory standards (Gisi,2023). This ensures that the production process is consistent and efficient, and reduces waste and errors. Studies and research have identified the following as the most crucial factors in fulfilling the need for standardization

1. Clear documentation and instructions (Kumar, et.al 2022)
2. Consistent processes and procedures (Bhadu, et.al 2022)
3. Use of standardized tools and equipment (Emanakov, & Ovchinnikov 2022)
4. Adherence to industry and regulatory standards (Kumar, et.al 2022)
5. Regular audits and reviews to ensure compliance (Bertagnolli, 2022).

Continuous Improvement

Continuous improvement, another fundamental requirement of sustainable lean practices refers to the ongoing effort to identify and eliminate waste, implement process improvements, and regularly review and update best practices (Kumar, et.al 2022). This helps to increase efficiency and reduce costs over time (Gisi, 2023). The most critical factors in meeting the need have been determined through studies and research.

1. Regularly monitoring and measuring performance (Saini, & Singh, .2023)
2. Identifying and eliminating waste (Kumar, et.al 2022)
3. Implementing process improvements (Guleria, et.al 2022)
4. Encouraging employee suggestions and innovation (Al-Shami, & Rashid, 2022)
5. Regularly reviewing and updating best practices (Bertagnolli, 2022).

Employee Involvement

The term employee involvement is one of the important principles of lean manufacturing, meaning the active participation of employees in the processes of production (Al-Shami, & Rashid, 2022). It includes open communication and feedback, decision-making and ownership, training and development opportunities, involvement in decisions and problem-solving, and recognition and rewarding for employee contributions and achievements (Saini, & Singh, 2023). The various studies and research carried out identified the key areas needed for meeting the requirement for employee involvement.

1. Stimulating open communication and lending an ear to feedback (Bertagnolli, 2022)
2. Providing training and development opportunities (Al-Shami, & Rashid, 2022)
3. Employees actively participating in decision-making and problem-solving (Lizarelli et al., 2022)

Barriers to Sustaining Lean Manufacturing

As stated by Mohd-Zainal (2011), numerous organizations across the globe have attempted the implementation of lean, but very few could boast about any substantial ongoing success as adopting lean brings more failure than success in industry after industry. According to Hines et al. (2004), certain common elements contribute to the failure in sustaining lean manufacturing such as poor leadership and ineffective

communication, lack of established processes or mechanisms, vague targets or directions, unsupportive environment, resistance from employees, and limited learning opportunities that interfere with understanding lean manufacturing.

A major challenge for organizations in maintaining lean practices is often due to insufficient focus on developing lean competencies among personnel. Jorgensen et al. (2007) emphasized that organizational members are more likely to develop lean capabilities when supported by a learning environment that fosters a lean culture. Additionally, alienate (2009), Bashir et al. (2010), Olatunji (2008), and Sarhan and Fox (2013) categorized lean barriers into issues related to processes, people, resources, and management.

Management Related Barriers

Management support is vital for the continuity of lean approaches that have been put into operation. According to previous studies, the absence of senior management, leadership, and commitment forms a critical stumbling block toward the continued use of lean (Alinaitwe 2009). These studies have also pointed out many kinds of management-related weaknesses: planning is weak; poor understanding of customer needs; low participation in the management style by the workforce; lack of delegation to improve work flow; almost logistically of very low participation in the management style; low look-ahead planning by management; poor coordination among units and their activities (Alinaitwe, 2009; Olatunji, 2008; Tourki, 2010). After the detailed literature review management related barriers were divided into five main factors which include

1. **Lack of Leadership Commitment:** Lean initiatives require strong leadership support and commitment to be successful. Without this, it can be difficult to get buy-in from other members of the organization, which can lead to resistance to change (Maware, & Parsley,2022)

2. **Poor Communication:** If communication is poor within the organization, it can be difficult to effectively implement and sustain lean initiatives (Prasad, et.al 2022)

3. **Lack of Employee Engagement:** Lean initiatives often require significant involvement and participation from employees. Without adequate engagement and participation, it can be difficult to sustain these initiatives (Hariyani, & Mishra, 2022).

4. **Limited Budget:** Limited budget can be a barrier to the sustainability of lean initiatives (Sreenivasan, & Suresh, 2022).

5. **Lack of Knowledge:** Lean initiatives often require employees to learn new skills and processes. Without proper training and development, it can be difficult for employees to effectively adopt and sustain these new practices (Prasad, et.al 2022).

Human Capital-Related Challenges

A crucial component of an organization's culture is its people or workforce, which plays a pivotal role in driving corporate performance and managing change. Workforce-related barriers encompass a range of challenges that can impede the achievement of a project or organizational goal (Blincoe, K., 2022). These barriers may stem from individual differences, such as personality clashes or misunderstandings, as well as broader group dynamics like power imbalances of communication breakdowns (Lopes et al., 2023). External factors, including cultural differences or divergent values

and beliefs, can contribute to these obstacles. While overcoming workforce-related barriers can be challenging, addressing and resolving them is essential for ensuring the success of any project or objective (Arora et al., 2023). Moffet et al. (2002) find that transforming an organization's culture requires a shift in people's values, norms, and behaviors. Mindsets must be thoughtfully adapted to ensure that individuals align with and contribute positively to the organization's collective culture. Several factors can contribute to workforce-related barriers, with some common examples being:

1. **Limited Employee Skills and Knowledge:** Lean initiatives often demand employees to acquire new skills and adopt new processes. A lack of necessary skills or knowledge to effectively implement these practices can pose a significant barrier to sustainability (Sreenivasan & Suresh, 2022).

2. **High Employee Turnover:** High employee turnover can be a barrier to sustainability because it disrupts the implementation and maintenance of lean initiatives (Lewis, 2000).

3. **Lack of Employee Empowerment:** Lean initiatives often require employees to have a greater degree of autonomy and responsibility in their work. Without adequate empowerment, it can be difficult to sustain these initiatives (Souza, & Alves, 2018).

4. **Resistance to Change:** Change can be difficult for some individuals, and resistance to change can be a barrier to the sustainability of lean initiatives (Asnan, et al.2015).

Process Related Barriers

Successful implementation of lean sustainability concepts requires a complete understanding of the methodology, as well as a clear concept of long-term gains. In other words, training provided to the team is ineffective unless it is reinforced by ongoing systematic follow-ups that change how work is performed (Wiklund, 2002). Lean initiatives often require significant changes to the way work is done, and employees must understand and support these changes. Without employee buy-in, it can be difficult to sustain lean initiatives. Several process-related barriers can hinder the sustainability of lean initiatives; few are listed below.

1. **Lack of Standardization:** Lean initiatives often rely on the standardization of processes to reduce waste and improve efficiency. Without proper standardization, it can be difficult to sustain lean initiatives (Zargun, S., & Al-Ashaab, A.2014).

2. **Complex Processes:** overly complex processes can hinder sustainability as they may be difficult to comprehend and improve (Jamwal et al., 2019).

3. **Poorly Defined Processes:** when processes lack clear definitions, identifying areas for improvement and maintaining lean initiatives becomes challenging (Benkarim & Imbeau, 2021).

4. **Lack of Process Visibility:** Lean initiatives often depend on the visibility of processes to spot improvement opportunities. Without sufficient visibility, sustaining these efforts can be difficult (Maware & Parsley, 2022).

5. **Limited Process Control:** Effective lean practices typically require tight control over processes to identify and eliminate waste. Insufficient process control can construct the sustainability of these initiatives.

Resource-Related Challenges

Achanga (2007) noted that employee training programs and external consultants often demand financial resources. Another challenge is organizational financial constraints, particularly training costs, which have been identified as a significant barrier to lean implementation and execution.

1. **Limited Budget:** Lean initiatives often involve investing in new equipment, training, and other resources. Without an adequate budget, sustaining these initiatives can be challenging (Siegel et al., 2022).

2. **Lack of Available Resources:** Successful lean initiatives typically require access to specific resources, such as a skilled worker or specialized equipment. Without these resources, sustaining lean practices can be difficult (Qureshi et al., 2022).

3. **Poor Resource Allocation:** Ineffective distribution of resources can make it challenging to maintain lean initiatives (Abd Samad & Othman, 2022).

4. **Limited Capacity:** If any organization is not able to cope with the increased demands of lean practices can lead to a challenge to sustainability (Orisaremi et al., 2022).

5. **Resource Constraints:** Restrictions on the availability of essential resources, such as raw materials or energy, can also pose a big challenge to sustainability (Abd Samad & Othman, 2022).

Conceptual Framework of Research

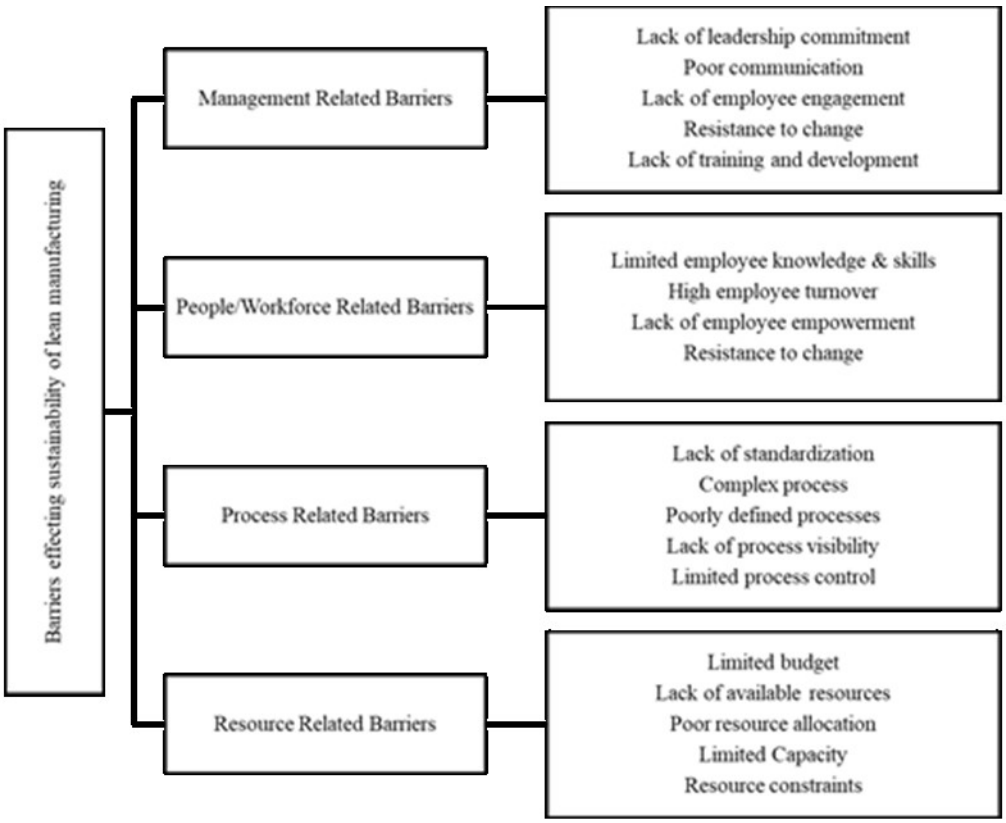

Figure 1**:** Research Framework

Hypotheses

Given the significance of the management, workforce, process, and resource-related issues in sustaining lean culture, the research hypothesis is

H_{a1} Management-related barriers significantly impact the sustainability of lean.

H_{a2} People-related barriers significantly impact the sustainability of lean.

H_{a3} Process-related barriers significantly impact the sustainability of lean.

H_{a4} Resource-related barriers significantly impact the sustainability of lean.

Material and Methods

To conduct this study survey approach was employed to acquire data. The most efficient approach to acquiring and analysing data is through surveys. For the study, a sample of over fifty automotive manufacturing companies in Karachi, comprising both original equipment manufacturers and auto parts manufacturers, were selected. Surveys in the form of Google Forms were then sent to the senior management of these companies. The research survey which was applied in the study, mainly used earlier research literature to construct the findings. Its intention was to assess organizational, technological, and human barriers which constrain the practice of Lean sustainability in the manufacturing sector. It is the appreciation of Imane Elboujdaini, Noureddine Zeraoulia, and Ahmed Bouchikhi (2018), which grants businesses with a helpful approach to identifying and ranking potential barriers to implementing Lean sustainability in their organizations.

The questionnaire was based on a Likert scale with 5 as strongly agree and 1 as strongly disagree. The questionnaire was based on three parts, the first part inquired about the respondent's age, designation, years of experience, and size, type, and age of the organizations they are working for. The second part comprises questions about the level of awareness and implementation and sustainability status of lean methodology.

The last part consists of barriers to sustaining lean, these four critical factors were selected after a detailed literature review. The goal of this study was to analyze the influence of these factors on the sustainability of lean culture in their organization from the perspective of management in terms of relevance, and then compare their responses to real practices in their particular sectors. There were 5 items for measuring management-related issues, 4 people or workforce-related barriers, 5 items for process-related barriers, and 5 items for resource-related barriers. The independent variable barriers impacting the sustainability of lean has 15 items.

The data collected was analyzed using the Statistical Package for Social Sciences (SPSS). Descriptive statistics were calculated to determine the demographic information of the participants, including the number of respondents, their ages, years of experience, and the age of the organization they are currently working for. The reliability of the data-gathering instrument was verified by assessing its internal consistency through pilot testing and final testing. Additionally, an ANOVA test was performed to test the research hypotheses. The reliability of the data-gathering instrument was assessed by conducting tests on its major segments using SPSS 22.0 as shown in Table 1. It is considered acceptable when the Cronbach's alpha is above or equal to 0.7. The face and content

validity of the questionnaire were determined by industry and academic experts knowledgeable about lean concepts.

Table 2
Reliability Analysis

	Items	Cronbach's alpha
Lean Barriers	24	0.872
Lean Sustainability	15	0.834

This table shows the results of various tests for the reliability and validity of the lean sustainability questionnaire. The Cronbach's alpha coefficient indicates that the questionnaire has good internal consistency, with a value of 0.78.

Results and Discussions

Figure 2 displays the demographics of respondents and their respective organizations. The figure shows the background information of 150 respondents, including their age, years of experience, education and the department they are currently working in. Figure 3 displays the size, type, and age of the respondent's organization. According to Singh, M., & Rathi, R. (2022). A small, medium, and large organization defines the size of the company or business based on its employee strength, annual revenue, or assets. Small organizations typically employ less than 50 workers and make less revenue as compared to medium and big organizations. Medium-sized organizations have about 50 to 499 employees and earn moderate revenue as compared to small and big organizations. Big organizations have 500 or more employees and earn more revenue compared to small and medium organizations. This information provides a context for understanding the respondents and the data they have provided.

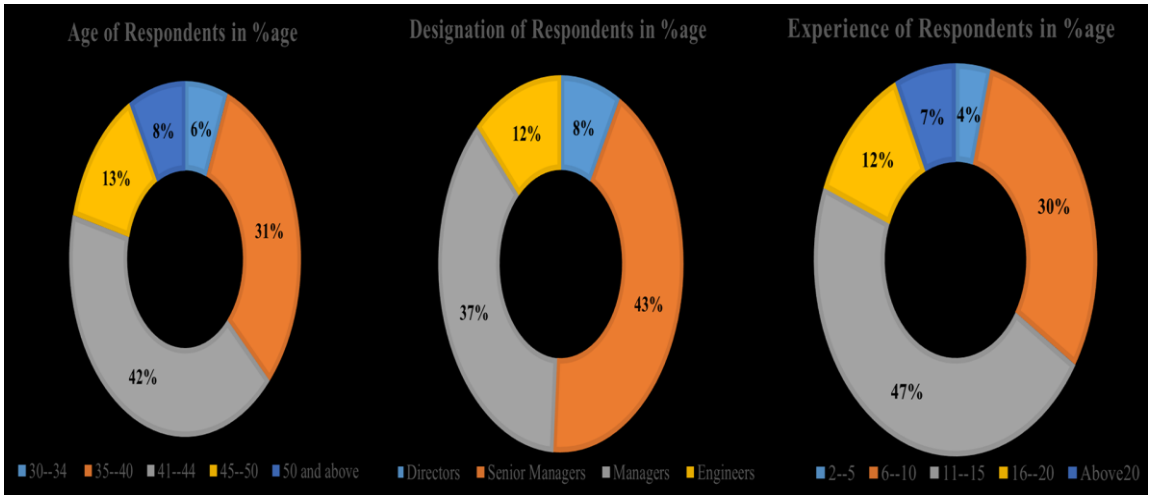

Figure 2: Respondents Profile

More than 10 years of experience was had by most respondents (47%), as presented in Figure 2. Most respondents (43.1%) worked as senior managers, which were selected for the study since those individuals had first-hand knowledge and experiences in the implementation of lean manufacturing programs in their companies and directly involved in the process.

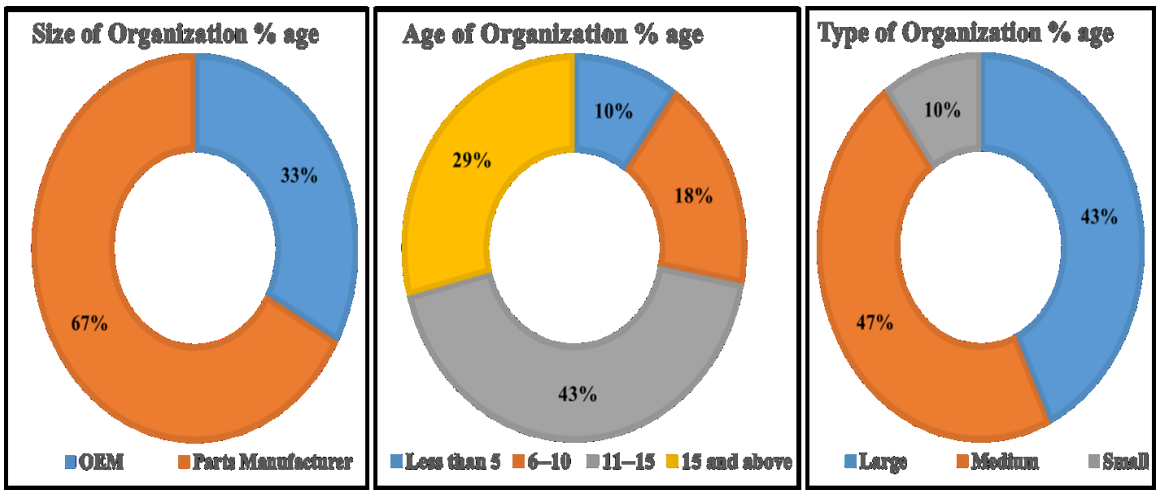

Figure 3: Respondents Organizations Profile

The study further examined the background of the respondent's organizations. Factors such as the types of organization, age of organization, and size of organizations were involved in the investigation. The finding shows that (67%) of respondent's organizations were OEM (Original Equipment Manufacturers) whereas (33%) were auto parts manufacturers. The majority of the respondent's companies (47%) were large organizations. (Where (43%) of organizations were established more than ten years ago and (29%) of organizations have more than fifteen years of experience.

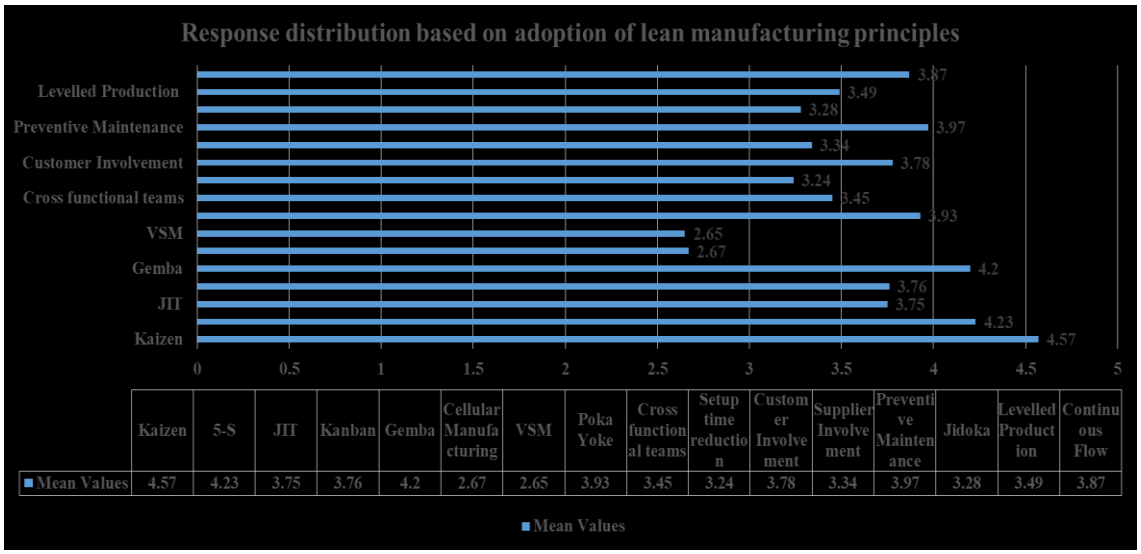

Figure 4: Application of Lean Manufacturing Tools in Respondents' Organization

The survey respondents, therefore, had to rate the present state of manufacturing practices and their implementation of lean practices in order to assess the extent of lean practice adoption in the automotive sector. Assessment results are shown in Figure 4, which gives average adoption scores of each practice. The frequency distribution of responses shows the proportion of respondents who have adopted one or more lean manufacturing practices into their processing. With this information one can get to know how popular or common is the various lean practices among a certain group or industry. The mean values in this table suggest that the most highly rated lean tools are Kaizen, 5-S, Gemba, and Poka Yoke, which all have mean values above 3.75. These tools are generally perceived as being effective and useful for optimizing and streamlining

processes. The tools with the lowest mean values, such as Cellular Manufacturing, VSM, and Jidoka, have an average usage rating below 3.28, indicating that they may not be as widely used as other lean tools.

Correlation Analysis

Correlation analysis was performed to analyze the correlation between management-related, people-related, process-related, and resources-related barriers to understand how they are related to each other.

Table 3
Correlation

	Management-related barriers	People-related barriers	Process-related barriers	Resources-related barriers
Management-related barriers	1.00	0.54	0.67	0.78
People-related barriers	0.54	1.00	0.45	0.56
Process-related barriers	0.67	0.45	1.00	0.34
Resources-related barriers	0.78	0.56	0.34	1.00

That means a variable holds a perfect correlation with itself (hence the diagonal elements which start from the main diagonal from the top left to the bottom right will read as 1.00). The off-diagonal positions will indicate the different correlations between the barriers. A value of 1.00 shows a positive perfect correlation, while a value of -1.00 shows negative perfect correlation, and a value of 0.00 indicates no correlation at all. In this sample matrix, we can see that management-related barriers have a moderate positive correlation with people-related barriers (0.54), and a moderate positive correlation between management-related barriers and process-related barriers (0.67). Among all types, management- and resource-related barriers are said to be strongly related to one another (0.78). This suggests that the management barriers in place are very much likely to be associated with the other types of barriers.

Regression Analysis

Multiple regression analysis examines the effect of four barriers (management-related barriers, people-related barriers, process-related barriers, and resources-related barriers) on the sustainability of lean manufacturing.

Model summary

R-squared: 0.70

Adjusted R-squared: 0.68

ANOVA Results:

F-statistic: 9.12

P-value: 0.000

There is a statistically significant difference among the means of the groups that are being compared according to ANOVA results. An F-statistic of 9.12 is used for testing the null hypothesis which states that means of all groups are equal. Since the P-value of

0.000 is less than the common significance level of 0.05, we reject the null hypothesis assuming less than 0.05 probability that results would be by chance alone. Hence, the means of the groups are statistically significantly different from each other.

Table 4
Investigate the Relationship

Variable	Coefficient	Standard Error	p-value
Management related barriers	-0.45	0.05	0.000
People related barriers	-0.32	0.03	0.001
Process related barriers	-0.23	0.07	0.00
Resources related barriers	-0.15	0.06	0.000
Management related barriers	-0.45	0.05	0.000

This table shows the relationship between the various barriers and the sustainability of lean manufacturing, as measured by the dependent variable. The coefficient represents the strength of the relationship, with a negative coefficient indicating a negative effect on sustainability. The p-value indicates the statistical significance of the relationship, with a p-value less than 0.05 indicating a statistically significant relationship. Table 5 reveals the overall status of all variables in terms of their acceptance and rejection.

Table 5
Acceptance and Rejection

No.	Hypotheses	Sig value	Status
$\mathbf{H_{a1}}$	Management Barriers have a significant impact on Lean Sustainability	.000	Accepted
$\mathbf{H_{a2}}$	People Related Barriers have a significant impact on Lean Sustainability	.001	Accepted
$\mathbf{H_{a3}}$	Process Barriers have a significant impact on Lean Sustainability	.000	Accepted
$\mathbf{H_{a4}}$	Resource Barriers have a significant impact on Lean Sustainability	.000	Accepted

Table 5 shows the results of four hypotheses tests that were conducted to investigate the relationship between different types of barriers and lean sustainability. All four hypotheses, H_{a1}, H_{a2}, H_{a3}, and H_{a4}, suggest that each type of barrier (Management, People, Process, and Resource related) has a significant impact on Lean Sustainability. The significance values (Sig value) of all four hypotheses are less than 0.05 (0.000, 0.001, 0.000, and 0.000 respectively), which means that the probability of obtaining these results by chance is less than 0.05. Therefore, all four hypotheses are accepted and it can be concluded that there is a statistically significant relationship between each type of barrier and Lean Sustainability.

Discussion

Sustainable Lean Manufacturing attempts to increase efficiency by adequately locating previously unused workforce and resources for innovation and quality control. As a result, academicians and experts have indicated this technique as a business modelling approach that requires quick attention. However, to take long-term advantages of this technique automotive industry needs to gear up with full enthusiasm to focus on the analysis of the factors that are affecting the sustainable lean manufacturing culture. After a systematic literature review, five main barriers have been identified. These include factors related to Management, People, Processes, and Resources. Statistical methods are used to see the correlation between these factors and also analyse the impact of these factors in the case of Pakistani automotive industries.

The sample correlation and regression analysis presented above suggest that management-related barriers have a strong negative effect on the sustainability of lean manufacturing. This aligns with the notion that strong leadership and management support are essential for the success of lean initiatives. Without management backing, employees may resist change and fail to fully engage in lean activities, which can undermine sustainability. The finding that workforce-related barriers negatively impact sustainability is expected, as lean sustainability depends on active employee participation and engagement. Resistance to change and limited employee involvement can hinder the implementation of lean practices and reduce their sustainability.

It is somewhat surprising that process-related and resource-related barriers have a weaker effect on sustainability, as these factors are typically seen as key enablers of lean practices. Additional research is needed to understand why these barriers have a lesser impact and to develop strategies addressing them. All in all, these findings underscore the importance of tackling management-related barriers to enhance the sustainability of lean manufacturing. Organizations should also consider the interrelated nature of the various barriers and take a holistic approach to addressing them. Future research should aim to confirm these findings and explore other factors that may impact the sustainability of lean manufacturing.

Conclusion

The research studies are identifying and prioritizing Lean issues in manufacturing organizations and focusing more on the important issues to solve them with appropriate solutions in order to maintain culture and take full benefit of lean manufacturing. In this study through an extensive literature search and professional advice, 24 barriers to sustaining lean manufacturing practices were identified which were further classified under four primary categories of issues i.e. management, people, process, and resource challenges. They conducted a correlation analysis to check against these barriers, while regression was done to see the actual impact of these barriers onto the sustainability of LM culture. Sample correlation and regression analyses reiterated the negative impact management-related barriers have on the sustainability of lean manufacturing even more strongly. Management-related barriers demonstrated relatively strong correlations with the other categories of barriers: people-related, process-related, and resources-related, indicating that all these barriers are highly related. From regression analysis, it is seen that management-related barriers have the most adverse impact on the sustainability of lean manufacturing, followed by workforce-related and process-related barriers. Resource-related barriers had the least impact, although the relationship remained statistically significant.

These results strongly encourage a management-focused approach to breaking down what barriers are likely the most successful paths toward their sustained awesome improvement in lean manufacturing. It may also be worthwhile to consider barrier interrelationships and adopt a holistic approach. Further studies are, however, needed to test this finding and discover any additional influences on the sustainability of lean manufacturing. Lean culture will definitely prove to be a challenge within an organization, as it involves altering attitudes and behaviour at all levels within the organization to some extent. While lean manufacturing practices can improve efficiency and reduce waste, embedding a lean culture demands ongoing effort and commitment from leadership and employees alike. It requires continuously finding and eliminating waste, continuously improving, and encouraging staff to take ownership of their jobs and identify improvements. Training and development must be very strong in an

organization so that employees have those necessary skills and knowledge to support the lean culture. By keeping faith with, and reinforcing, the definitions of lean thinking, organizations tend to psychological conditioning toward establishing and progressively nurturing a really successful lean culture.

Recommendation

To ensure the long-term sustainability of Lean manufacturing (LM), organizations must address the challenges related to management, workforce, process and resources. Top management must actively support Lean initiatives by providing clear directions, allocating resources and fostering a culture of continuous improvement. Leadership training programs should be implemented to enhance managers understanding of Lean principles and their role in sustaining these practices. Organisations must also invest in regular training and development program to build Lean competencies and ensured employees are well trained in its principles. In addition the mechanism of follow ups and performance tracking is also essential to achieve the desired results. Employee involvement in decision making process can also enhance motivation and commitment to Lean Practices. In order to deal with limited financial and human resources organisations should adopt a phased approach to lean implementation. Prioritising high impact area first. Following these proposed recommendations organizations can enhance the sustainability of Lean Manufacturing practices ensuring long term operational efficiency, cost reduction and continuous process improvements.

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