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The Relationship between Lean Management Practices and Environmental Performance among Manufacturing Companies in Selangor

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Abstract

This research paper discussed the relationship between lean management and environmental performance in manufacturing companies in Selangor, where environmental performance is a significant factor in contributing to sustainable manufacturing by enhancing energy efficiency, waste, and regulatory compliance. Lean dimensions like Just-in-Time (JIT), Total Productive Maintenance (TPM), Kaizen, and waste management are generally considered to have the ability to increase the efficiency of resources and improve environmental impact, but research that combines lean management and environmental sustainability is still limited in developing nations. A quantitative research design was utilized to collect data via a structured questionnaire on 377 manufacturing companies in Selangor and analyzed using descriptive and correlation analysis. According to the findings, lean management practices and environmental performance is highly implemented, especially in waste minimization, continuous improvement, energy efficiency, and environmental regulations, owing to the difficulties being presented by high implementation cost due to the use of early-stage technologies and their low implementation rates within the local manufacturing industry. Nonetheless, correlation analysis indicated that lean management practices had a weak and statistically insignificant correlation with the environmental performance ($p = 0.720$), making it clear that lean management practices do not necessarily lead to better environmental performance unless they are explicitly combined with environmental management practices. In general, the paper underscores the need to embrace integrated lean-green processes to contribute to sustainable manufacturing growth in Selangor and Malaysia.

1. Introduction

In several decades, companies needed to alter their production mode since the population became more environmentally-oriented. Lean management was originally aimed at increasing productivity in the workplace, however, it is currently viewed as a method of financial prosperity as well as environmental safety. Just-in-Time (JIT) and Total Productive Maintenance (TPM) are lean management strategies that help in minimizing waste, enhancing productivity, and environmental protection (llcadmin, 2024). Research indicates that the practice of

JIT and TPM can assist companies to use less, use less energy and decrease emissions and this is especially true in Southeast Asian companies (Ferrazzi *et al*., 2025). The adoption of lean methods provides a good basis for sustainability in production. Lean supply practices in Malaysia assisted the manufacturers in adapting to changes in demand, as well as mitigating adverse effects on the environment, which led to improved environmental performance. In this paper, the review of the application of lean methods by manufacturing companies in Selangor and their effects on the environment will enable companies and leaders to learn more about how environmental protection efforts can be achieved by the lean improvement strategies.

To ensure environmental performance optimization remains a top priority, manufacturing companies today must meet sustainability objectives as well as regulatory demands. Environmental performance is monitored with the help of Key Performance Indicators that include energy efficiency, waste reduction, and emission control to help make sound decisions (Papamichael, 2023). Formal measurement systems assist manufacturers to enhance operational effectiveness, minimize long-term expenses, and reinforce market positioning, and assist in sustainability and compliance objectives. Nonetheless, manufacturers, particularly SMEs, find it hard to handle the expectations of the environment and practice the main lean practices because of the low leadership commitment, limited resources, poor communication, and absence of plans or enforcement of green activities. The desire to meet the speed and cost requirements of the market only increases the difficulty in companies adhering to environmental rules, and consequently, they lag in environmental performance objectives (Gatell & Avella, 2024).

Although conventional lean management is about productivity and reduction of wastes, researches indicate that some of the lean practices, like Just-in-Time and Total Productive Maintenance, have the potential to enhance the performance of the environment without requiring green activities to be in place (Sadiq, 2023). However, the studies of combining lean management and environmental sustainability are not common in developing countries. This study addresses a research gap in Selangor that is faced by a lack of empirical evidence in Malaysia, which is extremely low in research (Cadden, 2021; Debnath, 2022). In general, lean management facilitates the idea of environmental sustainability by cutting waste and enhancing efficiency, yet obstacles confronting the idea of green business, like market pressure, leadership complications, and management of change, constrain further developments, particularly in the case of SMEs. Regular monitoring of environmental indicators and the introduction of structured decision-making models can assist manufacturers to enhance the environmental and operational performance. To become sustainable and efficient at the same time, it is important to integrate lean management with green strategies and effective leadership (Abdullah *et al*., 2023; Kosasih *et al*., 2023).

The research objective of this study is to examine the level of lean management practices and the level of environmental performance among manufacturing companies in Selangor, as well as to measure the relationship between lean management practices and environmental performance among these companies.

2. Literature Review

2.1 Lean Management Practices

Lean management practices entail enhancing customer satisfaction, eradicating non-value-adding spending, and the overall focus is on a continuous improvement in the operations, whereby non-value activities are eliminated. The Toyota Production System gave birth to the concept of lean, which has been implemented in healthcare, manufacturing, and construction, and has been perceived as a collection of tools and a shift in values that prioritize efficiency and teamwork. Some of the key lean tools are waste management, continuous improvement (Kaizen), value stream mapping (VSM), 5S, Just-in-Time, Kanban, and quality circles, which deal with overstocking, repetitive processes, working environment safety, and engagement of employees. Practical experience demonstrates the fact that lean practices enhance speed, cost reduction, productivity, and quality, and enable faster reaction to demand fluctuations with minimum errors. Moreover, lean activities eliminate energy wastage, scrap, and better utilization of resources, proving that lean management positively influences business and environmental responsibility, particularly in rapidly growing economies.

2.1.1 Just in time (JIT)

Just-In-Time (JIT) is one of the principles of lean management where the production scale is set in accordance with the real-time demands of the customers so that the manufacturer would produce the goods at the right quantity and at the right time, and this aspect minimizes the cost of the expendable products and elevates responsiveness toward market fluctuations (Abdullah *et al*., 2025). The JIT needs good relationships with its suppliers and real-time data systems that are reliable enough to avoid breaks in production. It also improves the efficiency of the processes and stimulates process improvements by highlighting inefficiencies more accurately (Lee, 2025). But the system is very vulnerable to breaks in the supply chain, and in order to achieve success, it will require investment in flexible systems, contingency planning, and supplier development.

2.1.2 Kaizen

Kaizen or continuous improvement is one of the fundamental lean philosophies whereby small and insignificant improvements are made in a bid to make processes more efficient, minimize wastages, and improve quality (Croft, 2025). It facilitates the involvement of different levels of the organization and introduces the daily process enhancement via the schemes of suggestions and teamwork. This engagement helps to build morale, as well as a sense of ownership and flexibility. The companies that implement Kaizen usually have more innovation, better teamwork, and enhanced attachment to quality (Lean Manufacturing: Principles, Tools & Techniques, 2025).

2.1.3 5S (Sort, Set in Order, Shine, Standardize, Sustain)

5S is an organized lean practice that enhances organization and efficiency in the workplace, and it is structured in five steps Sort, Set in Order, Shine, Standardize, and Sustain (Xuan *et al*., 2025). It de-clutters, helps tools to be in order, helps to keep it clean, and standardizes the processes. They maximize the possibilities to eliminate downtimes, accidents, and ensure the same quality (Lean Production, 2024). As a part of company culture where 5S can be learned and routinely audited, it increases employee morale, aids safety, and can be the basis of greater lean efforts.

2.1.4 Total Productive Maintenance (TPM)

Another lean approach that engages the entire workforce is Total Productive Maintenance (TPM). This is the process of maintaining equipment, preventing machines failures, and guaranteeing an optimum performance of equipment (Lee, 2025). TPM involves both corrective and preventive measures, which include self-inspection as well as systematic training and have the effect of prolonging equipment Mid-Systems and lowering expenses (View of Total Productive Maintenance and Industrial Applications, 2025). It promotes a spirit of constant and consistent upgrade and process trustworthiness. The predictive analytics and real-time monitoring enhancements have allowed TPM to benefit the manufacturers by improving their efficiency and long-term competitiveness.

2.1.5 Value Stream Mapping (VSM)

Value Stream Mapping (VSM) is another significant lean management tool that is commonly used in the production to visualize and design the flow of information and materials in the manufacturing process (Lean Enterprise Institute, 2024). VSM also engages all processes involved in the production of raw materials to finished products, allowing manufacturers to determine the bottlenecks, redundancy, and waste, and increase efficiency. It is usually undertaken by cross-functional teams, which observe the existing processes, and evaluate some key metrics, which include cycle time, lead time, and inventory levels (Ariff *et al*., 2025). With this analysis, the organizations will be able to see where there is inefficiency and make specific improvements. Another benefit of VSM is that it promotes the teamwork in the creation of future-state processes that are consistent with the principles of lean, which often leads to shorter lead times, decreased inventory, and the flow of work. Moreover, VSM facilitates other lean deployment programs like Kaizen and Just-in-Time (JIT), and its constant renewal enables organizations to be dynamic to the dynamic customer requirements and market conditions (Ariff *et al*., 2025).

2.2 Environmental Practices

In recent years, lean management has enabled manufacturing firms to attain sustainability targets and enhance efficiency. Lean practices, which were initially aimed at producing more and less waste, also contribute to environmental efforts. According to Ferrazzi *et al*. (2025), there are some practices of lean management, such as employee engagement and Total Productive Maintenance (TPM), which result in improved environmental outcomes, such as cleaner production systems that use less input and produce less waste. Environmental performance is quantified by decreases in resource consumption and waste generation, and such practices as Continuous Improvement, Root Cause Analysis, and Total Quality Management also result in less waste, in particular in cases when the managers are devoted to soft practices that contribute to the effectiveness of technical means. The overall lean initiatives applied by firms can hence significantly enhance sustainability, especially in the industrial sector in Selangor. Also, it is emphasized by Yang *et al*. (2024) that the environmental performance depends on more general factors, including green innovation and compliance with regulations, and green technology innovation (GTI) promotes the improvement of the ESG performance due to better internal operations and favorable responses on the market. The integration of lean management and green technologies and compliance with environmental programs could enable the manufacturers of Selangor to achieve the maximum possible sustainability.

2.2.1 Environmental Management System (EMS)

The Environmental Management Systems (EMS) give a systematic way for manufacturing organizations to manage in an organized way to enhance their environmental performance. The most widespread standard in use is the ISO 14001, which targets firms to recognize the influence on the environment, establish performance targets as well as tracking development (Muktiono *et al*., 2022). The rapid rise of adoption of EMS in manufacturing industries can be attributed to the growing calls of regulatory bodies and interested stakeholders; the benefits being reported as including lessened resource consumption, greater compliance, and reputation. Another major aspect of EMS is lifecycle thinking or evaluation of the environmental cost at the extraction of raw materials, all the way up to disposal of products, which in turn prompts the manufacturer to reduce waste and emissions within the supply chain (Renaud Anjoran, 2020). Green manufacturing strategies that are resource efficient, pollution prevention strategies, and clean technologies can also be carried out with the help of EMS. The adoption of EMS is growing with the government and industry initiatives, like the sharing of best practices and joint research. It may, however not be effective due to ineffective planning and individualization to particular manufacturing processes.

2.2.2 Environmental Performance Indicators (EPIs)

Environmental Performance Indicators (EPIs) are objective measures taken by the manufacturer to quantify the impact they have on the environment and manage it, and in most cases, they monitor energy and water consumption, levels of greenhouse emissions, waste volumes, and the percentage of recycled materials (Wendling *et al*., 2022). The use of EPIs has been increasing since 2020 through 2025, boosted by digital monitoring systems of data accuracy and efficiency. As an example, the tire industry employs annual KPIs that help it track the main sustainability indicators, indicating steady progress and focus on the environmental agenda (WBCSD, 2021). When EPIs are integrated with Environmental Management Systems, the manufacturers know where to focus efforts to improve so as to meet the needs of the stakeholders and regulations. Amid the barriers presented by the COVID-19 pandemic, the manufacturers have not ceased to invest in renewable energy sources, process optimization, and superior technologies to uphold sustainability and productivity (2025 Manufacturing Industry Outlook, 2024).

2.2.3 Ecological and Carbon Footprint

Ecological and carbon footprints are significant environmental measures of a manufacturing function, but the carbon footprint of both a given manufacturing and the chain of energy supply and use are taken into account. In 2020, 23% of all greenhouse gas emissions were emitted by the industrial sector in the U.S context, proving the necessity to decarbonize manufacturing (EPA, 2025). In the years that have followed, increased use of renewable energy sources, energy efficiency, material optimization, and the principles adhered to in the circular economy have been adopted by the manufacturers to minimize their carbon footprints (Business Wire, 2020). Such initiatives not only help the environment but are more financially rewarding and competitive in the market. Consumer and regulatory pressure have led to the emergence of a better future and emission reduction planning though an implementation of tools that manage carbon. Nevertheless, despite the obstacles associated with its implementation, including significant initial investment costs, regulatory risks, and others, carbon footprint reduction becomes an important long-term strategy which can provide the following benefits: cost reductions, a positive brand image, and even access to new markets (Shaw, 2024).

2.2.4 Total Quality Management (TQM)

Total Quality Management (TQM) is an integrated strategy more sensitive on continuous improvement, customer satisfaction and integration of quality in all manufacturing processes affecting the management. Over the last few years, TQM has been changing by adding green concerns to its agenda, where quality targets become the same as those of sustainability (Rashid *et al*., 2025). This combination favors the use of green supply chain management and improves environmental performance. According to a 2020 to 2025 survey, there is a positive effect of integrating TQM with Just-In-Time (JIT) and green supply chain activities to enable manufacturers to minimize wastage, fumes, and usage of harmful materials without lowering the quality of products (Rashid *et al*., 2025). Such countries as China are orienting their TQM with the regards to environmental management systems worldwide to promote Sustainable Development Goals and carbon neutrality promises. TQM need a powerful management, active workforce and continuous training to be well implemented so that the manufacturer can become excellent in its operational and environmental results.

2.2.5 Reduce Waste

A major and important pillar of sustainable manufacturing is reduction of waste that also plays a large role in enhancing environmental performance. Between 2020 and 2025, manufacturers have come a long way in achieving this with optimization of processes, the involvement of the principles of circular economy, and reduction in waste prevention as opposed to end-of-pipe behaviors (US EPA, 2018). A small percentage of manufacturing

waste released to the environment in 2022 in the U.S. equated to 5 percent, with most being recycled, treated, or used to produce energy facilitated by pollution prevention practices like equipment and process improvement (US EPA, 2018). A case in point, the European Union also had some of the ambitious goals, such as over 55 percent of municipal waste and 65 percent of packaging waste being recycled by 2025, including the waste-to-energy strategy (Environmental Impacts of Waste Management Strategies Case Studies Compilation, n.d.). This is not only useful in so far as it helps in the conservation of the environment but it also ensures better efficiency and profitability in the manufacturing process by ensuring a circular.

2.3 Previous studies

In the past, researchers indicate that lean management enhances sustainability performance among manufacturing companies. In a Selangor research, lean practices, including process and equipment optimization and customer relationship management, have a positive effect on economic, environmental, and social performance, and their impact on such aspects of lean practices as manufacturing planning, human resource, and supplier relations are less notable (Xiang *et al*., 2021). An analysis of 29 case studies (2001-2022) also found out that lean manufacturing positively affects the environmental performance by reducing waste and emissions, particularly in situations where the organization commitment is high (Santos *et al*., 2024). Equally, a 377 manufacturers study in Malaysia indicated that lean supply chain approaches, such as suppliers integration, just-in-time production, waste management, and inventory control lead to environmental performance through less emission, energy consumption, and material wastes (Sustainable Social Development, 2023).

Evidence itself is even more recent, and it has proven that lean practices lead to minimization of waste, consumption of resources and carbon emission by making processes simpler (Diiste *et al*., 2019). The 5S and other approaches used in the Southeast to boost workplace safety, employee involvement, and continuous environmental improvement (Koh *et al*., 2025). By combining sustainability efforts with lean, the companies will experience more waste reduction, adherence to other standards including ISO 14001 and the SDGs, and operational and environmental advantages.

2.4 Underpinning Theory

The contribution of lean management towards overall sustainability is evaluated using the Triple Bottom Line (TBL). Researchers at Selangor have discovered that process and equipment design enhance waste reduction and efficiency of resources, which has a positive impact on TBL performance. According to Xiang *et al*. (2021), companies minimized their environmental impact by improving their operations and the maintenance of equipment, which aids in sustaining the business. Based on the views of Resource-Based View (RBV) and Natural Resource-Based View (NRBV), lean activities like supplier partnership and development of employee skills empower the market advantage as well as the environmental performance. Regulatory compliance and long-term sustainability can also be achieved with the help of a balanced lean and environmental approach (Chiet *et al*., 2019).

Also, Institutional theory affirms that companies implement lean to fulfill the demands of the society and regulation, and the companies that have become lean-certified are more environmentally compliant in Selangor. The contingency theory emphasizes that the environment has positive benefits according to the size and technology of the firm and SMEs have captured significant gains in waste and use of resources. In general, lean management can be used to enhance environmental performance in terms of its contextual application with the support of TBL, RBV/NRBV, institutional, and contingency theories.

2.5 Research framework

Fig. 1 below presents information on how lean management practices affect the environmental performance of manufacturing companies in Selangor. According to the framework, following lean management practices will enable factories to improve resource efficiency, cut waste and emissions, and become greener. Simply put, lean approaches should affect firms' performance in terms of ecological responsibility and compliance with laws.

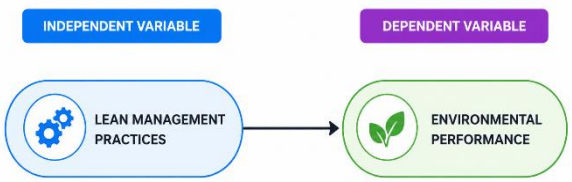

Fig.1 *Research Framework*

3. Research Methodology

3.1 Research Design

The design of the research should remain adjustable so that any unpredictable changes during the project won't weaken the research results. A quantitative approach was used in this study to examined the relationship between lean management practices and environmental performance among manufacturing companies in Selangor. According to Hrgarek & Zlatolas, (2025), in quantitative research, the influenced of independent factors on the dependent variable were investigated by adjusting the factors. The questionnaire has been distributed to a group of manufacturer companies in Selangor, Malaysia. Furthermore, using various statistical analyses helped ensured that the findings in this study were reliable and valid. Therefore, the researchers used the software Statistical Package for the Social Sciences (SPSS) for analysing the data that was collected. Through the above investigations, it was concluded that the relationship between lean management practices and environmental performance among manufactories contribute to better green management in Selangor, Malaysia.

3.2 Research Population and Sample

The population in research can be explained as the overall number of individuals or objects that satisfy a set of criteria that applied to a specific study. It is the wider frame of understanding research results and was usually characterized by certain similarities within a specified parameter (Revutskaya *et al*., 2025). The proposed study has been related to the manufacturing firms in Selangor which is an industrial hub in Malaysia famous because of its strategic location, a skilled workforce and advanced infrastructure (Invest Selangor, 2023). According to official communication issued by the Malaysian government portal, Selangor boasts of about 19,062 manufacturing firms (Personal Communication, June 3, 2025). Such businesses include SMEs and bigger corporations, which provide a wide outlook on how lean management practices are employed in the state.

Sampling was one of the fundamental research methods that helped to pick a particular subgroup within a bigger population to gather data economically and conveniently (Gao *et al*., 2025). Two major types exist which include probability (random) and non-probability (non-random) sampling. In this study, the non-random sampling strategy is used, and it is a purposive sample when the targets of the participants are chosen depending on their connection to research content (Ahmed, 2024). Purposive sampling helped the investigators to collected valid information that is meaningful among the people who are distinctively familiar with lean management and environmental performance (Ahmad & Wilkins, 2024). In the given research, a group of 377 respondents was selected, and the results of the research could be used to reason about lean practices in the manufacturing industry of Selangor.

3.3 Data Collection

Data collection methods were crucial in research as they helped gathered information to address research questions (Maji *et al*., 2025). This study used specific tools and methods to collected data on the relationship between lean management and environmental performance in Selangor's manufacturing companies. By employing multiple data collection methods, the researcher was able to validate findings and gain a deeper understanding of the topic.

Primary data was collected directly by the researcher through surveys, chosen as the best method to assess how well lean management is practiced and environmental standards were met in Selangor's manufacturing sector. Secondary data came from existing sources like journal articles, books, reports, and reliable online sites, which helped to explain lean management, environmental performance, and key manufacturing frameworks. Only the most credible and relevant information from previous studies was included.

3.4 Pilot Study

A pilot test has been run so that the research can go on without issues. It helps determine if the data collection tools, especially on the questionnaire, are accurate enough. The questions asked are straightforward, relevant, and good for companies following lean management practices in manufacturing. The pilot test was designed to identify and solved any misunderstandings regarding principles of lean, environmental results, or industry-related terms. It also helped assess how useful and efficient the chosen sample is. A pilot test is an important step to ensure accuracy, make the data collection process efficient, and remove any barriers before working on a larger scale.

3.5 Research Instruments

When we use a device to gather, measure and analyze data about a certain subject, it is considered a research instrument. Some research tools include tests, questionnaires and checklists (Gupta *et al*., 2025). The instrument of study involved using a questionnaire developed through Google e-Forms, divided into Sections A, B, and C to gather data from 377 manufacturing employees in Selangor. Section A collected demographic and company information using nominal and ordinal scales, while Sections B and C measured lean management practices and

environmental performance, respectively, using a five-point Likert scale. The Likert scale was chosen for its simplicity and efficiency in capturing agreement levels. SPSS software was used to analyse the collected data. To ensure the study's accuracy and consistency, the validity and reliability of the instrument were emphasized. Validity refers to how well the tool measures what it is intended to measure, while reliability indicates the consistency of the results when used repeatedly. The study followed established principles to ensure that the questionnaire provided credible and dependable findings, minimizing errors and enhancing the trustworthiness of the research outcomes.

The questionnaire has three sections, which are Part A, which consists of the demographic information, Part B, which consists of the lean management practices, and Part C, which consists of the environmental performance as presented in Table 1.

Table 1 F*ive points Likert scale*

Scale	Interpretation
1	Strongly Disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly Agree

3.6 Data Analysis

The data analysis section describes how statistical methods were used to explore the relationship between lean management and environmental performance in Selangor's manufacturing sector (Kopalle *et al*., 2025). Four main techniques were applied which is descriptive, reliability, normality, and correlation analysis. Descriptive analysis provided a summary of lean and environmental data using measures like mean, median, mode, standard deviation, and range. Visual tools such as histograms, box plots, and scatter plots were used to spot trends and outliers, offering a clear view of how lean practices and environmental performance vary across companies.

Reliability analysis focused on internal consistency using Cronbach's alpha, a method that determines how closely related items on a questionnaire are. High Cronbach's alpha values ensured that the measurement tools used were trustworthy and consistent across different companies. Normality analysis was also conducted to check if the data followed a normal distribution. Transformations like logarithmic or square root methods were applied when necessary. Outliers were identified using box plots and histograms to avoid skewing results, ensuring that statistical assumptions were met for accurate analysis.

Correlation analysis examined the strength and direction of relationships between lean practices and environmental performance. Pearson's correlation should be applied with normally distributed data, and Spearman's rank correlation is suitable for data that is simply ranked. Apart from them, some researchers rely on partial correlation to fix errors and use structural equation modeling to reveal the process of energy savings and pollution reduction thanks to 5S and Kaizen (QuestionPro, 2024).

4. Results and Discussion

4.1 Survey Return Rate

In this study, a quantitative approach was utilized, employing online questionnaires created through Google Forms and distributed to the intended participants. The distribution of the Google Forms questionnaire took place through various social media platforms, including Gmail, WhatsApp, LinkedIn, and other online platforms, which helped to contact the respected group of respondents. The data collection period involved distributing a total of 380 sets of digital questionnaires to the target group of respondents. Unfortunately, only 229 Google Form responses were received from the targeted group of respondents. Resulting in a response rate of 60.74% for this study, as shown in Table 2.

Table 2 *Response Return Rate*

Population	Sample Size	Questionnaires Returned	Percentage
19,062	*377*	229	60.74%

4.2 Reliability Analysis

Table 3 shows a pilot study of 20 respondents was used to test the internal consistency of the questionnaire whereby the reliability of lean management practices (Cronbach's Alpha = 0.941) and the reliability of environmental performance (Cronbach's Alpha = 0.749) were excellent and acceptable respectively meaning that the items can be used to measure the two scales were consistent and applicable in future collection of data. In the real data collection involving 229 respondents, the analysis of reliability revealed good consistency in both the lean management practices (Cronbach's Alpha = 0.804) and environmental performance (Cronbach's Alpha = 0.887), indicating that the finalized measurement items were successful in measuring the intended constructs with a larger sample.

Table 3 *Reliability for Pilot Study and Actual Study*

	Pilot Study		Actual Study	
	Cronbach's Alpha	Interpretation	Cronbach's Alpha	Interpretation
Independent Variables				
Lean Management Practices	0.941	Excellent	0.804	Good
Dependent Variables				
Environmental Performance	0.749	Acceptable	0.887	Good

4.3 Descriptive Analysis

The data were summarized by descriptive analysis to give insights into the respondents and the study variables using frequency, percentage, mean, and standard deviation as presented in Table 4. The analysis will be used to determine the degree of lean management practices and environmental performance of manufacturing companies in Selangor, and the mean scores will show how the respondents have been low, moderate, or high in their application, and the standard deviation will show the deviation in perceptions of the respondents. It also presents findings, which can be used to form inferences, including the relationship between lean management practices and environmental performance.

These findings indicate that the adopted lean management practices among sampled manufacturing companies are at high levels. Flexible layouts of production, multi-purpose machines, small batch sizes, one-piece flow, Kanban, and continuous improvement (Kaizen) practices had mean values of 3.75 to 3.83, which means that they fully embrace the flow-based production and resourceful production techniques. In the same way, the environmental performance was rated very high, and there was an increase in energy consumption, water consumption, wastes, hazardous materials, and carbon dioxide emissions, with mean scores of 3.71 to 3.89. These findings indicate that lean management and environmental initiatives are both being well-used but could still be optimized and improved upon further.

Table 4 *Overall Result for Descriptive Analysis*

	Mean	Interpretation
LMP (IV)	*3.79*	High
EP(DV)	3.76	High

4.4 Normality Analysis

The purpose of the normal test was to find out whether the data obtained in the practices of lean management and environmental performance in Selangor manufacturing firms were distributed normally. Normality is also important to be assessed because it determines whether a parametric or non-parametric approach will be used in statistics. Kolmogorov-Smirnov and Shapiro-Wilk tests were the tools of analysis, which were backed by graphs like histograms and Q-Q plots. The Kolmogorov-Smirnov test is mostly used when the sample is large whereas the Shapiro-Wilk when the sample size is small to medium, with a p-value of above 0.05 showing normal distribution

Table 5 shows the outcome of both tests indicated that the significance levels of lean management practices and environmental performance were lower than 0.01, implying that the p-values were lower than 0.05. Thus, the null hypothesis of normality was rejected, which showed that the data of both variables were not normally distributed. Consequently, normality was not met, and the non-parametric test. Spearman's rho was chosen as the more suitable.

Table 5 *Normality Test*

Variables	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistics	Df	Sig	Statistics	Df	Sig
Lean Management Practices (IV)	0.23	229	<0.01	0.909	229	<0.01
Environmental Performance (DV)	0.23	229	<0.01	0.902	229	<0.01

4.5 Correlation Analysis

Table 6 presents the Spearman's rho correlation analysis to examine the relationship between lean management practices and the environmental performance of manufacturing companies in Selangor. The Spearman's rho was adopted due to the non-normality of the data, which was confirmed by the Kolmogorov-Smirnov and Shapiro-Wilk tests. A total of 229 respondents were used in the analysis, which was adequate to perform a correlation test.

Results indicate a very weak positive association of lean management practice with environmental performance, with a correlation coefficient (r) value of 0.024. The 2-tailed significance value (Sig. 2-tailed) was 0.720, which is greater than the 0.05 value, implying that there is no statistical significance in the correlation. Thus, one cannot reject the null hypothesis that there is no significant relationship. These results indicate that although lean management is largely linked with increases in efficiency, the practice might not necessarily lead to better environmental performance, and other variables like environmental management systems, regulatory compliance, or green technologies might be more important.

Table 6 *Correlation Test*

	Spearman's Rho	LMP (IV)
EP (DV)	*Correlation Coefficient*	1
	Sig(2-tailed)	0.72
	N	1

5. Conclusion

In conclusion, this research has investigated the connection between lean management practices and the environmental performance of manufacturing companies in Selangor. Even though lean practices and environmental performance were observed to be high, the correlation between the two variables was weak and insignificant. It means that lean activities in the analyzed environment are primarily focused on operational efficiency and cost reduction, but not on environmental sustainability.

The research makes a contribution to both theory and practice since it disproves the view that lean management is always an exciting way of enhancing environmental performance. It highlights the importance of clear inclusion of environmental plans in lean initiatives, which are backed by leadership support and policy frameworks. All in all, the research has presented important empirical information that can inform managers, policymakers, and researchers to a more integrated and sustainable production process in Selangor and Malaysia.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Ainaa' Elisya Mohd Zulkepli and Mohd Zarir Yusoff;* ***data collection:*** *Author Y;* ***analysis and interpretation of results:*** *Ainaa' Elisya Mohd Zulkepli;* ***draft manuscript preparation:*** *Ainaa' Elisya Mohd Zulkepli and Mohd Zarir Yusoff. All authors reviewed the results and approved the final version of the manuscript.*

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