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INVESTIGATION OF THE IMPACT OF LEAN METHOD AND TOOLS ON THE ENVIRONMENTAL PERFORMANCE OF MANUFACTURING INDUSTRIES

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Abstract: Due to the higher competition in the manufacturing sector, the industries intend to enhance their performance. Hence, in recent days, most industries have integrated lean methods and tools into their manufacturing process for enhancing operation excellence and efficiency. However, the real environmental performance of these lean methods and tools is unclear regarding the characteristics of industries. So, this research study investigates the impact of lean methods and tools on the environmental performance of manufacturing industries. The research investigation considers four major lean methods, such as JIT, TPM, TQM, and HRM. Then, six main environmental measures are considered for the assessment. The research investigation is a descriptive quantitative analysis. The correlation analysis and descriptive analysis are carried out to assess the impact of lean methods and tools on the environmental performance of the manufacturing industry. In total, 73 industries are included in this investigation. The result of the research investigation revealed that the TPM, TQM, and JIT attained higher performance concerning environmental measures. This research study provides further evidence for a better understanding of the relationship between lean methods and environmental performance.

Keywords: Just-in-Time (JIT), Total Productive Maintenance (TPM), Total Quality Management (TQM), Human Resource Management (HRM), Lean methods and tools, Environmental performance, and Manufacturing industries.

1. INTRODUCTION

Since the Industrial Revolution, the manufacturing industry has developed rapidly. The manufacturing industries not only improve economic growth but also improve the living standards of human beings (Chen et al., 2020). To extend this improvement in the manufacturing industry, the manufacturing industry should achieve improved operational and financial performance (Singh et al., 2020). Nowadays, companies adopt several management models to improve their competitiveness. The tools and methods mostly used for reducing the waste in manufacturing industry are Lean methods and tools (García-Alcaraz et al., 2021) (Ghouat et al., 2021). The main concept of the lean practice is "doing more with less" and it is defined by five major principles, such as defining value, mapping the value stream, creating flow, establishing pull, and seeking perfection (Olah et al., 2022). In general, the lean management process consists of two aspects, such as hard and soft lean practices. Those practices are applied according to the characteristics of the industry (Sahoo, 2019).

Also, green manufacturing is an important component of sustainable development in the manufacturing industry. Green manufacturing with lean practices gains more attraction than general lean practices (Zhu et al., 2019). Most of the researchers are interested in developing greener solutions that not only concentrate on minimizing waste but also focus on other environmental practices, such as excessive use of water, emission of gases, harmful pollution, and so on (Abualfaraa et al., 2020). The most frequently used lean practices are just-in-time (JIT), total quality management (TQM), and human resource management (HRM). Those lean practices have an interrelated and internally consistent basis of lean practices (Hao et al., 2020). However, the existing research works failed to assess the lean practices with environmental factors on long-term stability (Nawanir et al., 2020).

Hence, this study investigates the effect of lean methods and tools on environmental practices in the manufacturing industry along with considering long-term stability assessment.

1.1 Problem Statement

The existing research works have some research problems, which are discussed here,

- Existing research works failed to focus on the long-term effect of lean methods and tools on the environmental performances of the manufacturing industry.
- Existing (Makwana & Patange, 2019) didn't concentrate on the environmental performances of the implementation of lean methods and tools.
- Existing (Dieste et al., 2019) failed to focus on the list of environmental measures based on the company characteristics.
- Existing research work (Dieste et al., 2019) didn't assess the challenges and opportunities of industries in adopting lean practices to enhance environmental performance.
- Most of the existing research didn't assess the performance before and after implementing the lean methods and tools in the manufacturing industry.
- Recommendations were not provided in existing research works for enhancing the quality of manufacturing products.

1.2 Objectives

The proposed work has some research objectives, which are listed here,

- To investigate the long-term effect of lean methods and tools on the environmental performances of the manufacturing industry.
- To analyze the environmental impact of lean implementation in the manufacturing industry.
- To assess the impact of the lean implementation on environmental measures by considering the characteristics of the manufacturing company.
- To assess the challenges and opportunities faced by industries in adopting lean practices to enhance environmental performance.
- To measure and compare the improvements in environmental performance metrics before and after lean method implementation.
- To provide recommendations for integrating lean tools into manufacturing processes to achieve sustainability goals.

The structure of the proposed paper is organized as follows: in section 2, the existing research works related to the lean implementation are explained, in section 3, the proposed research methodology is explained, in section 4, the outcome of the study is discussed, and in section 5, the paper is concluded with future enhancement.

2. RELATED WORK

(Dieste et al., 2019) intended to analyze the relationship between the lean and environmental performances in two main stages. The research first developed the relevant literature study. Then, multiple case studies were conducted in five manufacturing companies. The findings of the study revealed that the environmental practices of the manufacturing process were mainly improved by utilizing JIT and TQM practices in lean transformation. Nevertheless, the research failed to focus on the list of environmental measures based on company characteristics.

(Makwana & Patange, 2019) presented the study related to the implementation of strategic 5S at a plastic machinery manufacturing company in India. The relationship between the presented lean method and the productivity of the product was determined by hypothesis testing. The outcome of the research revealed that the 5S method was utilizing the resources more effectively and efficiently. However, the research didn't concentrate on the environmental performance of the implementation of lean methods and tools.

(Shokri & Li, 2020) designed the green implementation of the Lean Six Sigma project in the manufacturing sector. The research framework investigated the choice of different types of Lean Six Sigma (LSS) projects and analyzed the environmental impact under different conditions. The

evaluation outcome showed that the framework achieved greener, customized, and finance-oriented outputs. The research failed to assess the challenges and barriers in green LSS.
(Logesh & Balaji, 2020) investigated the green manufacturing process through the reduction of waste using lean tools in an electrical components manufacturing company. The research framework determined the relationship between lean waste and the effect of waste on green practices. The research outcome showed that lean methods-based manufacturing makes the industry more efficient in the utilization of resources and less energy efficient. But, the research failed to assess the sustainability of the manufactured products by considering lean manufacturing methods and tools.
(Yadav et al., 2021) suggested the integration of the Green Lean Six Sigma (GLSS) method-based manufacturing process. The research framework also presented a five-faceted GLSS framework for the manufacturing sector to enhance organizational sustainability. The findings of the study revealed that the GLSS method in the manufacturing process increased operational excellence and environmental sustainability. However, the GLSS method wasn't tested practically.

3. RESEARCH METHODOLOGY

In this research, the implementation of lean methods and tools on the environmental performance of manufacturing industries is assessed. To analyze the effect of the lean methods and tools, the environmental measures are considered as the dependent variable, and the lean methods and tools are considered as the independent variable. This study adopts a descriptive and analytical research design to investigate the impact of lean manufacturing methods and tools on the environmental performance of manufacturing industries. The approach combines case studies and quantitative data analysis to provide both conceptual understanding and practical applications. The conceptual framework for the research work is displayed in Figure 1,

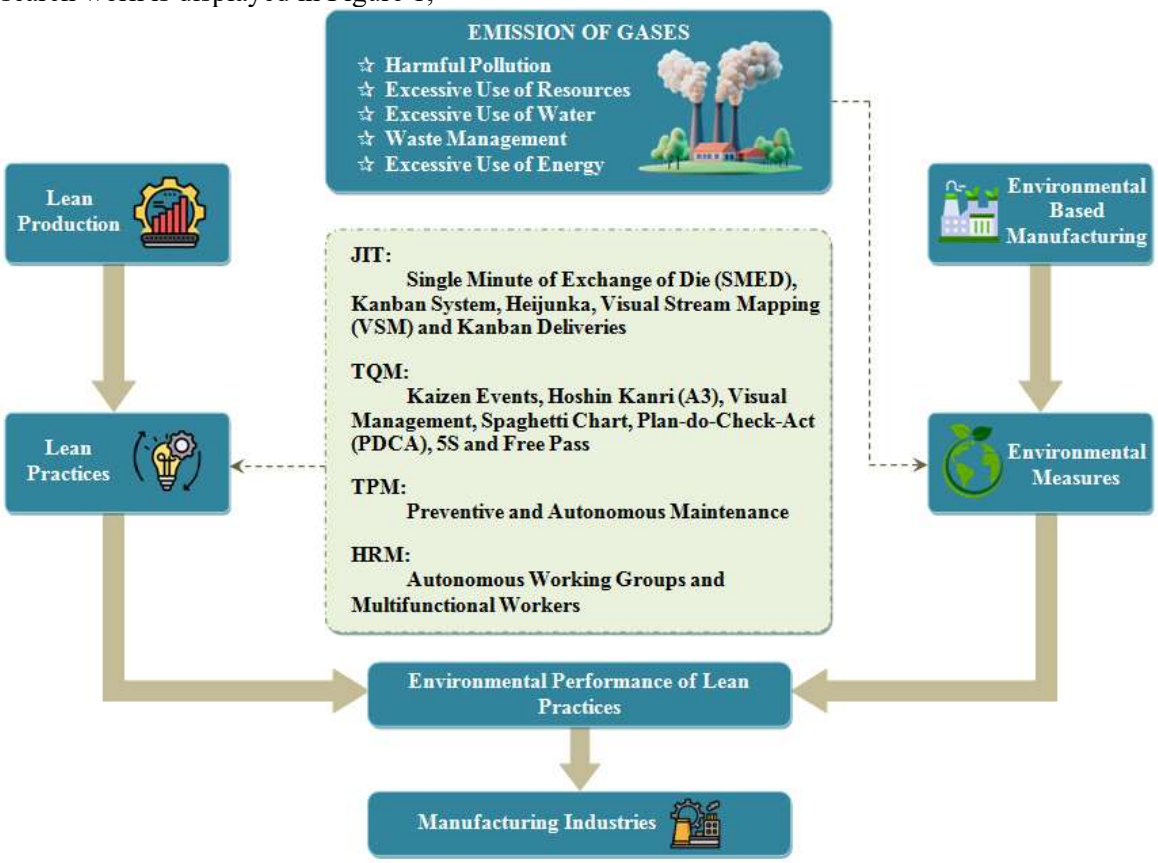


Figure 1: Conceptual framework for the proposed research

3.1 Data collection

The data collection phase consists of two sub-phases, such as sources and criteria for selecting lean companies.

(a) Sources

The research framework considered both primary and secondary sources. The primary data is collected in the form of a questionnaire. The questionnaire design consists of three segments, such as details about their manufacturing company, details about the usage of lean practice, and details about considering environmental practices in their lean methods and tools. For the secondary data collection, the industry reports, journal articles, and case studies of lean manufacturing and environmental performance metrics from the publicly available datasets and sustainability reports are used.

(b) Criteria for selecting the lean implemented companies

The lean companies are selected with the help of the recently conducted Green and Lean Production Conference. More number of lean and green-maintained manufacturing companies attended this conference. So, it is highly helpful to find long-term lean practice-maintained companies. 200+ manufacturing companies have attended the conference. Among the company list, 73 companies are selected using the purposive sampling technique. This would confirm data relevance and reliability for an analysis.

(c) Questionnaire distribution and collection

The designed questionnaires are distributed to professionals in the manufacturing industries with information on lean tool adoption, problems encountered, and environmental performance outcomes. In addition, there will be semi-structured interviews conducted with industry experts, lean practitioners, and environmental managers to produce more understanding views of practical challenges and strategies that go with the implementation of lean practices.

3.2 Lean tools and environmental metrics

The research study focuses on the long-term maintained lean methods and tools used in manufacturing industries along with considering environmental performances. The research study considered the main five lean methods and tools in the manufacturing industry, such as JIT, TQM, HRM, and TPM. Environmental performance metrics for assessment are the emission of gases (G_{ems}), harmful pollution (H_p), excessive use of resources (X_{ru}), excessive use of water (X_{wu}), waste management (W_m), and excessive use of energy (X_{eu}). The derivation for the environmental performance metric is derived as follows,

$$G_{ems} = \Delta U_g + \Delta U_m + \Delta R_e \quad (1)$$

$$H_p = E_f + W_g + E_{ec} \quad (2)$$

$$X_{ru} = A_{rc} + O_{rc} \quad (3)$$

$$X_{wu} = A_{wc} + O_{wc} \quad (4)$$

$$W_m = I_w - W_{ali} \quad (5)$$

$$X_{eu} = A_{ec} + O_{ec} \quad (6)$$

Where, A_{rc}, A_{wc}, and A_{ec} denotes the actual resource consumption, actual water consumption, and actual energy consumption, respectively, O_{rc}, O_{wc}, and O_{ec} defines the optimized resource consumption, optimized water consumption, and optimized energy consumption, respectively, ΔU_g is the reduction in energy usage, ΔU_m denotes the reduction in material waste, ΔR_e specifies the reduction in inefficient processes, E_f, W_g, and E_{ec} indicates the emission factor, waste generation,

and excess energy consumption, respectively, I_w denotes the initial waste, and W_{ali} specifies the waster after lean implementation.

3.3 Analytical techniques

After the collection of all data, the data are analyzed using statistical methods, such as regression and correlation analysis. The statistical method is used to examine the relationships between lean practices and environmental performance improvements. Additionally, case studies from manufacturing industries will also be analyzed to validate findings and illustrate successful implementations of lean manufacturing methods.

3.4 Recommendations

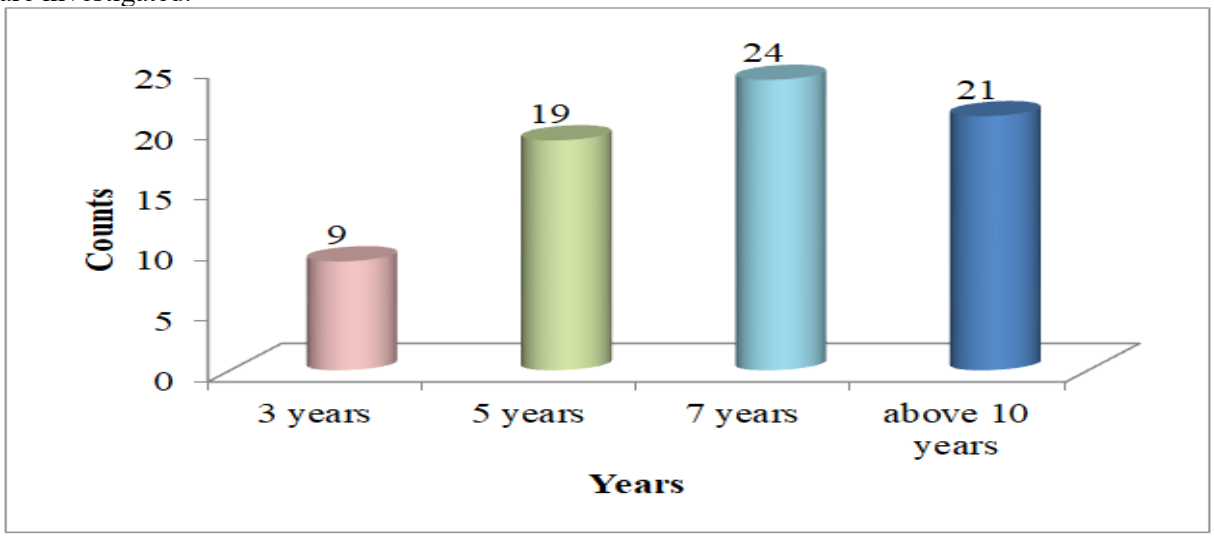
Based on the analyzed outcome, some strategies are recommended for integrating lean tools in the manufacturing process to attain sustainability goals. In the further section, the performance of the research is investigated.

4. RESULT AND DISCUSSION

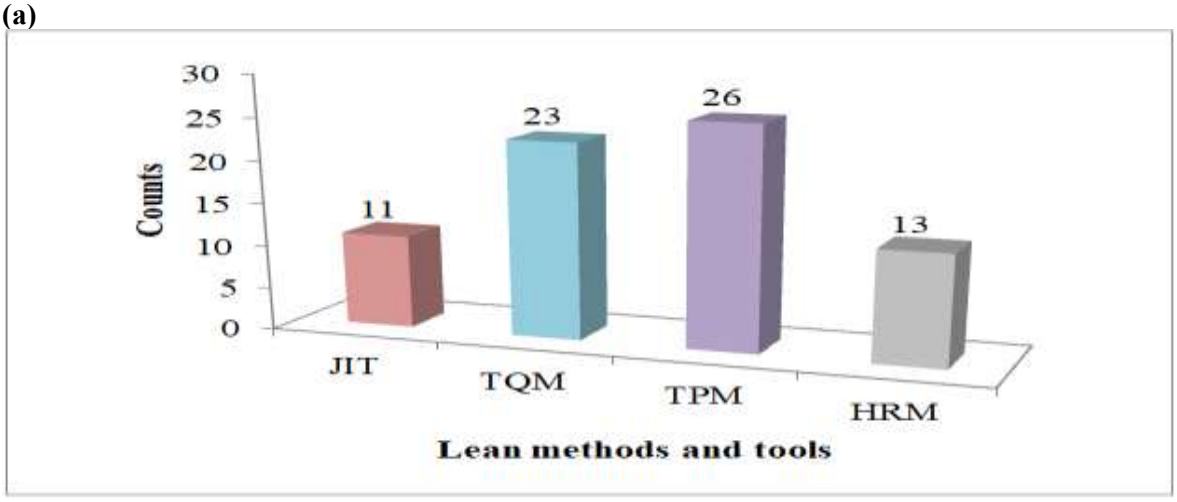
In this section, the primary and secondary data collected from manufacturing industries are assessed.

4.1 Manufacturing practices

Here, the practices of the manufacturing industry are analyzed. First, this study investigates how long lean practices are considered in their manufacturing industries. Secondly, the most used lean practices are investigated.



(a)



(b)

Figure 2: Graphical plot for manufacturing practices (a) duration of using lean methods, and (b) type of lean methods

The graphical analysis plot for manufacturing practices is displayed in Figure 2. Figure 2(a) defines how long the lean method and tools are implemented and followed by the companies, and Figure 2(b) shows the types of lean methods used by the companies. Here, the companies that followed the lean method for 7 years and above 10 years are highly selected for the investigation. A higher count is obtained for the TPM and TQM lean methods in the manufacturing industry.

4.2 Analysis of the relationship between lean methods and environmental factors

Here, the effect of lean methods and tools on the environmental performance of the manufacturing industry is analyzed.

Table 1: Correlation results of lean methods on environmental measures in manufacturing industries

Lean methods/Environmental measures	G_{ems}	H_p	X_{ru}	X_{wu}	X_{eu}	W_m
JIT	.097	.163**	.223*	.195*	.073	.096
TQM	.214*	.213*	.212*	.214*	.265*	.213*
TPM	.231*	.253*	.205*	.185*	.237*	.201*
HRM	.086	.043	.008	.067	.055	.078

*-Correlation is significant at the 0.01 level
**-Correlation is significant at the 0.05 level

Table 1 shows the correlation result of lean methods on environmental measures in manufacturing industries. According to the G_{ems}, the JIT and HRM are not affected. Based on harmful pollution measures, the correlation analysis suggests that the TQM and TPM have a significant effect on environmental performance at a significant level of 0.01, and JIT has a significant effect on environmental performance at a significant level of 0.05. Overall, the correlation analysis shows that the most significant relationship is presented between the JIT, TQM, and TPM lean methods and environmental measures.

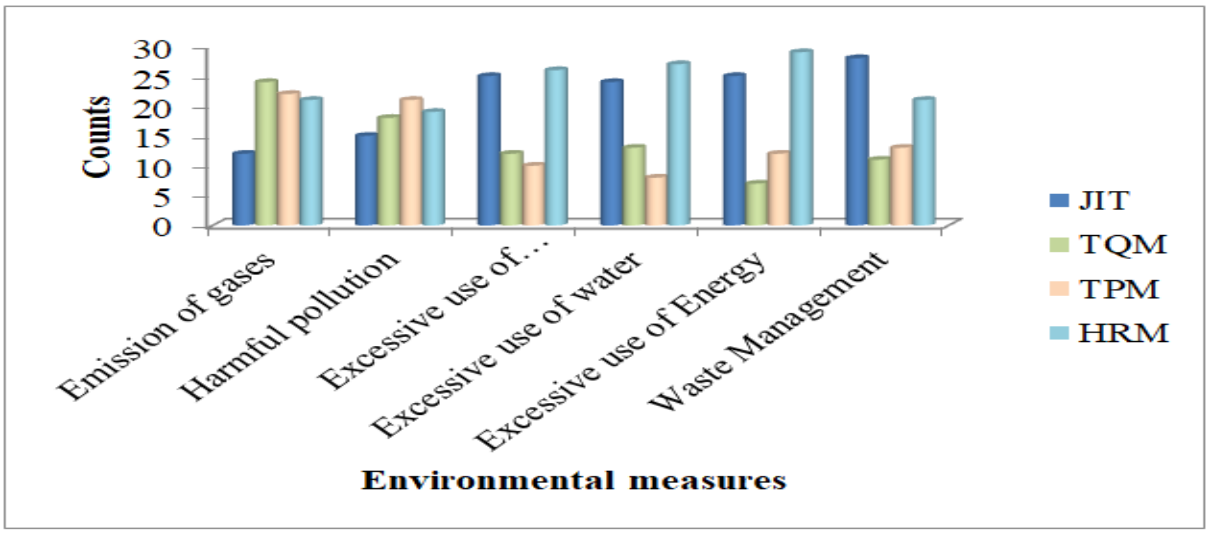


Figure 3: Analysis of the effect of lean methods with respect to environmental measures

Figure 3 shows the analysis of the effect of lean methods with respect to the environmental measures. The analysis displayed that the JIT and HRM are higher in excessive use of resources, excessive use of water, excessive use of energy, and waste management. The emission of gases and harmful

pollution measures are higher for the TQM and TPM lean methods implemented by manufacturing companies.

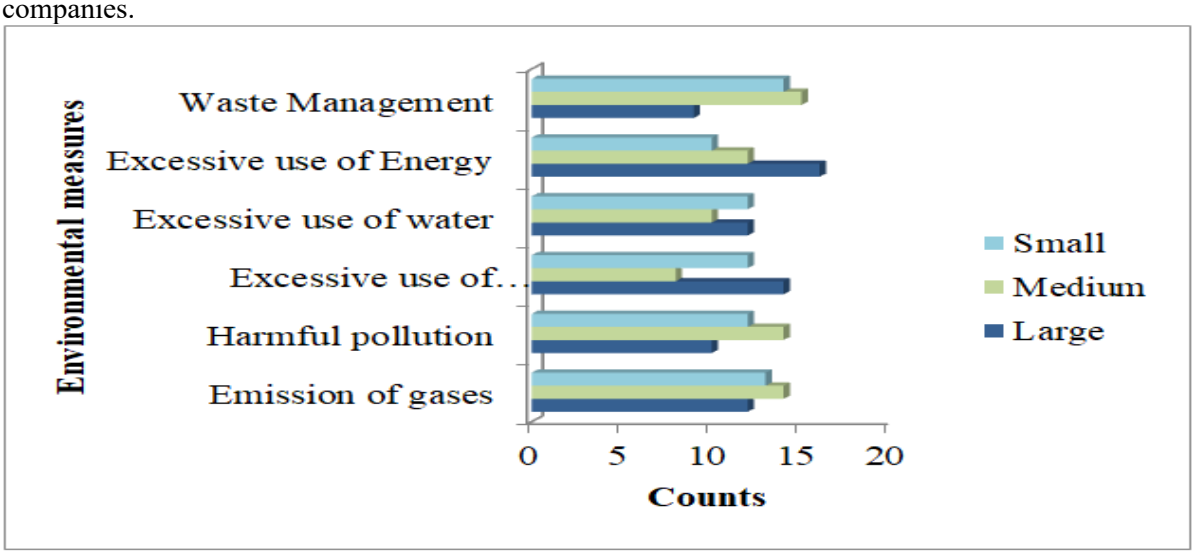


Figure 4: Assessment of environmental performance according to the company's characteristics

Figure 4 depicts the assessment of environmental performance according to the company's characteristics. Here, the interviewed manufacturing industries are grouped according to their company details, such as large, medium, and small. The graphical representation of the analysis shows that medium and small industries are mostly affected by environmental factors.

4.3 Analysis of challenges of industries in adopting lean practices

In this sub-section, the challenges of the industries in adopting lean practices are analyzed. In this analysis, six major challenges, such as Lack of Environmental Knowledge (LEK), Lack of Training of Employees (LTE), Insufficient Government Support (IGS), Lack of Dedicated Supplier (LDS), Absence of Sound Planning System (ASPS), and Lack of Awareness about Potential Benefits (LAPB), are considered.

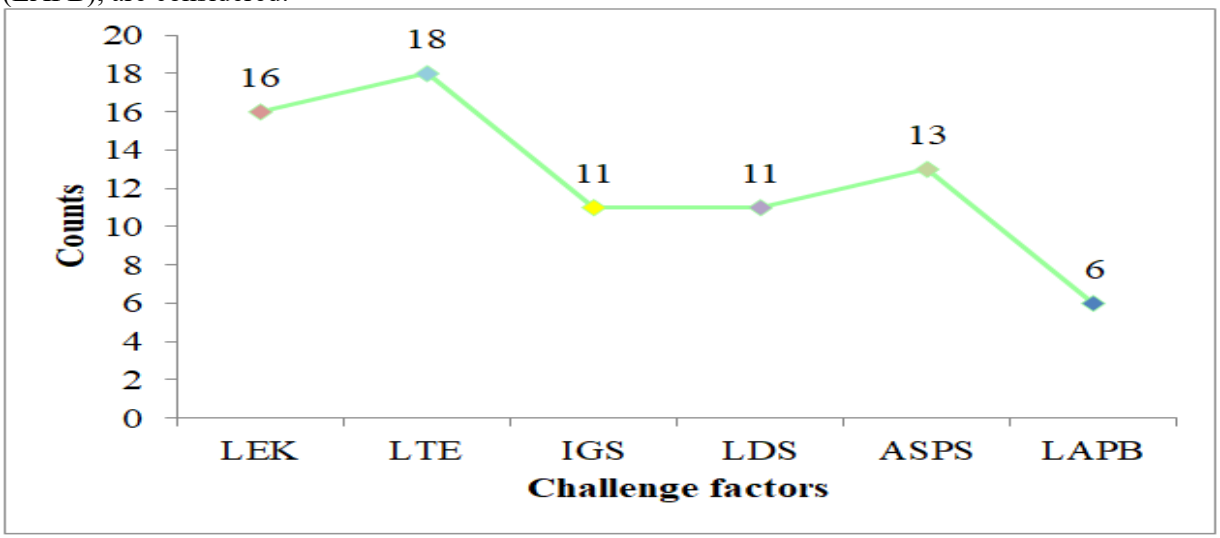


Figure 5: Challenge analysis while adopting lean methods and tools in manufacturing industries

Figure 5 shows the pictorial plot for challenge analysis while adopting lean methods and tools in manufacturing industries. Most of the experts accept the LTE factor and LEK factor. LAPB factor was only accepted by 6 experts from the manufacturing industries.

4.4 Analysis of the environmental performance of the industry

Here, the environmental performance of the industry is analyzed before and after the implementation of lean methods and tools.

Table 2: Reduction analysis

Lean methods	Before implementation (reduction of environmental factors) in %						After implementation (reduction of environmental factors) in %					
	G_{ems}	H_p	X_{ru}	X_{wu}	X_{eu}	W_m	G_{ems}	H_p	X_{ru}	X_{wu}	X_{eu}	W_m
JIT	12	17	21	18	23	27	26	35	42	39	47	52
TQM	17	14	25	09	25	29	32	28	47	23	53	59
TPM	22	19	23	15	19	18	41	38	55	32	36	42
HRM	16	27	17	12	26	21	35	43	38	41	54	45

Table 2 shows the reduction of G_{ems}, H_p, X_{ru}, X_{wu}, X_{eu}, and W_m before and after implementation of lean methods in the manufacturing industry. The reduction level is presented in percentages. According to all environmental measures, the after-implementation of lean methods achieved higher results than the before-implementation process.

4.5 Case study

In recent days, the manufacturing sector has faced numerous challenges in improving environmental performance. One of the most attractive approaches is lean manufacturing, which focuses on reducing waste, optimizing processes, and improving efficiency. Many existing research works investigated the lean methods-based manufacturing industry. Some of the investigated studies are discussed as: Existing (Daniyan et al., 2022) implemented lean methods to improve the assembly process efficiency in the manufacturing industry. The result of the study revealed that a 27.9% reduction was obtained in the lead time. However, the application of the lean methods was carried out on a single organization only, leading to insufficient general conclusions. Inversely, existing (García Alcaraz et al., 2022) presented lean manufacturing tools for improving the sustainability of the manufacturing industry. The outcome revealed that the automation system enhanced the sustainability of the manufacturing industry. Similarly, the existing (Dey et al., 2019) assessed the impact of lean management practices and sustainability-oriented innovation on the sustainability performance of small-medium-sized enterprises. The analysis revealed that both lean management practices and sustainability-oriented innovation achieved sustainability and economic performances. However, improvement was still needed. So, this research investigated and enhanced the environmental performance of the lean methods. According to all environmental measures, the manufacturing industries achieved a minimum of 20% improvement after the implementation of lean methods.

4.6 Recommendations

The analysis of the research demonstrates that product manufacturing by considering numerous factors related to environmental performance, sustainability, and economic-based lean methods and tools achieves higher efficiency in manufacturing industries. Also, according to the industry sector, each factor varies. Hence, the structured framework is important for maintaining lean methods and tools.

5. CONCLUSION

This research paper studied the effect of lean methods and tools on the environmental performance of the manufacturing industry. Existing research works only focused on lean methods and environmental performance; but, they did not cover the companies that maintained long-duration lean methods. The research framework considered the descriptive quantitative analysis. For the investigation, semi-structured interviews were conducted in some manufacturing industries. Also, in this study, according to the company characteristics, the investigation was carried out to determine the actual status of environmental management in the manufacturing industry. The interviews and case studies were

mainly based on the JIT, TQM, TPM, and HRM lean methods. Among the lean methods, the TQM, TPM, and JIT attained better environmental performance and higher levels of improvement in the reduction process. However, the research only focused on the environmental measures and didn't concentrate on the economic factors for improving the efficiency of the manufacturing industry.

Future Scope: In the future, the presented research work will consider the economic factors for assessing the performance of lean methods and tools in the manufacturing industry.

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