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

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Abstract: The industries intend to enhance their performance due to the higher competition in the manufacturing sector. Therefore, for enhancing operation excellence and efficiency, most industries have integrated Lean Methods And Tools (LMT) into their manufacturing process in recent days. Nevertheless, regarding the characteristics of industries, the real Environmental Performance (EP) of these LMTs is unclear. Therefore, the impact of LMT on the EP of manufacturing industries is investigated in the research study. Four major lean methods like Just-In-Time (JIT), Total Productive Maintenance (TPM), Total Quality Management (TQM), and Human Resource Management (HRM) are considered in the research investigation. After that, for the assessment, six main environmental measures are considered. The research investigation is a descriptive quantitative analysis. For assessing the effect of LMT on the EP of the manufacturing industry, correlation analysis and descriptive analysis are carried out. Totally, in this investigation, 73 industries are included. The research investigation's outcomes exposed that the TPM, TQM, and JIT attained higher performance concerning environmental measures. Further evidence for a better understanding of the association betwixt lean methods and EP is provided in this research study.

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

The manufacturing industry has advanced rapidly since the Industrial Revolution. The manufacturing industries improve economic growth and the living standards of human beings (Chen et al., 2020). The manufacturing industry should achieve improved operational and financial performance for extending this improvement in the manufacturing industry (Singh et al., 2020). Currently, several management models are adopted by companies to enhance their competitiveness. LMT are the tools and methods mostly used for reducing the waste in manufacturing industry (García-Alcaraz et al., 2021) (Ghouat et al., 2021). The key concept of the lean practice is "doing more with less". It is defined by five major principles: defining value, mapping the value stream, generating flow, presenting pull, and seeking perfection (Olah et al., 2022). Generally, hard and soft lean practices are the two aspects that comprise the Lean Management (LM) process. According to the characteristics of the industry, those practices are applied (Sahoo, 2019).

In addition, in the manufacturing industry, a significant element of sustainable development is green manufacturing. 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 concentrate on minimizing waste and other environmental practices,

such as excessive use of water, emission of gases, harmful pollution, and so on (Abualfaraa et al., 2020). JIT, TQM, and HRM are the most frequently used lean practices. Those lean practices have an internally consistent and connected basis of lean practices (Hao et al., 2020). Nevertheless, the prevailing research works failed to assess the lean practices with environmental factors on long-term stability (Nawanir et al., 2020). Hence, the influence of LMT on environmental practices in the manufacturing industry along with considering long-term stability assessment is investigated in this study.

1.1 Problem Statement

The prevailing research works have some research issues, which are discussed here,

- Prevailing researches failed to concentrate on the long-term effect of LMT on the manufacturing industry's EP.
- Existing (Makwana & Patange, 2019) didn't focus on the EPs of the implementation of LMT.
- Prevailing (Dieste et al., 2019) failed to concentrate on the list of environmental measures centered on the company characteristics.
- Existing research work (Dieste et al., 2019) didn't validate the challenges and opportunities of industries in adopting lean practices to augment EP.
- Most of the prevailing research didn't assess the performance before and after implementing the LMT in the manufacturing industry.
- Recommendations were not rendered in prevailing research works for augmenting the quality of manufacturing products.

1.2 Objectives

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

- For examining the long-term effect of LMT on the manufacturing industry's EP.
- To investigate the environmental effect of lean implementation in the manufacturing industry.
- To evaluate the effect of lean implementation on environmental measures by deeming the manufacturing company's characteristics.
- To assess the challenges and opportunities faced by industries in adopting lean practices to augment EP.
- To measure and compare the improvements in EP metrics before and after lean method implementation.
- To render recommendations for integrating lean tools into manufacturing processes to achieve sustainability goals.

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

2. RELATED WORK

(Dieste et al., 2019) intended to investigate the association betwixt lean and EPs in 2 crucial stages. The relevant literature study was first developed in this research. After that, multiple case studies were carried out in 5 manufacturing companies. As per the findings, by employing the JIT as well as TQM practices in lean transformation, the environmental

practices of the manufacturing process were mainly enhanced. However, the research failed to concentrate on the list of environmental measures centered on the company characteristics.

(Makwana & Patange, 2019) illustrated the investigation associated with the application of strategic 5S at a plastic machinery manufacturing firm in India. The hypothesis testing determined the relationship between the presented lean methodology and the productivity of the product. As per the research outcome, the 5S methodology was utilizing the resources more effectively and efficiently. Nevertheless, the research didn't focus on the EP of the implementation of LMT.

(Shokri & Li, 2020) designed the green implementation of the Lean Six Sigma (LSS) project in the manufacturing sector. The selection of diverse sorts of LSS projects was investigated by the research framework, which also analyzed the environmental impact under distinct situations. As per the evaluation, the framework achieved greener, customized, and finance-oriented outputs. The research failed to assess the challenges as well as barriers in green LSS.

(Logesh & Balaji, 2020) assessed the green manufacturing process via the diminution of waste utilizing lean tools in an electrical components manufacturing company. The association betwixt lean waste and the impact of waste on green practices was determined in the research framework. As per the research results, lean methods-centric manufacturing made the industry more effectual in resource utilization and less energy efficient. However, this study failed to assess the sustainability of the manufactured products by deeming lean manufacturing methods and tools.

(Yadav et al., 2021) recommended the integration of the Green-LSS (GLSS) methodology-centric manufacturing process. For enhancing organizational sustainability, a five-faceted GLSS framework was presented by the research framework for the manufacturing sector. As per the study findings, operational excellence and environmental sustainability were augmented by the GLSS method in the manufacturing process. Nevertheless, the GLSS methodology wasn't tested practically.

3. RESEARCH METHODOLOGY

This research assesses the implementation of LMT on the EP of manufacturing industries. To analyze the effect of the LMT, the environmental measures and the LMT are considered as the dependent variable and independent variable, correspondingly. A descriptive and analytical research design is adopted in this research for exploring the effect of LMT on the EP of manufacturing industries. To provide both conceptual understanding and practical applications, case studies and quantitative data analysis are combined in this approach. Figure 1 displays the conceptual framework for the research work.

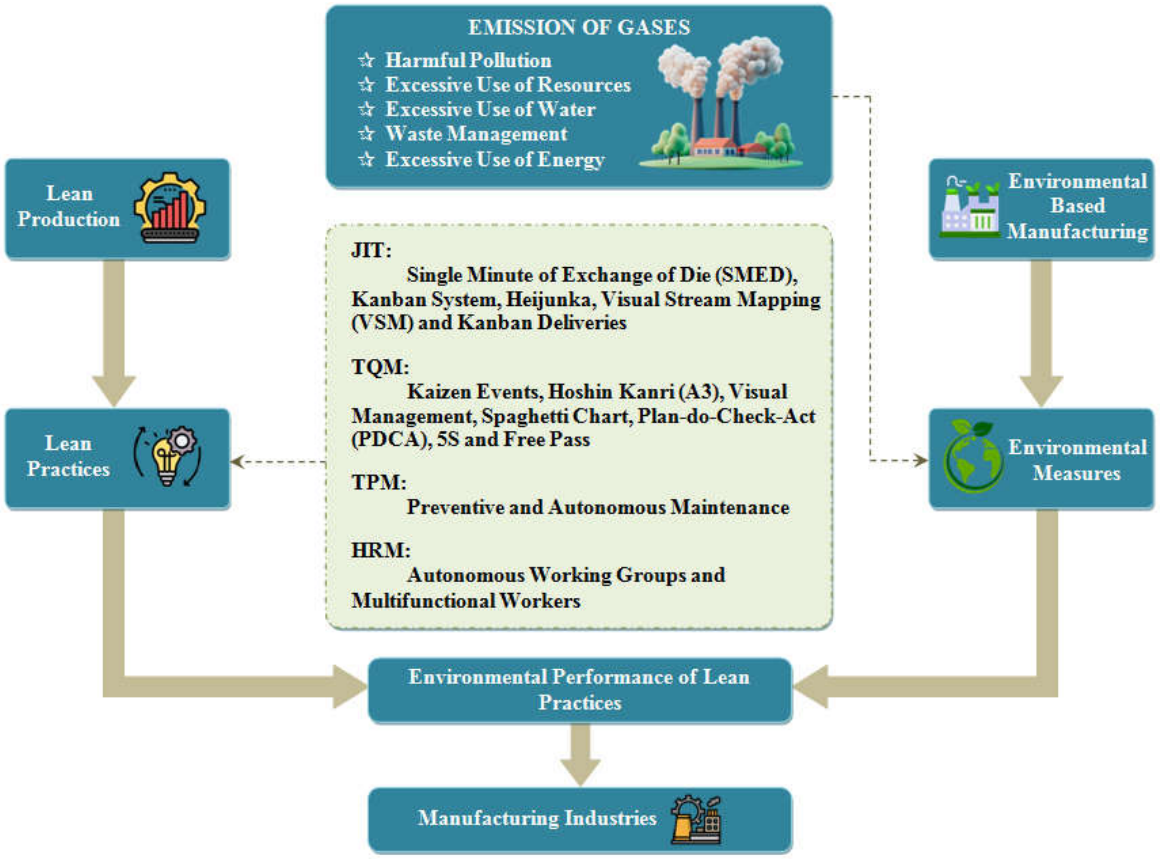


Figure 1: Conceptual framework for the proposed research

3.1 Data collection

For selecting lean companies, the data collection phase encompasses 2 sub-phases, such as sources and criteria.

(a) Sources

Primary and secondary sources are considered in this research methodology. The primary data is gathered in the form of a questionnaire. Three segments, such as details about their manufacturing company, details about the usage of lean practice, and details about considering environmental practices in their LMT are comprised in the questionnaire design. The industry reports, journal articles, and case studies of lean manufacturing and EP metrics from the publicly available datasets and sustainability reports are used for the secondary data collection.

(b) Criteria for selecting the lean implemented companies

With the help of the recently conducted Green and Lean Production Conference, the lean companies are chosen. Numerous lean and green-maintained manufacturing companies attended this conference. Therefore, it is highly beneficial to identify long-term lean practice-maintained companies. The conference have been attended by 200+ manufacturing companies. Out of these, 73 companies are chosen by utilizing the purposive sampling technique. This would confirm data relevance and reliability for an investigation.

(c) Questionnaire distribution and collection

The designed questionnaires are disseminated to professionals in the manufacturing industries with information on lean tool adoption, problems encountered, and EP outcomes. Additionally, semi-structured interviews will be carried out with industry experts, lean practitioners, and environmental managers for generating more understanding views of practical challenges and strategies that go with the implementation of lean practices.

3.2 Lean tools and environmental metrics

In this research study, long-term maintained LMT used in manufacturing industries as well as their EPs are focused on. The main five LMT in the manufacturing industry, such as JIT, TQM, HRM, and TPM are considered in the research study. 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}) are the EP metrics for assessment. The derivation for the EP metric is derived as,

$$G_{ems} = \Delta U_g + \Delta U_m + \Delta R_e \tag{1}$$

$$H_p = E_f + W_g + E_{ec} \tag{2}$$

$$X_{ru} = A_{rc} + O_{rc} \tag{3}$$

$$X_{wu} = A_{wc} + O_{wc} \tag{4}$$

$$W_m = I_w - W_{ali} \tag{5}$$

$$X_{eu} = A_{ec} + O_{ec} \tag{6}$$

Where, the actual resource consumption, actual water consumption, and actual energy consumption are denoted as A_{rc}, A_{wc}, and A_{ec}, respectively, the optimized resource consumption, optimized water consumption, and optimized energy consumption are defined as O_{rc}, O_{wc}, and O_{ec}, respectively, the reduction in energy usage is denoted as ΔU_g, the reduction in material waste is illustrated as ΔU_m, the reduction in inefficient processes is specified as ΔR_e, the emission factor, waste generation, and excess energy consumption are indicated as E_f, W_g, and E_{ec}, respectively, the initial waste is notated as I_w, and the waster after lean implementation is specified as W_{ali}.

3.3 Analytical techniques

Subsequent to data collection, the data are analyzed utilizing statistical methods like regression and correlation analysis. For examining the relationships between lean practices and EP improvements, the statistical method is employed. Moreover, to validate findings and illustrate successful implementations of lean manufacturing methods, case studies from manufacturing industries will also be analyzed.

3.4 Recommendations

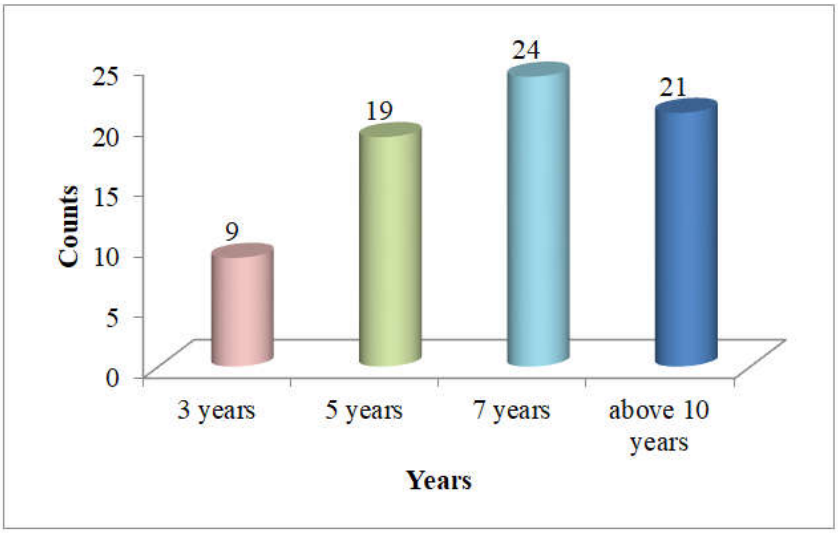
Some strategies are recommended centered on the analyzed outcome for integrating lean tools in the manufacturing process to attain sustainability goals. Then, the research's performance is investigated in the further section.

4. RESULT AND DISCUSSION

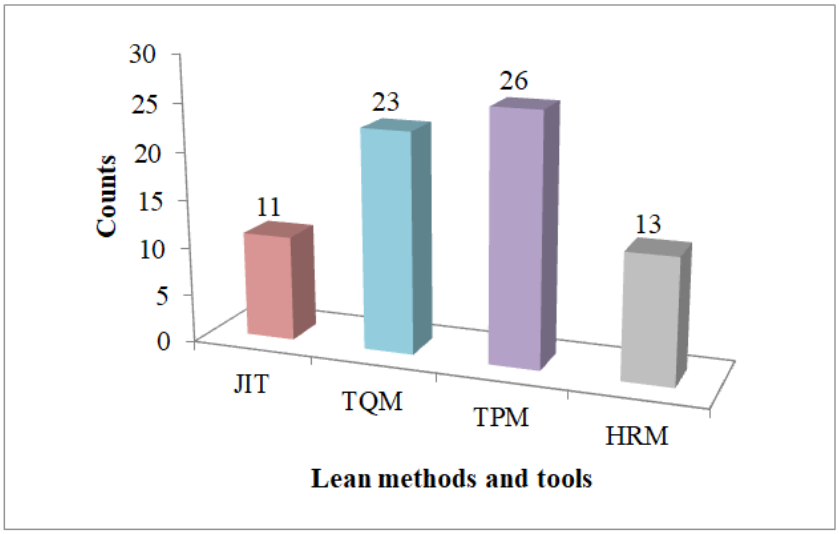
Here, the primary and secondary data gathered from manufacturing industries are assessed.

4.1 Manufacturing practices

Here, the manufacturing industry's practices are analyzed. First, this study explores how long lean practices are deemed in their manufacturing industries. Then, the most utilized lean practices are examined.



(a)



(b)

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

Figure 2 displays the graphical analysis plot for manufacturing practices. Figure 2(a) defines how long the lean method and tools are implemented and followed by the companies, and Figure 2(b) exhibits the types of lean methods deployed by the companies. For the investigation, this study highly selected the companies that followed the lean method for 7 years and above 10 years. 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 LMT's effect on the manufacturing industry's EP 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

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

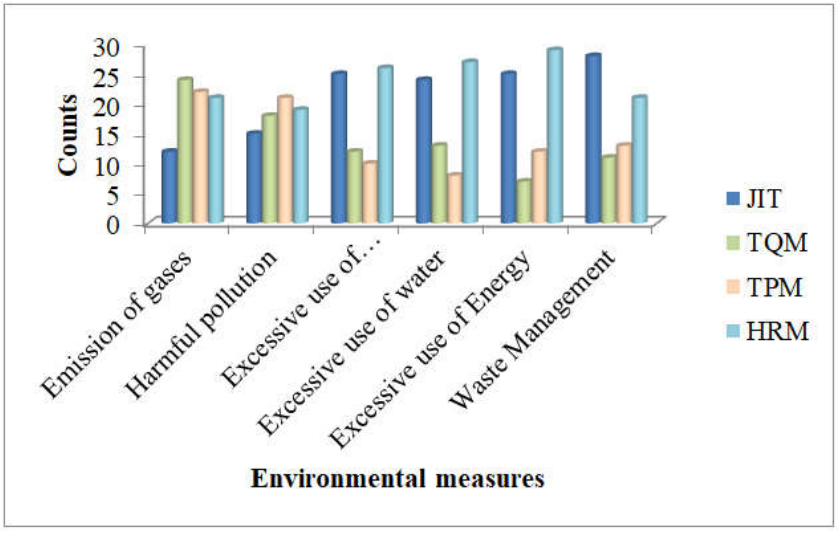


Figure 3: Analysis of the effect of lean methods with respect to environmental measures

Regarding environmental measures, the analysis of the lean method's effect is investigated in Figure 3. As per the analysis, 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.

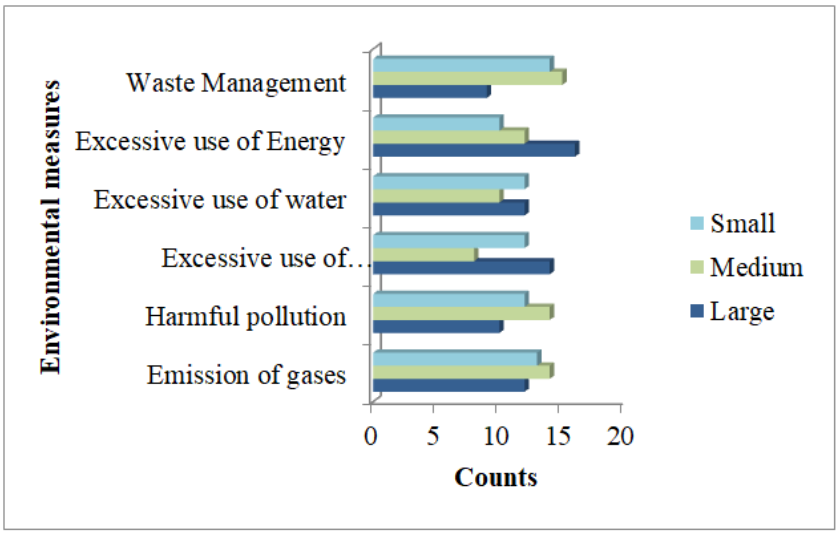


Figure 4: Assessment of environmental performance according to the company's characteristics

The assessment of EP as per the company's characteristics is displayed in Figure 4. Here, according to their company details like large, medium, and small, the interviewed manufacturing industries are grouped. As per the graphical representation of the analysis, environmental factors mostly affected the medium and small industries.

4.3 Analysis of challenges of industries in adopting lean practices

The challenges of the industries in adopting lean practices are analyzed in this section. 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 the six major challenges considered in this analysis.

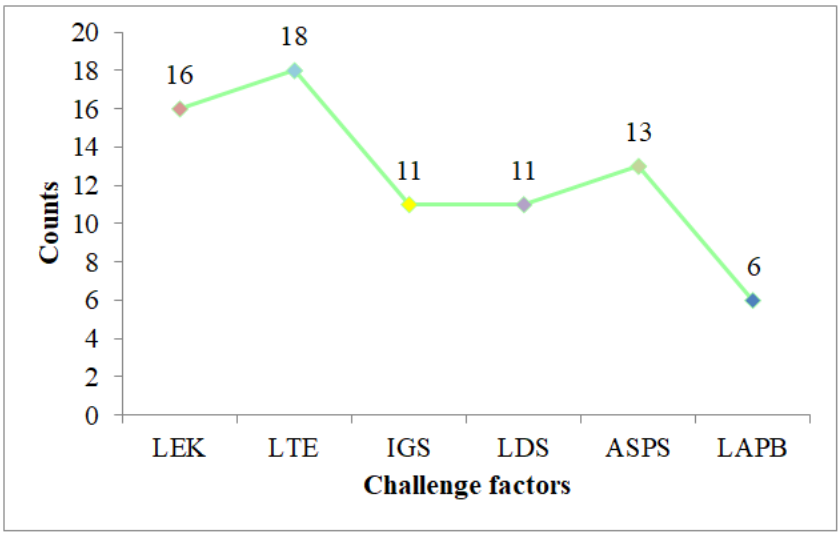


Figure 5: Challenge analysis while adopting lean methods and tools in manufacturing industries

The pictorial plot for challenge analysis while adopting LMT in manufacturing industries is shown in Figure 5. The LTE factor and LEK factor were accepted by most of the experts. LAPB factor was only accepted by 6 experts from the manufacturing industries.

4.4 Analysis of the environmental performance of the industry

Here, before and after the implementation of LMT, the EP of the industry is analyzed.

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

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 is exhibited in Table 2. The reduction level is expressed in percentages. As per the environmental measures, the after-implementation of lean methods achieved superior outcomes when compared with the before-implementation process.

4.5 Case study

The manufacturing sector has faced numerous challenges in recent days for enhancing EP. Lean manufacturing is among the most attractive frameworks, which focuses on reducing waste, optimizing processes, and improving efficiency. In many existing research works, the lean methods-based manufacturing industry was investigated. Some of the investigated studies are discussed as: Lean methods were implemented in existing (Daniyan et al., 2022)

to improve the assembly process efficiency in the manufacturing industry. As per the result of the study, a 27.9% decrease was obtained in the lead time. Nevertheless, the application of the lean methods was performed on a single organization only, resulting in insufficient general conclusions. In reverse, lean manufacturing tools were presented in existing (García Alcaraz et al., 2022) for improving the manufacturing industry's sustainability. As per the outcome, the automation system improved the sustainability of the manufacturing industry. Likewise, the effect of LM practices and Sustainability-Oriented Innovation (SOI) on the sustainability performance of small and medium-sized enterprises was assessed in the existing (Dey et al., 2019). According to the analysis, sustainability and economic performances were achieved by both LM practices as well as SOI. Yet, improvement was still required. Thus, the EP of the lean methods was assessed and enhanced. According to all environmental measures, after the implementation of lean methods, the manufacturing industries achieved a minimum of 20% improvement.

4.6 Recommendations

As per the research analysis, product manufacturing by deeming various factors associated with EP, sustainability, and economic-based LMT achieves higher efficiency in manufacturing industries. Also, each factor varies according to the industry sector. Therefore, for maintaining LMT, the structured framework is important.

5. CONCLUSION

In this research paper, the effect of LMT on the EP of the manufacturing industry is studied. Prevailing research works only concentrated on lean methods and EP. Nevertheless, the companies that maintained long-duration lean methods were uncovered. The descriptive quantitative analysis was considered in the research framework. Semi-structured interviews were carried out in some manufacturing industries for the investigation. In addition, according to the company characteristics, the investigation was done in this study for determining the actual status of environmental management in the manufacturing industry. The interviews and case studies were mainly centered on the JIT, TQM, TPM, and HRM lean methods. Among those methods, better EP and higher levels of improvement in the reduction process were attained by the TQM, TPM, and JIT. Nevertheless, the research only focused on the environmental measures and didn't focus on the economic factors for enhancing the manufacturing industry's efficiency.

Future Scope: The presented research work will consider the economic factors in the future for assessing the performance of LMT in the manufacturing industry.

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