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The Impact Of Integrating Lean Manufacturing And Quality Management Systems On Enterprise Efficiency

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Abstract:

This article investigates the implementation of a quality management system based on lean production principles and the assessment of its effectiveness. The study analyzes approaches aimed at reducing losses in production processes, ensuring efficient use of resources, and continuously improving quality. In particular, production processes were optimized based on 5S, Kaizen, value stream analysis, and standardized work methods. The results showed that integrating lean production elements with the quality management system helps reduce defect levels, decrease production costs, and improve management efficiency in enterprises.

Keywords: lean production, quality management system, 5S, Kaizen, value stream analysis, production efficiency, loss reduction, standardization, continuous improvement, management efficiency, production costs, defect level.

Introduction

Ensuring competitiveness in modern mechanical engineering enterprises is directly related not only to maintaining product quality in compliance with established requirements, but also to improving the efficiency of production processes. Practical experience shows that despite the implementation of quality management systems in enterprises, excessive operations, time losses, and inefficient use of resources still persist within production processes. This indicates the existence of a gap between quality management and production efficiency.

Under these conditions, integrating the quality management system with lean manufacturing principles has become one of the key directions for improving enterprise performance. While the lean manufacturing approach focuses on identifying and eliminating activities that do not create value within production processes, the quality management system ensures process stability and management discipline. The integration of these two approaches can transform quality assurance from a control-based model into an efficiency-oriented management system.

Experience in the effective organization of lean manufacturing in industrial enterprises demonstrates that the success of the implementation process is closely associated with establishing clear target indicators, carrying out pilot projects on a trial basis, and evaluating the economic effectiveness of the implemented changes. This approach makes it possible to transform implementation activities from a general initiative into a managed and results-oriented process.

Materials And Methods

The issue of integrating lean manufacturing and quality management systems is widely studied as one of the important directions for improving efficiency in modern industrial enterprises. In scientific research, the concept of lean manufacturing is interpreted as a systematic approach aimed at reducing losses in production processes, ensuring efficient use of resources, and increasing operational efficiency [1]. At the same time, the quality management system serves to satisfy customer requirements by ensuring product quality and process stability. Studies indicate that the combined application of these two approaches creates an environment of continuous improvement within enterprises and enhances production efficiency.

Empirical studies conducted in recent years demonstrate that the integration of lean manufacturing and total quality management has a significant impact on the sustainable development of enterprises. In particular, research carried out in the food industry shows that the harmonization of these approaches improves economic, environmental, and social performance indicators [2]. Furthermore, the results obtained through structural modeling indicate that lean manufacturing is one of the key tools for increasing the effectiveness of quality management systems.

The practical effectiveness of lean manufacturing tools has also been widely discussed in the literature. According to the results of systematic analyses, the application of these tools leads to increased production efficiency, reduced inventories, and improved product quality. Some studies reported reductions of up to 70% in setup time, a 26% decrease in worker movements, and a significant increase in overall efficiency within production processes [3]. These findings confirm the direct impact of lean manufacturing on economic efficiency.

Other studies emphasize that the integration of lean manufacturing and quality systems has not yet been sufficiently investigated, especially regarding the interaction of these approaches within the food industry [4]. Nevertheless, practical research demonstrates that integrating these systems contributes to improving production efficiency, enhancing product quality, and optimizing management processes.

Research related to the implementation of quality management systems also provides important scientific conclusions. In particular, studies conducted in European food enterprises reveal that the effectiveness of quality systems remains low when they are not fully implemented, and in many enterprises the system exists only at a formal level [5]. This further strengthens the necessity of integrating quality management systems with lean manufacturing tools.

In addition, studies on the practical implementation of lean manufacturing show that it contributes to reducing costs, increasing profitability, and strengthening competitiveness in enterprises[6]. Especially under global market conditions, it has been scientifically proven that enterprises can reinforce their market position through the application of efficient production methods.

Modern research also indicates that lean manufacturing systems are entering a new stage through integration with digital technologies. In particular, industrial digitalization and the application of advanced technologies contribute to increasing the effectiveness of quality management systems[7]. This enables real-time monitoring of production processes and ensures stable quality assurance.

The analysis of the above-mentioned scientific sources demonstrates that the integration of lean manufacturing and quality management systems is an important instrument for increasing production efficiency, reducing losses, and ensuring competitiveness in enterprises[8]. However, particularly in the conditions of developing countries, the issues related to the comprehensive implementation of these systems and the evaluation of their economic effectiveness have not been sufficiently studied, which determines the scientific relevance of the present research.

Result And Discussion

Ensuring competitiveness in modern mechanical engineering enterprises is directly related not only to maintaining product quality in compliance with established requirements, but also to improving the efficiency of production processes.

Practical experience demonstrates that despite the implementation of quality management systems in enterprises, excessive operations, time losses, and inefficient use of resources still remain within production processes. This indicates the existence of a gap between quality management and production efficiency[9].

Within the framework of the research, the necessity emerged to develop a mechanism for the practical implementation of the proposed improvement model in mechanical engineering enterprises. The implementation process should not be carried out through disorganized or episodic measures, but rather through an algorithmic approach with clearly defined stages. Such an approach makes it possible to systematically analyze enterprise activities, identify priority areas, select appropriate lean manufacturing tools, and continuously evaluate the achieved results[10].

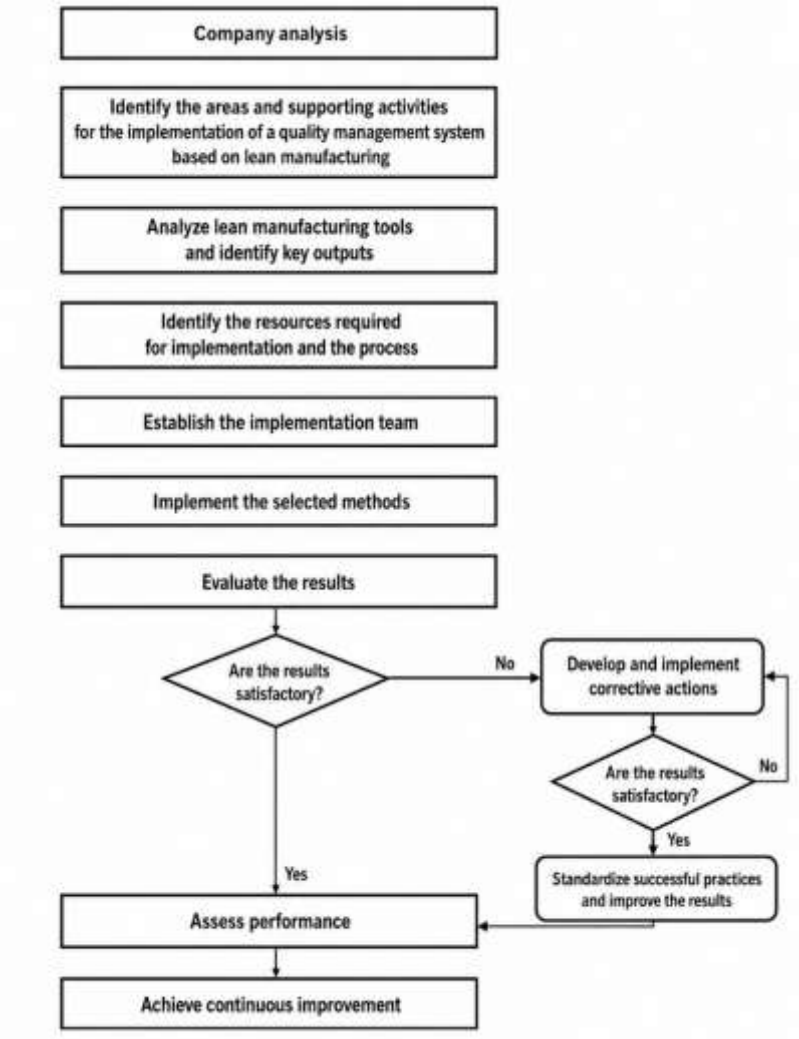

Figure 1. Scheme for Implementing a Quality Management System Based on Lean Manufacturing

The process of implementing a quality management system based on lean manufacturing principles in mechanical engineering enterprises should be organized through a step-by-step management scheme supported by feedback mechanisms. The proposed scheme ensures consistency in improving production processes, rational use of resources, and continuous monitoring of the effectiveness of implemented changes. This scheme covers all processes, beginning with the assessment of the actual state of enterprise activities and extending to continuous improvement[11].

One of the important features of the proposed model is the inclusion of a stage for evaluating results and formulating new objectives. Through this stage, the achieved outcomes are systematically analyzed, and further development directions are identified. Such an approach fully corresponds to the concept of continuous improvement, which is one of the fundamental principles of lean manufacturing[12].

Within the framework of the model, the use of an expert evaluation mechanism is also envisaged in order to determine the effectiveness of implementation. This mechanism makes it possible to comprehensively assess the changes achieved in production processes. The results of this evaluation serve as the basis for managerial decision-making at subsequent stages and are presented in the corresponding Table 1.

Table 1. Comparative Table of Performance Indicators

Evaluated Indicator	Average Score (Before)	Average Score (After)
1. Strategic Management Subsystem		
Existence of strategic direction	5.5	7.3
Formation of lean manufacturing philosophy	5.6	7.3
Lean manufacturing principles	7.6	8.3
Personal involvement of top management	5.8	7.5
Key Performance Indicators (KPI)	4.0	6.4
System for identifying customer requirements	3.9	6.2
Assessment of customer satisfaction level	3.9	6.2
Overall average	**5.2**	**7.0**
2. Personnel Subsystem		
Employee involvement in lean manufacturing	6.7	7.8
Employee motivation and incentive system	4.6	7.0
Quality and activity of improvement suggestions	7.1	8.1
Training and development of internal leaders	5.3	7.3
Existence of a learning (self-developing) organization	4.0	6.5
Overall average	**5.5**	**7.3**
3. Process Subsystem		
Level of 5S system implementation	6.2	7.9
Demand-based (pull) production system	3.2	6.1
Balanced distribution of workload	4.2	6.5
Visual management and control tools	4.7	7.0
Level of identifying and reducing losses	5.3	7.3
Improvement in product quality	5.5	7.6
Quality of service	4.7	7.0
Level of cooperation with suppliers	3.7	5.7

Level of cooperation with dealers	3.9	5.7
Overall average	**4.6**	**6.7**

The data presented in Table 1 indicate that after the implementation of the quality management system scheme based on lean manufacturing principles, significant positive changes were observed in the main management areas of enterprise activities. The results of the expert evaluation confirm that all subsystem indicators demonstrate a growth trend, which indicates the systematic nature of the implemented measures[13].

The expert evaluation results obtained after the improvement process show that the lean manufacturing system has been established within the enterprise as a stable and self-developing management model. This creates a solid foundation for increasing production efficiency, reducing losses, and ensuring product competitiveness.

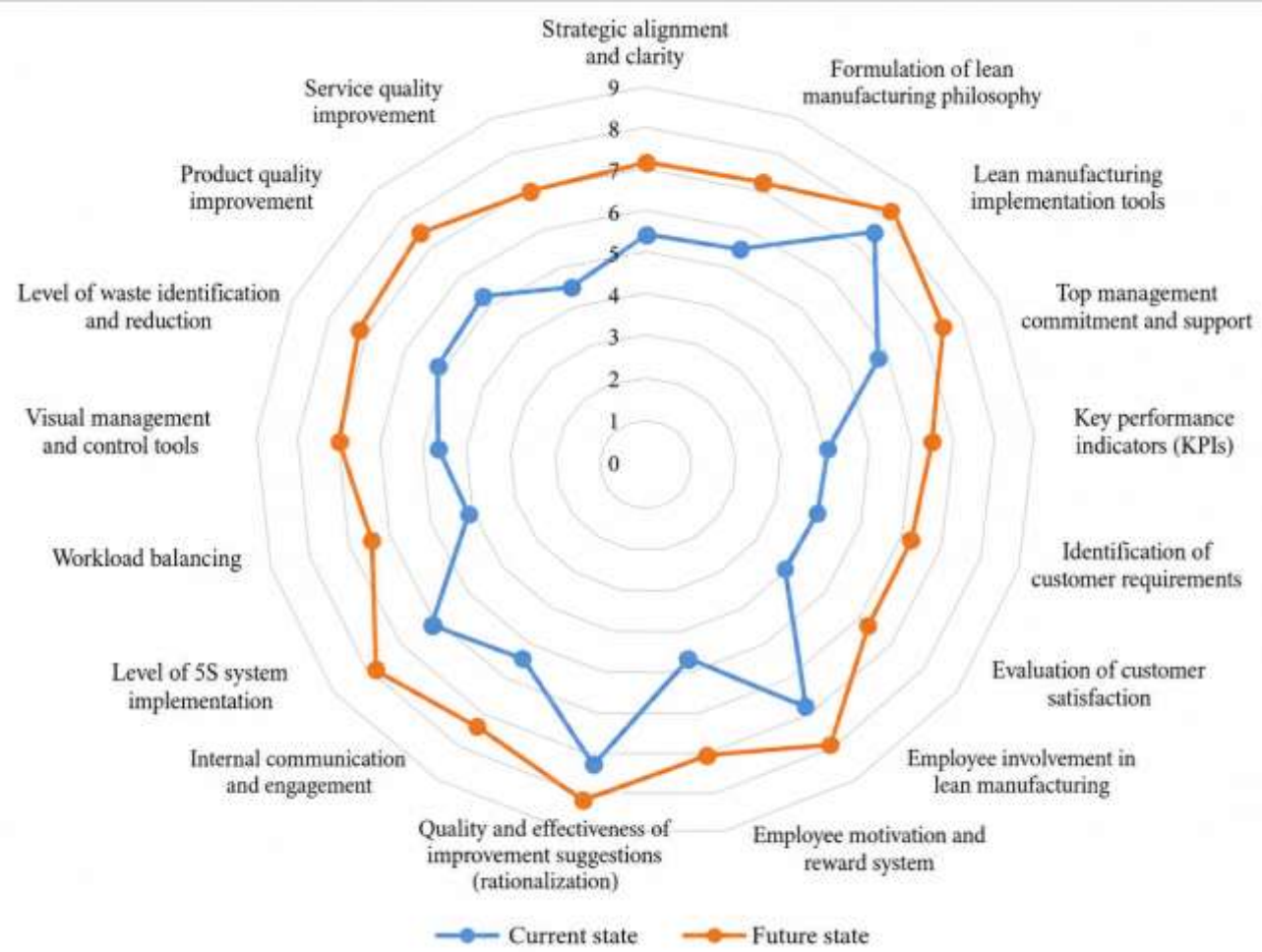

Figure 2. Expert Evaluation of the Lean Manufacturing System

Since the lean manufacturing approach is aimed at reducing activities that do not create value within production processes, economic efficiency is primarily achieved through the reduction of losses. Such indicators include, among others, the reduction of production inventories, shortening of transportation routes, decrease in unplanned equipment downtime, and improvement in the utilization level of production capacities. As a result of these changes, the achieved resource savings or additional increase in production volume are evaluated as conditional economic benefits.

To conduct the descriptive statistical analysis, the “before” and “after” values for each subsystem of the expert evaluation presented in Table 1 were used as the basis for analysis. This table includes 7 indicators related to strategic management, 5 indicators related to personnel, and 9 indicators related to processes. Based on these values, the following results were obtained (see Table 2)[14].

Table 2
Descriptive Statistics of Expert Evaluation Indicators

Subsystem	Condition	n	x̄	x_min	x_max	R	s²	s	V, %
Strategic Management	Before	7	5.19	3.9	7.6	3.7	1.88	1.37	26.33
	After	7	7.03	6.2	8.3	2.1	0.62	0.79	11.25
Personnel	Before	5	5.54	4.0	7.1	3.1	1.77	1.33	24.04
	After	5	7.34	6.5	8.1	1.6	0.39	0.63	8.65
Processes	Before	9	4.60	3.2	6.2	3.0	0.92	0.96	20.77
	After	9	6.76	5.7	7.9	2.2	0.64	0.80	11.89

Based on the analysis, it can be observed that the average scores significantly increased across all subsystems: from 5.2 to 7.0 in strategic management, from 5.5 to 7.3 in personnel, and from 4.6 to 6.7 in processes. This indicates that the improvement measures had a comprehensive impact on all areas of the management system.

In all subsystems, the mean value (x̄) increased, which indicates, according to expert evaluations, that the system elements have improved. The range of dispersion (R) decreased in all cases (for example, in the personnel subsystem from 3.1 to 1.6). This means that the gap between "strong" and "weak" indicators has narrowed, and management practices have become more balanced and consistent.

The standard deviation (s) and coefficient of variation (V) also decreased. In particular, in the personnel subsystem, the coefficient of variation declined from 24.04% to 8.65%, indicating that the evaluation results became more stable and consistent.

Table 3
Amount of Change and Growth Rate by Subsystems

Subsystem	x̄_before	x̄_after	Δx̄	Growth Rate, %
Strategic Management	5.19	7.03	+1.84	135.45
Personnel	5.54	7.34	+1.80	132.49
Processes	4.60	6.76	+2.16	146.96

Table 3 shows that the increase in the process subsystem was relatively higher (+2.16), indicating that the improvement measures had a stronger effect in the area of practical processes, such as 5S, visual management, reduction of losses, and related activities.

The descriptive analysis of the expert evaluation results demonstrated that after the implementation of improvements based on lean manufacturing principles, the average scores increased significantly across all three subsystems.

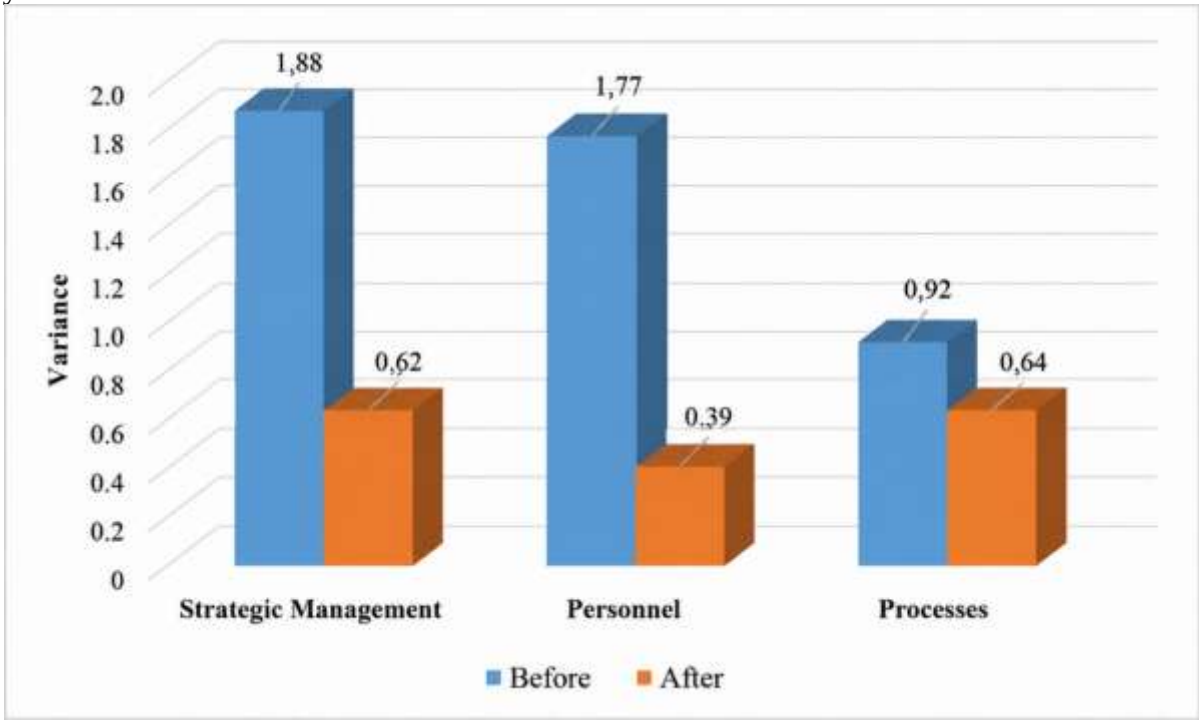

Figure 3. Comparison of Variance Based on Evaluation Results

As can be seen from the graph, the variance values in all subsystems significantly decreased after the improvement process. For example, in the strategic management subsystem, the variance decreased from 1.88 to 0.62; in the personnel subsystem, from 1.77 to 0.39; and in the process subsystem, from 0.92 to 0.64. This indicates that the expert evaluation results became closer to each other and that the differences in the development level of system elements were reduced.

The results of the conducted research confirmed that the integration of lean manufacturing principles with the quality management system is one of the important factors for improving management efficiency in enterprises. During the study, it was determined that the implementation of 5S, Kaizen, value stream analysis, and standardized work methods contributed to reducing excessive losses in production processes, increasing the efficiency of resource utilization, and ensuring process stability. In particular, the high growth rate observed in the process subsystem demonstrated the direct and strong influence of lean manufacturing tools on production efficiency[15].

According to the expert evaluation results, the average indicator in the strategic management subsystem increased from 5.19 to 7.03, in the personnel subsystem from 5.54 to 7.34, and in the process subsystem from 4.60 to 6.76. This indicates that lean manufacturing principles contributed not only to the improvement of production operations, but also to the enhancement of the enterprise's strategic management and human resource management systems. The research findings are consistent with the scientific conclusions of Shah and Ward and Womack and Jones, once again confirming the positive impact of lean manufacturing on production efficiency and quality performance indicators.

During the research, the reduction in variance and coefficients of variation was also evaluated as an important scientific and practical result. In particular, the decrease in the coefficient of variation in the personnel subsystem from 24.04% to 8.65% indicates that management practices became more standardized and that differences among system elements were reduced. This demonstrates that lean manufacturing principles strengthened management discipline within the enterprise through standardization and visual management tools. In this regard, the research findings practically confirm the scientific views of Bortolotti and co-authors concerning organizational culture and "soft lean practices."

Furthermore, the research results showed that the participation of top management and the involvement of employees are important factors in the implementation of lean manufacturing tools. The increase in the quality and activity of employees' improvement suggestions indicates the formation of a continuous improvement environment within the enterprise. At the same time, certain indicators, including the KPI system, customer requirement identification, and the pull production system, were found to be insufficiently developed. This suggests that, in addition to technological tools, it is necessary to develop management culture and motivational mechanisms when implementing lean manufacturing systems in enterprises.

Another important aspect of this study is that the integrated model of lean manufacturing and the quality management system was substantiated not only theoretically, but also through practical and statistical analysis. The results obtained through descriptive statistical analyses quantitatively confirmed the effectiveness of the implemented measures. This demonstrates the high potential for practical application of the developed model in mechanical engineering enterprises.

Conclusion

The results of this research demonstrated that the implementation of a quality management system based on lean manufacturing principles is an important factor in optimizing production processes, reducing losses, and improving overall management efficiency in enterprises. Through the application of 5S, Kaizen, value stream analysis, and standardized work methods, excessive operations in production were reduced and opportunities for the efficient use of resources were expanded. As a result, the level of defects decreased, while product quality and service performance improved.

The results of the expert evaluation also confirmed a significant increase in indicators across all subsystems, including strategic management, personnel, and processes. In particular, together with the increase in average evaluation scores, the reduction in variance and the coefficient of variation indicate that the management system became more stable and operational activities became more consistent. The highest growth observed in the process subsystem indicates that lean manufacturing tools had a strong direct impact on production processes.

At the same time, the problems identified during the study — including insufficient employee motivation, the underdeveloped KPI system, and the incomplete implementation of pull production principles in certain processes — indicate the necessity for further improvement of the system. By addressing these shortcomings, the integrated model of lean manufacturing and the quality management system can achieve even higher levels of effectiveness.

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