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Impact of Mechanical Automation Implementation, Lean Manufacturing System and Total Quality Management to Enhance Mechanical Firm Performance: Mediating Role of Operational Efficiency

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ABSTRACT

Purpose: In present competitive age, the aim of mechanical firms is to improve their performance by enhancing operational efficiency. Therefore, the aim of the present study is to explore the effect of mechanical automation implementation, lean manufacturing system, and TQM on mechanical firm performance. This study also explores the mediating effect of operational efficiency. Design/ method/ approach: In order to achieve the above-mentioned objective, the present study used a positivism approach. Quantitative research methodology was adopted. Data were collected from employees of mechanical firms using convenience sampling through questionnaires developed from past studies. Gathered data were analysed using SPSS and Smart PLS 4. Findings: The findings of the research show that mechanical automation implementation, lean manufacturing system, and TQM have positive effect on operational efficiency. Moreover, operational efficiency also has positive effect on mechanical firm performance. Additionally, mediating effect of operational efficiency is also significant as well. Originality: This study is among the few ones that discuss the mediating role of operational efficiency in the proposed framework. Importance of automated systems is also highlighted to enhance mechanical firm performance.

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1. Introduction

Mechanical automation implementation is considered a key strategy to improve production systems in modern manufacturing industries. Instead of depending on labor manually, organizations are preferring to adopt digital control systems, advanced sensors, programmable machines, and robotics to manage the activities of production (Deepika et al., 2024). Through mechanical automation implementation, machines are able to work with higher consistency and precision, minimizing dependence on human intervention. This factor also connects mechanical processes with intelligent monitoring systems, enabling better coordination and supervision of production tasks (Szeszák et al., 2025). By mechanical automation implementation, firms get the ability to strategize and rethink their flow of work to achieve more stable production output and smoother operations.

The importance of mechanical automation implementation can be viewed through faster production cycles and increased reliability (Koul, 2025). Mechanical automation implementation plays an important role in minimizing human error, supporting real-time monitoring, and enhancing product consistency of machine performance. Mechanical automation implementation enables predictive maintenance that helps to reduce downtime and prevent unexpected breakdowns. Through the improvement of production accuracy and machine utilization, operational cost is lowered and operational efficiency is strengthened. As a result, organizations that invest in mechanical automation implementation mostly achieve improved overall performance, stronger competitiveness, and better productivity (Atieh et al., 2025).

Total quality management is mainly recognized as a vital management system that focuses on continuous improvement of quality through technical tools, organizational values and structured processes (Peres et al., 2025). TQM emphasizes enhancing customer satisfaction through improvement of quality of services and goods while making sure that resources are utilized at the optimum level. The base of TQM is within the concept of quality that is defined as predictable reliability and uniformity at cost that is aligned with expectations of market (Uong, 2025). TQM is conceptualized as the factor that integrates managerial techniques with operational tools to improve both strategic outcomes and organizational processes. The basic idea of TQM is to focus on employee involvement, customer focus, and continuous improvement. TQM improves the consistency of the process by eliminating waste, minimizing defects and reducing variation, thereby operational efficiency is strengthened (Bobe & Teklay, 2025). Implementation of TQM in an effective manner needs alignment with organizational strategic plans, innovation-oriented strategies and trained human resources. By using different TQM practices, operational efficiency, competitiveness, and productivity of the firm is enhanced.

Lean manufacturing system is changed on the basis of a strategic production approach with the aim to restructure the process of manufacturing around systematic waste elimination and value creation. Rather than only focusing on reduction of cost, lean manufacturing system restructures the operational priorities through alignment of every activity that is linked with production and provides value to the customers (Yang et al., 2025). From this perspective, lean manufacturing system provides a challenge to the organization to examine unnecessary motion, waiting time, excess inventory, and process redundancies that increase operational costs. There is zero tolerance for activities that provide no value to the organization, so lean manufacturing system uses different performance and discipline transparency within the environment of manufacturing (Pereira et al., 2025). The strategic importance of lean manufacturing system is based on its ability to transform production systems into demand-driven, synchronized, and streamlined operations. Lean manufacturing systems provide strength to organizational productivity by enhancing coordination, improving process predictability, and stabilizing workflow (Saleem, 2022). By continuous standardization and improvement, lean manufacturing system enhances operational responsiveness and conformance quality. Lean manufacturing system is vital to improve the operational efficiency by reducing process variability and optimizing resource utilization.

Operational efficiency shows the effective utilization of human resources and raw materials, including workforce, equipment, machinery, and supplies, to enhance productivity while keeping cost under control (BERNADETTE et al., 2024). In the modern industrial environment, operational efficiency is not only a mechanism of cost control. In fact, it is one of the strategic capabilities that impacts the way organizational inputs are transformed into valued products in an effective way. Operational efficiency in different studies is conceptualized as procedural effectiveness and organizational competency, focusing on stakeholders' engagement in operational processes, structured resource deployment, and following performance-based standards (González-Blanco et al., 2024). Organizational size, production systems, and operational technology also impact the operational efficiency level achieved by the organization. When organizational resources are aligned systematically with the goals of production, operational efficiency strengthens overall operational control, reduces process variability, and enhances workflow visibility (Pakkala et al., 2024). The vitality of operational efficiency becomes more importance in mechanical and manufacturing industries where production systems are precision driven and capital intensive. Organizations that are able to improve their operational efficiency are able to minimize material waste, reduce downtime, optimize machine utilization and lower unit production costs (Burawat, 2024).

In mechanical industries, firm performance is important to reflect reliability, durability, and technical strength. It is also important to analyze the market competitiveness, profitability, and productivity of the mechanical industry firm (Kharub et al., 2022). Mechanical firm performance integrates business performance indicators with engineering efficiency, ensuring that different production systems operate consistently, efficiently, and safely. The performance and evaluation of mechanical firm performance are mostly dependent on output quality, precision, structural integrity, toughness, and stability. All these factors impact the financial performance of the mechanical firm. Mechanical firm performance is important for improvement in production workflows, reduction of inefficiencies, and enhancement of process coordination (Yılmaz et al., 2025). There are a number of benefits of strong mechanical performance such as stronger financial returns, better delivery performance, improved product quality and higher production reliability. Therefore, it is important for mechanical firms to look for factors that can improve mechanical firm performance. So, the aim of this study is to examine the effect of mechanical automation implementation, lean manufacturing system, TQM, and operational efficiency on mechanical firm performance.

2. Literature Review

2.1 Operational Efficiency and Mechanical Firm Performance

In literature operational efficiency is referred to as utilization of material resources and human resources encompassing the deployment of supplies, apparatus, instruments, and personnel (BERNADETTE et al., 2024). Using

these resources in a better way can be beneficial for organizations in a way that it will boost productivity and will save cost. Some of the past studies have characterized term operational efficiency as competency and efficiency of the organization. It is also termed as anything from chances given to the stakeholders of organization, so they get engaged in the process of policymaking and put into procedures and rules that meet the interests of stakeholders (Krishnamoorthy et al., 2025). The operational technology and organizational size play a key role in determining operational efficiency. On the other hand, mechanical performance is referred to as measurable ability of system, component and material to withstand strains, stresses and forces under certain conditions. It is used to evaluate important factors of engineering like stability, toughness, stiffness, and strength ensuring efficiency and safety (Ogunnowo et al., 2021).

There exists positive and direct association between mechanical firm performance and operational efficiency. In context of manufacturing and mechanical industries, organizations mainly rely on raw materials, skilled labor, technology and machinery for the production of goods (Zhang et al., 2018). Utilizing these resources in efficient way determines the way a firm can effectively convert input into outputs of high quality. When organizations optimize process of production, improve workflow coordination, determine downtime, and minimize waste, they enhance operational efficiency that has direct effect on the performance of organization in the form of improved performance outcomes (Arshad et al., 2020). Improvement in operational efficiency lowers the cost per unit at the production level, improves quality of products, and increases level of output. Therefore, organizations mostly experience better returns on assets, improved profitability, and higher operating margins. Usage of capital-intensive equipment in efficient way has reduced unnecessary expenditure, and increased asset utilization. In industries that are highly competitive, it is important to improve productivity and control the cost to sustain market position and maintain price competitiveness (Laužikas et al., 2021).

Furthermore, strategic position of the organization is strengthened because of operational efficiency (Obiki-Osafiele et al., 2024). Mechanical organizations that adopt advanced technologies, automation and manufacturing practices such as IoT and artificial intelligence has the ability to achieve consistent production performance and streamline operations (Zhang et al., 2018). Financial results of the organizations have improved because of this improvement along with improvement in customer satisfaction through quality assurance and timeline delivery. On the other hand, inefficient operations of organizations mostly lead to quality defects, equipment breakdowns, production delays and higher costs that negatively impact the performance of organizations. So, operational efficiency plays the role of important driver of mechanical firm performance. Organizations that prioritize process utilization and effective resource utilization are likely to achieve superior long term performance, stronger competitive advantage, and sustainable growth (Handoyo et al., 2023).

So, this research hypothesis that:

H1: Operational Efficiency has positive effect on Mechanical Firm Performance

2.2 Total Quality Management and Operational Efficiency

Studies have explained TQM as management system that focuses on improvement of quality through the application of processes, values and instruments (Efendi, 2022). The main aim of TQM is to enhance customer satisfaction by raising the quality of services and goods, whereas at the same time the usage of resources must remain low (Bhatti et al., 2025). The base of the definition of TQM is the definition of quality. In most of the studies, quality is defined as predictable level of dependability and uniformity at a cost that is low and suited to the market. There is distinction in definitions of TQM on the basis of processes, elements and content. The study by Riaz et al. (Riaz et al., 2023) has defined TQM as collection and philosophy of guiding principles for the combination of management techniques along with technical tools with improvement efforts in a system with improvement that targets firm management and process. TQM is considered as method based on environmental orientation that can help to diminish waste through the efficient and effective usage of reserves and resources (Zaidi & Ahmad, 2020). Ideology of TQM is continuous improvement and customer focus. Most of the organizations follow strategies of quality management to improve efficiency of services and goods to meet stakeholders and customer demands (Qerimi et al., 2023).

The consistency of the product can be boosted through total quality management by minimizing variation of the process leading to increased productivity gains, creativity and operational efficiency. The application of TQM is based in consistency in the strategic plan of the organization. Innovative learning activities should be promoted in the manufacturing sector to improve the efficiency and effectiveness of operations of organization. It is also needed to improve sustainable ability to innovate in long term and short term. It is possible to accomplish TQM if human resource of the organization is properly trained and they participate actively in management of quality to enhance operational efficiency (Nehme et al., 2024). The operations of manufacturing firms can be extended by focusing on innovation that will lead to improved performance. The rate of innovation within the organization is important for long term competitiveness and operational efficiency (Khan et al., 2020). In other words, TQM improves operational

efficiency by enhancing process consistency, minimizing waste, and reducing defects. TQM also plays important role in promoting customer focus, employee involvement, and continuous improvement. Therefore, organizations through TQM experience competitiveness, better performance, improved product quality, higher productivity and lower cost (Bhatti & Otamurodov, 2025). The results of Niyi Anifowose et al. (Niyi Anifowose et al., 2022) revealed the positive effect of TQM on operational efficiency.

Thus, this study assumes that

H2: Total Quality Management has significant positive effect on Operational Efficiency

2.3 Lean Manufacturing System and Operational Efficiency

In past studies, lean is explained as improvement of product value by eliminating waste during the production process. Lean manufacturing in industry plays important role in enhancing efficiency of production, lowering cost, reducing lead time and minimizing waste without compromising quality. Lean is a philosophy of management that focuses on minimizing waste and improving value during process of production (Ghelani, 2021). By using term value, lean means any product that fulfills the needs of the consumer who are also willing to spend on the product. When lean principles are integrated in organizational processes, it creates discipline in the system. In such process or system, there is almost zero acceptance for waste, and non-value adding programs, activities, and decisions that has the ability to result to higher cost of production. As a result, the productivity and profitability of the organization become limited (Okolocha & Anugwu, 2022). Lean manufacturing is production method that is systematic. It is used by the organizations to minimize the waste within the within the system of production keeping focus on quality and productivity (Cusiatado et al., 2024). Important lean manufacturing practices for manufacturing organizations are respect for human and its elements, continuous improvement, elimination of waste, detection of defects, mistake proofing and following standard procedure.

Lean manufacturing is used by organizations to improve their efficiency and effectiveness. It improves efficiency and effectiveness of the organization by reducing waste. In other words, the performance of organization is improved through reduced inventory levels, improving productivity, conformance quality and cost efficiency. Organizations around the globe are facing challenges of sustaining the operational efficiency and management of waste. Lean manufacturing use a sophisticated network of activities with purpose of improving efficiency. It also helps in creation of value through ongoing process improvement and waste reduction (Panigrahi et al., 2023). Several studies examined relationships between lean manufacturing and operational efficiency of the organization. scholars reported positive association between lean manufacturing system and organizational operational efficiency (Amos et al., 2018). Likewise, the study of Onwughalu et al. (Onwughalu et al., 2017) also documented that lean manufacturing has positive effect on operational efficiency by minimizing variation in demand, processing time and suppliers; thus elimination of waste. Similarly, the research of MONEME (MONEME, 2016) concluded that lean manufacturing system plays key role in optimizing organizational resources, and minimizing operational costs. They mentioned that lean manufacturing has positive effect on operational efficiency. So, it is hypothesized that

H3: Lean Manufacturing system has positive effect on Operational Efficiency

2.4 Mechanical Automation Implementation and Operational Efficiency

Studies has referred mechanical automation implementation as the systematic process of deploying, installing and designing technologies such as control systems, sensors and robotics with purpose mechanical production machinery with no or minimal human intervention (Mo et al., 2023). Engineering expertise combines with advanced hardware and software to control, execute and monitor manufacturing processes (Jasperneite et al., 2020). The integration of mechanical and control design is not only a simple technology execution. In fact, it is deep collaborative and fusion innovation of more than one field such as mechanical design theory, artificial intelligence technology, computer technology, and automatic control technology. By the implementation of automation, whole process of production of mechanical manufacturing can be controlled and optimized. It covers all aspects of process planning, structural design, and conceptual design of the project to production management, quality inspection and production processing (Xu et al., 2025). The main purpose is to build a flexible, intelligent and efficient mechanical manufacturing system that enables mechanical products to meet the personalized and diverse need of the customers. Such system also enhances the market competitiveness and production efficiency of and organization (Kozlova et al., 2021).

Mechanical automation implementation plays important role for the transforming of traditional manufacturing through replacement of manual labor with self-regulated and automated systems to enhance efficiency, safety, consistency and speed. The industrial operations are being revolutionize through automation by enhancing operational reliability, productivity, and efficiency in manufacturing (Wei et al., 2025). Mechanical automation systems has the ability to adjust different parameters, predict maintenance needs, and monitor output on real time analysis of data (Aminzadeh et al., 2025). By the process automation, different industries can ensure consistent quality of product,

reduce downtime and enhance production efficiency. Moreover, automated systems has the ability to coordinate with suppliers, manage shipments and track levels of inventory in real time leading to reduced operational costs and efficient operations. Such capability is important in different supply chains that are complex where accurate and timely data is impirtant for the process of decision making (Ajiga et al., 2024). Maintenance operations get benefit from automation of software. Different predictive maintenance systems use machine learning algorithms and data analytics for the forecasting of failure of equipment before they failure. Through the analysis of real time performance metrics and historical data, these systems have the ability for the prediction of maintenance at the time of need (Emma & Victoria, 2023). Therefore, downtime and unexpected breakdowns are reduced. The lifespan of different equipment is extended as a result of this proactive approach that later impacts operational efficiency (Deepika et al., 2024). Likewise, the research by Badhan et al. (Badhan et al., 2022) revealed positive effect of mechanical automation implementation on operational efficiency. So, this research hypothesized that

H4: Mechanical Automation Implementation has significant effect on Operational Efficiency

2.5 Mediating Role of Operational Efficiency Between TQM and Mechanical Firm Performance

Studies have widely acknowledged the strategic importance of TQM to enhance the mechanical form performance through process standardization, employee involvement, customer focus, and continuous improvement (Pawanr et al., 2025). Whereas the relationship between mechanical firm performance and TQM is indirect. In mechanical firms, where production reliability, cost control and precision engineering are vital, operational efficiency plays a key mediating role. Different practices of TQM include continuous improvement, preventive maintenance, supplier quality integration, and statistical process control initiatives to reduce rework, waste and defects. As a result of these improvements, production cycle is shortened, resource utilization are optimized, and production cost is optimized (Reza et al., 2025).

Subsequently, efficiency of the whole process is increased and that further improves customer satisfaction, product quality consistency and reliability that are later translated into enhanced market and financial performance. Thus, operational efficiency plays the role of conversion mechanisms by which initiatives of TQM are converted into measurable performance outcomes in mechanical firms. In past, operational efficiency is discussed as mediating variable (Liu & Jiang, 2025). The study of Mantje et al. (Mantje et al., 2023) revealed mediating effect of operational efficiency in their study. So, this research hypothesized that:

H5: Operational efficiency mediates between TQM and Mechanical firm Performance

2.6 Mediating Role of Operational Efficiency Between Lean Manufacturing System and Mechanical Firm Performance

Studies discussed that lean manufacturing systems are basically designed for the enhancement of process flow and elimination of non-value adding practices. Different lean practices including continuous flow, value streaming and just-in-time production are mostly linked with improved outcomes of the firm (Habib et al., 2023). The performance of these organizations is dependent on the effectiveness of internal operations of organizations. In context of mechanical firms that operate with complex machinery, tight production tolerance, and high material costs, operational efficiency is treated as important transmission channel. Different lean initiatives optimize sequencing of workflow, minimize downtime of machine, and reduce excess inventory thus improving capacity utilization and organizational output (Mohammadkamal et al., 2025).

As a result of these operational improvements, production responsiveness and cost effectiveness are enhanced that later impacts the competitive positioning and profitability of the mechanical firm. In the absence of tangible gains in the context of operational efficiency, lean implementation may just work as procedural rather than enhance performance (Panigrahi et al., 2023). So, operational efficiency plays the role of structural mediator that improves different principles of manufacturing into financial and operational gains. The research by Mantje et al. (Mantje et al., 2023) and Zhihuang and Yuchen (Zhihuang & Yuchen, 2025) revealed positive mediating role of operational efficiency in their study. So, present study assumes that:

H6: Operational efficiency mediates significantly between lean manufacturing systems and Mechanical firm Performance.

2.7 Mediating Role of Operational Efficiency Between Mechanical Automation Implementation and Mechanical Firm Performance

Mechanical automation implementation by using different sensor monitoring, automated assembly lines, CNC systems and robotics shows advancements in technology having aim of improved production and precision capacity (Deepika et al., 2024). Whereas adoption of technology does not assure superior performance automatically. The gain of performance from automation is converted in case technological capabilities are translated into improved

operational efficiency. In different mechanical firms, automation plays very important role in increasing rates of machine utilization, shortens processing time, stabilizing production quality and reduces human error. These improvements minimize variability in the organizational output and continuity of the workflow. Therefore, operational efficiency of the mechanical firm is strengthened (Koul, 2025).

In case of improved efficiency, the production cost per unit is lowered, delivery speed is enhanced and support to the products is provided on regular basis that later improves market competitiveness and profitability collectively. The contribution of automation towards mechanical firm performance remains limited if only capital intensity is enhanced through automation without focusing on improvement pf process efficiency (Govindan et al., 2022). So, operational efficiency has the ability to operate as mediator between mechanical automation implementation and mechanical firm performance. The study of (Bindeeba et al., 2025) revealed positive mediating influence of operational efficiency. So,

H7: Operational efficiency mediates between mechanical automation implementation and Mechanical firm Performance.

On the basis of above literature, research frameowork is developed showing three independent variables, one mediator and one dependent variable (see figure 1).

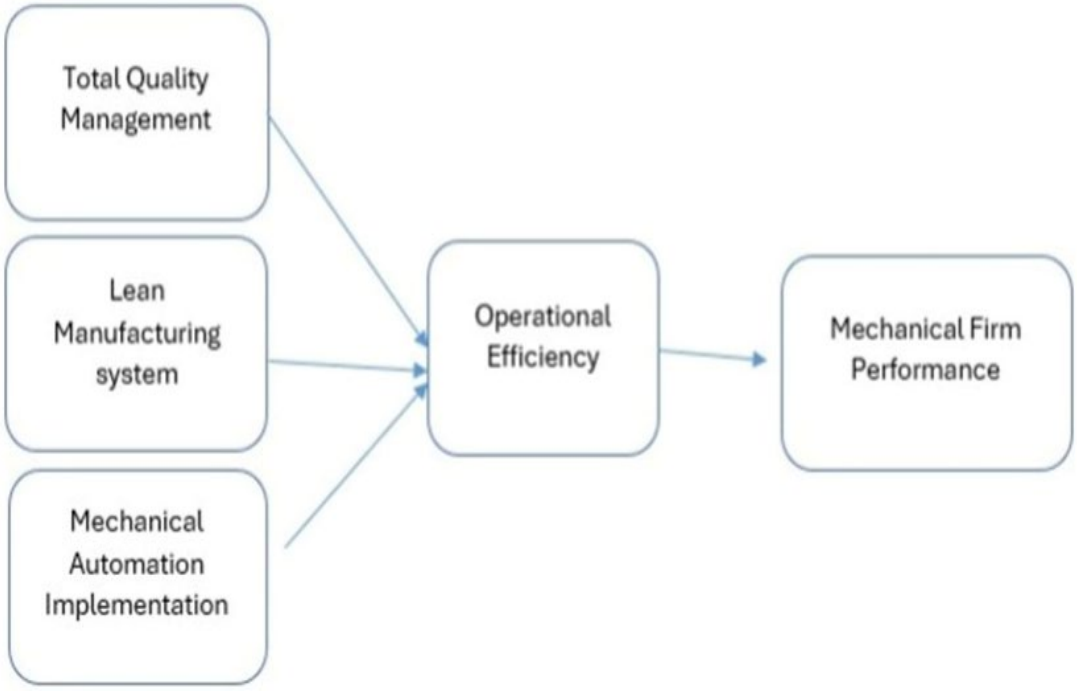

Figure 1: Framework

3. Methodology

The basic purpose of the present research is to explore the impact of TQM, lean manufacturing system, and mechanical automation implementation on mechanical firm performance through mediation of operational efficiency. On the basis of this aim, this research considered positivism because it is suitable way that helps the researchers to attain the aim of study. Consequently, quantitative and deductive approaches were used for gathering the research data. Questionnaire was used as a mean to collect the response from the respondents. Questionnaire are also important for testing the hypothesis and for generalizing the results. The population of the study were employees working in different mechanical firms. The questionnaire was developed on the basis of past studies to collect the response from the employees. The items of TQM were adapted from Demirbag et al. (Demirbag et al., 2006), measurement scale of mechanical automation implementation were adapted from the study of Uddin and Jayaram (Uddin & Jayaram, 2025), scale of lean manufacturing system was adapted from Shrafat and Ismail (Shrafat & Ismail, 2019), measurement items of operational efficiency were adapted from Lee et al. (Lee et al., 2012), and questionnaire of mechanical firm performance were adapted from Sahoo and Yadav (Sahoo & Yadav, 2017).

The sample size of the study was 350 employees. Convenience sampling technique was used for the data collection.

237 usable responses were received for further analysis. This collected data was analysed using SPSS version 26 and Smart PLS 4. Demographic analysis of the respondents was conducted through SPSS. Whereas hypothesis testing was carried out through Smart PLS 4. Present research selected Smart PLS because it is one of important tool to conduct SEM analysis. In past, different business and social science studies have mentioned greater dependency on SEM as vital method for the analysis purpose (Sarstedt et al., 2014). Moreover, PLS-SEM is best tool for the SEM analysis.

4. Results

The analysis at the beginning stage was conducted through SPSS with purpose to assess the demographics of the respondents. The outcomes show that 81.21% of respondents were male and 18.79% respondents were females. Moreover, 68.91% respondents were single and remaining were married. In terms of age, 27.11% respondents had the age between 18 to 30 years, 42.21% of employees mentioned their age between 31 to 40 years and remaining had the age of more than 41 years.

Table 1: Loading

	LMS	MAI	MFP	OE	TQM
LMS1	0.910				
LMS2	0.885				
LMS3	0.898				
LMS4	0.912				
LMS5	0.873				
LMS6	0.858				
MAI1		0.920			
MAI2		0.889			
MAI3		0.920			
MAI4		0.870			
MFP1			0.891		
MFP2			0.866		
MFP3			0.908		
MFP4			0.895		
MFP5			0.888		
OE1				0.918	
OE2				0.834	
OE3				0.903	
OE4				0.908	
OE5				0.865	
TQM1					0.887
TQM2					0.849
TQM3					0.853
TQM4					0.845
TQM5					0.830

The analysis through Smart PLS begin with measurement model, where first assessment is factor loading. According to Hulland (Hulland, 1999), cut-offline for factor loading is 0.40. The items having factor loading of less than 0.40 should be eliminated. Table 1 shows that items retained in present study have loading of more than 0.40.

In order to examine the internal consistency of the reflective variables, present study relied on the values of composite reliability. Hair Jr et al. (Hair Jr et al., 2017) mentioned that values of CR should be higher than 0.70. Table 2 of the present research shows that all values of CR are higher than 0.70 (Hair et al., 2012). Later, AVE was examined to evaluate the level of correlation among the variables. Based on recommendations of Sarstedt et al. (Sarstedt et al., 2014), the cut-off line of AVE is 0.50. Table 2 of the study shows that values of AVE are higher than 0.50, meeting the criteria.

Table 2: Internal Consistency

	CR	AVE
LMS	0.958	0.791
MAI	0.945	0.810
MFP	0.950	0.791
OE	0.948	0.785
TQM	0.930	0.727

Further, test of discriminant validity was carried out to confirm the sub type of validity of constructs. This test is carried out to explore the relatedness among variables of study (Henseler et al., 2015). Two different approaches are used for the confirmation of discriminant validity. One of the latest techniques used for the discriminant validity is HTMT technique, which supersede the Fornell and Larker approach. Henseler et al. (Henseler et al., 2015) recommended the values of HTMT table should be less than 0.85. Table 3 shows that all values of discriminant validity are less than 0.85, meeting requirement.

Table 3: Discriminant Validity

	LMS	MAI	MFP	OE	TQM
LMS					
MAI	0.614				
MFP	0.420	0.485			
OE	0.585	0.533	0.466		
TQM	0.301	0.386	0.402	0.631	

In the end of initial stage of assessment through Smart PLS 4, correlation of determination also known as R2 was carried out. The value of R square ranges from 0 to 1. It shows the effect of exogenous variables on outcome variables. Results, in Table 4, show that DV of the study is affected more than 19% and mediator is affected more than 50% by the proposed independent variables.

Table 4: R2

	R-Square
MFP	0.195
OE	0.517

4.1 Structural Equation Modelling Results

The second phase of the analysis is to evaluate the proposed hypothesis. For this purpose, bootstrapping procedure was adapted by using 5000 subsamples. Direct and mediating results were determined on the basis of P and T values. Whereas Beta value determined the nature of relationship among variables. The results (as mentioned in Table 5) of the study shows that LMS has positive influence on OE with t=4.854, so the proposed hypothesis is accepted. Likewise, MAI has positive effect on OE with t=2.077, accepting the hypothesis; TQM has significant positive effect on OE, with t=6.063, supporting hypothesis; and OE has significant effect on MFP with t=7.688, accepting hypothesis.

Table 5: SEM Results

	Beta	SD	T Value	P Values
LMS -> OE	0.349	0.072	4.854	0.000
MAI -> OE	0.147	0.071	2.077	0.019
OE -> MFP	0.441	0.057	7.688	0.000
TQM -> OE	0.431	0.071	6.063	0.000
TQM -> OE -> MFP	0.190	0.041	4.610	0.000
LMS -> OE -> MFP	0.154	0.036	4.271	0.000
MAI -> OE -> MFP	0.065	0.033	1.959	0.025

Table 5 also show the mediating results as well. The statistical figures show that OE mediates between TQM and MFP, having t=4.621, OE mediates between LMS and MFP, with t=4.271, and OE also mediates significantly between MAI and MFP, t=1.959. So, all proposed mediating hypotheses are supported.

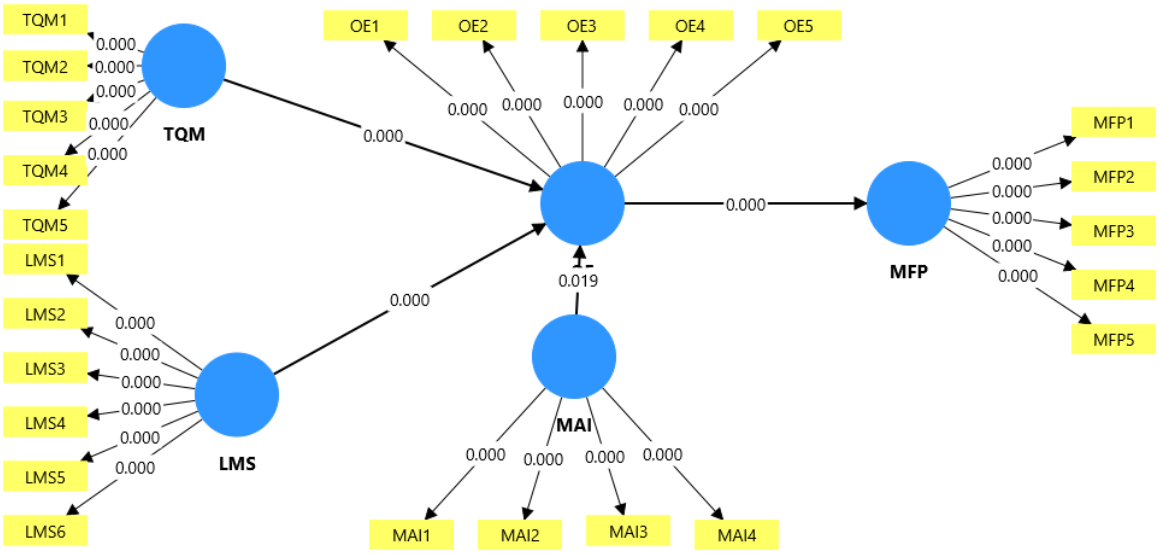

Figure 2: Structural Model

5. Discussion

Results of the study showed that operational efficiency has significant positive effects on mechanical firm performance. These results suggest that when mechanical firms are able to manage their operational processes in effective way, they will achieve higher mechanical firm performance. In different mechanical firms, different operational activities including timely completion of tasks, workflow management, machinery utilization and production coordination has direct contribution to improving mechanical firm performance. This result is further strengthened because data is collected from employees working in different mechanical firms. Employees who are involved directly in process of operations are able to observe the way improvement in operational efficiency impacts outcomes and daily activities within mechanical firms. The results also show that better use of organizational process, reduced delays and smoother operational processes contributes significantly to enhance mechanical firm performance.

Furthermore, mechanical firms are allowed to minimize their operational costs through operational efficiency while maintaining consistent product quality. Because of these improvements, strong support is provided to mechanical firm performance by enabling firms to remain competitive and operate in productive manner. So, improved operational efficiency is one of the important driver of mechanical firm performance in context of mechanical industry. These results are similar to the findings of (Handoyo et al., 2023) in Past.

Findings of the study also revealed that TQM has positive effect on Operational efficiency Niyi Anifowose et al. (Niyi Anifowose et al., 2022). This positive relationship shows that mechanical forms that implement different practices of TQM are able to manage their operational activities in very organized manner. Mechanical firm are encouraged because of TQM on continuous monitoring, process consistency and quality improvement of operational tasks. BY adopting TQM practices, mechanical firms are able to focus on continuous monitoring, process consistency and quality improvement of operational tasks. By the adoption of TQM, mechanical firms are able to introduce corrective measures after identification of weaknesses in their procedures that enhance their operational efficiency.

The basic rule of TQM is to promote structured management of process. It also focuses on maintaining quality standards at different stages of operations. When mechanical firms actively participate in TQM, their operational activities become more standardized and coordinated that minimize operational disruptions and inefficiencies. As a result of this structured approach of TQM, mechanical firms are able to control their operational workflows. Furthermore, culture of continuous improvement is encouraged through TQM that become important part of organizational operations. Mechanical firms are able to refine their operations and processes with the passage of time because of consistent focus on improvement. Ultimately, operational efficiency of the mechanical firm is strengthened that ensures effective operational performance.

The results of present research also indicate that lean manufacturing systems have significant effect on operational efficiency in context of mechanical firms as proposed by the study of MONEME (MONEME, 2016) in literature. These findings show that mechanical firms are able to improve their efficiency and streamline their process of production because of adoption of lean manufacturing system. Complex machinery is involved in production process of mechanical firms. There is need of continuous improvement and coordinated workflow in these mechanical firms.

In these scenarios, lean manufacturing system plays important role to improve process flow and minimize unnecessary operational steps.

Mechanical firms are able to ensure smoother production systems, improve resource utilization, and minimize waste by implementing lean manufacturing systems. Lean manufacturing system provides support to enhanced operational coordination and better organizational production tasks by eliminating activities that are non-value adding. Therefore, mechanical firms that adopt lean manufacturing systems are in better position to achieve higher level of operational efficiency. Additionally, mechanical firms are encouraged to improve their production activities on continuous basis through lean manufacturing system. By consistent usage of lean manufacturing systems, mechanical firms are able to maintain effective operational processes, strengthen overall operational efficiency and minimize production delays.

The empirical result of the present study reflects that mechanical automation system has significant contribution towards operational efficiency in perspective of mechanical firms. The application of mechanical automation system allows mechanical firms to perform their operations with greater consistency, speed, and precision. In different mechanical firms, Accurate machine coordination and continuous monitoring is required for routine manufacturing tasks. The usage of mechanical automation system provides support to these activities by allowing control and machine system to work in synchronized manners that improves their operational efficiency.

Mechanical firms are also able to reduce chances of any operational disruption that is caused by process inconsistencies and manual handling by implementing mechanical automation system. Through integration of mechanical automation system, mechanical firms ensure smoother management of workflow and maintain stable production cycle. Furthermore, mechanical automation system provides assistance to mechanical firms in minimizing operational delays and maintaining production reliability. The operational activities of mechanical firms become more structured by using mechanical automation system in production cycle. Ultimately, operational efficiency of the mechanical firm is strengthened. These results are aligned with the results of Badhan et al. (Badhan et al., 2022) in Past.

Study also analyzed mediating role of operational efficiency. The results reported that operational efficiency mediated between TQM and Mechanical firm Performance. when different mechanical firms apply practices of TQM, they focuses on systematic management, quality control, and process improvement of operational activities. As a result of these practices, operational efficiency is enhanced that contributes to mechanical firm performance. The application of TQM in mechanical firms help in reducing efficiencies and organizing operational processes. With improvement in operational efficiency, mechanical firms are in better position to achieve optimized mechanical firm performance. So, Operational efficiency plays key role to strengthen relationships of TQM and mechanical firm performance.

Results also confirms that Operational efficiency mediates positively between lean manufacturing system and Mechanical firm Performance. The focus of lean manufacturing system is on continuous improvement, streamlined workflows and waste reduction across production processes. When different mechanical firms use lean manufacturing systems, their resource utilization improves and operational activities become organized. As a result of such improvement delays are reduced, and production errors are minimized that further enhances operational efficiency. With enhancement of operational efficiency, mechanical firms deliver products with lower operational costs and with better quality. As a result, lean manufacturing lead to higher mechanical firm performance through enhanced operational efficiency.

Statistical results also show mediating effect of operational efficiency between mechanical automation implementation and Mechanical firm Performance. Implementation of different automation systems including control technologies, sensors and robotics, the operations of mechanical firms are speed up and human errors are reduced. It leads to higher quality of products. Whereas enhancement of operational efficiency shows the full benefits of automated system because it ensures that automated system integrate workflows on daily basis. By improving operational efficiency, machine productivity, resource utilization and process coordination, operational efficiency enhances positive effect of mechanical automation on mechanical firm performance. These mediation results are consistent with the results of Zhihuang and Yuchen (Zhihuang & Yuchen, 2025) who also confirmed mediating effect of operational efficiency.

6. Limitations and Suggestions

This section will discuss few limitations and recommendations to overcome these limitations in future. The R square value of DV shows that it is affected approximately 19% by other variables of the study. It means that other variables should be included to improve R square value. Moreover, present study used convenience sampling for the collection of data from the respondents. It is proposed that studies may use simple random sampling for the same purpose is future. Furthermore, Proposed framework of the study is based on one mediating relationship. It is proposed

to expand the model by introducing sequential mediation in the form of sustainability variables. In the end, tool used for analysis in present study is Smart PLS 4. It is proposed to analyse similar data through AMOS in future.

7. Theoretical and Managerial Contribution

This study has both managerial and theoretical contributions. From the lens of theoretical contributions, this research improves the understanding of the way lean manufacturing systems and mechanical automation implementation impacts mechanical firm performance by operational efficiency. Results also extends existing literature of operational efficiency by confirming mediating role of operational efficiency, shedding light on the importance of lean practices and automation system. Results also provide a different perspective on the relationship between process optimization, and technology adoption that contributes to literature through integration of performance outcomes, lean principles, and integrated automation in mechanical firms.

From the lens of mechanical contribution, this study provide guidance to practitioners and managers. For mangers, the results show the importance of investing in lean manufacturing and mechanical automation to improve the operational efficiency of the firms. Also, technology implementation cab help managers to improve competitiveness, lower costs and higher productivity. Future studies can use these results for their upcoming studies as well.

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