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Evaluating the Effect of Implementing Preventive Maintenance Systems on Productivity and Operational Efficiency in a Plant (Case Study: Lordegan Petrochemical)

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Abstract

The maintenance and repair process is one of the most vital processes in manufacturing organizations, with its primary task being the maintenance and preservation of production machinery in optimal conditions or returning them from conditions that hinder the production of a quality product to optimal operational conditions. This study examined the impact of the relationship between Total Productive Maintenance (TPM) and plant operational processes, with the mediating role of Total Quality Management (TQM) in the Lordegan Petrochemical Complex. The research method is quantitative and survey-based. The sample size, determined using Cochran's formula, consisted of 202 employees from the Lordegan Petrochemical Complex, and data collection was conducted via a questionnaire. Experts and specialists confirmed the validity of the questionnaire, including its convergent and content validity. Reliability coefficients for the variables of TPM, operational processes, and TQM were found to be 0.873, 0.881, and 0.859, respectively, indicating high reliability. Data analysis was conducted using SPSS 26, and inferential analysis of the research variables was performed through Structural Equation Modeling (SEM). The study's findings indicated that implementing TPM has a positive impact on improving operational processes and enhancing quality management in petrochemical industries. This impact is reinforced through reducing breakdowns, increasing productivity, and fostering a sense of responsibility among employees. Additionally, the mediating role of TQM in strengthening these effects has been confirmed.

Keywords: Total Quality Management, Maintenance, Operational Processes, Total Productive Maintenance, Lordegan Petrochemical Complex.

Introduction

The maintenance and repair process is one of the most critical processes in manufacturing organizations, with its primary function being to maintain and preserve production machinery in optimal conditions or restore it from conditions where a quality product is not possible. Machine breakdowns lead to the loss of available production time and increased organizational costs. Therefore, improving the performance of machinery consistently enhances the maintenance and repair process, a concern that has been the focus of specialists in the field (Zahabi, 2021). This method divides operational tasks among departments and prevents the concentration of operations within one section. On the other hand, Total Quality Management (TQM) is a process where management focuses on continuous quality improvement with the participation of employees, customers, and stakeholders. Today, Total Productive Maintenance (TPM) and quality management are integrated processes, so it is not feasible to implement them in a one-size-fits-all approach across organizations (Mahalle, 2018). TQM describes a culture and organizational structure aimed at providing products and services that meet customer expectations and ensure their satisfaction. Therefore, the first step is to eliminate weaknesses and deficiencies in processes so that they can be correctly and fully implemented. This structural model comprises five factors: three internal and two external factors. The internal factors include processes, products, and human resources (Talib et al., 2021). The external factors include customers and suppliers. Total Productive Maintenance (TPM) is a methodology for managing physical assets with a focus on maintaining and improving the performance of production machinery while simultaneously reducing production costs. TPM, or Total Effective Maintenance, is a type of maintenance policy aimed at maximizing the productivity and effectiveness of equipment through a comprehensive preventive maintenance system designed to enhance the equipment's entire lifecycle (Tzafilkou et al., 2022).

The increasing importance of internet-related issues has led to numerous studies in this field. Although thousands of network models have been created, only a few network policies can regulate all network models. (Sauze, 2020) Network policies are divided into two main categories: the protective network category or, in short, preventive maintenance, which refers to the operation of network activities before a failure occurs. This network is created while the system is still operational. An activity is a set of actions to maintain part of a system or the entire system in a specific and optimal state through regular inspections to prevent potential failures (Jafari et al., 2019).

The other category of networks is condition monitoring, which refers to the operation of network activities such as replacement or repair in the event of a failure. This observation occurs when an expected system failure takes place. Ultimately, this observation is defined as a set of activities resulting from failure to return the system to a defined and acceptable state (Sajadi Nejad et al., 2018). An organization must be sufficiently prepared to conduct preventive and corrective observations throughout production. Performing system repairs can lead to further failures, generally due to the unavailability of spare parts, trained personnel, specialized tools, and maintenance facilities. Preventive maintenance methods include inspections, replacements, repairs, and scheduled equipment servicing. Such a program obligates the organization to plan for its skilled personnel to monitor the equipment's condition and ensure its proper functionality. Ultimately, if the equipment is not in an optimal condition, the organization can repair or replace it. Addressing these issues highlights the importance and superiority of implementing a preventive maintenance system over condition monitoring. It explains to readers why preventive maintenance was chosen as the focus of the current study (Zeya et al., 2023). In today's competitive environment, manufacturing industries face numerous challenges in maintaining productivity and quality. One of the main concerns of managers is reducing the costs caused by equipment failures and production downtime, which can lead to decreased profitability and competitiveness. The Total Productive Maintenance (TPM) system has been introduced as a comprehensive solution aimed at enhancing the effectiveness of equipment and reducing failures. This system enables continuous process improvement through the involvement of employees and optimal equipment management. At the same time, Total Quality Management (TQM) is recognized as a strategic approach for enhancing organizational culture and improving the quality of services and products. Combining these two approaches can help reduce operational costs, increase customer satisfaction, and enhance the organization's competitive position. However, research in this area remains limited, especially within Iran's petrochemical industry. This study examines the effects of Total Productive Maintenance (TPM) on operational processes and the mediating role of Total Quality Management (TQM).

Research literature

Today, managers in manufacturing industries are striving to align their organizations with the current competitive environment. They aim to create a competitive edge by focusing on timely delivery, improving product quality, and reducing costs to establish a favorable position for their business. Maintenance plays a key role in reducing costs, minimizing machine downtime, increasing production capacity, improving quality, and enhancing the productivity and reliability of machinery, all of which contribute to achieving organizational goals (Prajogo, Huo, & Han, 2023). While the concept of Total Productive Maintenance (TPM) is not new in today's global competitive landscape, it has yet to achieve significant success in Iran due to a lack of proper training and insufficient attention to the effective role of human resources. Consequently, it remains underdeveloped (Prajogo & Sohal, 2024). Undoubtedly, employees are the main driving force behind the development of any industry. Even in industries with substantial equipment weight, employees are often excluded from decision-making due to weak teamwork (Yazdanjo et al., 2020). The current trend in the world has led to relative stability in the market for manufactured goods in many countries, causing competition to expand beyond local and regional levels to the global stage. Manufacturers relying on outdated methods and traditional approaches while neglecting modern knowledge will likely suffer in this global competition. Creating value in today's competitive world requires new knowledge and skills. World Class Manufacturing (WCM) is a level of organizational performance that enables competitiveness in the global arena and can provide an effective response to the current needs of the business world. Familiarity with modern sciences is the first step toward moving toward world-class production. As a new philosophy in production, world-class manufacturing enhances production and elevates the organization's overall level, positioning it among the top global companies and emphasizing the importance of production operations and quality control (Peyman, 2021). Among the concepts that have gained significant attention in many organizations today are quality and continuous improvement. Modern organizations must inevitably focus on the quality of their products and services to survive, retain existing customers, attract new ones, and ultimately increase their revenue. Effective management makes this goal possible (Tortora et al., 2023). To achieve sustainable development, each organization must employ complex models that combine Total Quality Management (TQM) and strategic management principles. The European Foundation for Quality Management (EFQM) model is a comprehensive framework for assessing organizational performance. It focuses on designing and implementing performance evaluation systems, measuring the agility of organizations in benchmarking and optimizing their path, efficiently executing objectives, reviewing outcomes, and evaluating the effectiveness of actions taken. This model determines the success levels of organizations in achieving their goals and attaining excellence (Arno et al., 2019). One of the management systems that can assist organizations in improving the quality of their products and services is Total Quality Management (TQM). TQM involves the participation of all employees in delivering the final product or service to the customer. It is a managed process that includes employees, systems, tools, and supporting techniques. Therefore, TQM is a change agent that creates an organization motivated by customer orientation (Harrison, 2023). Furthermore, the increase in investments in industrial machinery and automation, on the one hand, and the growing financial and economic value of these assets, on the other hand, have led managers and industrial owners to seek logical solutions that can maximize the useful life of production equipment and extend their economic lifecycle. The increase in the effectiveness of machinery and improvement in product quality, alongside cost reduction and the prevention of environmental damage, were among the factors that led to a new transformation in the field of maintenance and repair (Keres et al., 2021). Over time, this has expanded to include numerous concerns, describing various cost-effective methods for operationally maintaining equipment, whether before or after a failure. *Maintenance functions* are often defined as maintenance, repair, overhaul, maintenance, repair, and operation (Fouladgar et al., 2019). The terms "maintenance" and "overhaul" have been standardized in service practices. The United States Department of Defense uses the following definitions: activities such as tests, measurements, placements, adjustments, and repairs intended to maintain or restore a unit's functionality to a specific condition, allowing it to perform the necessary tasks. All actions are taken to keep materials usable or restore them to serviceability. This scheme includes inspections, testing, servicing, classification regarding serviceability, repair, overhaul, and restoration (Nikolopovas et al., 2023).

The main objective of preventive maintenance is to ensure that equipment operates from one scheduled service to the next without any failures caused by fatigue, neglect, or normal wear and tear (preventable issues). Scheduled maintenance, based on repairs and maintenance, helps achieve this by replacing worn-out parts before they fail. Maintenance activities include minor or full additional costs at specified intervals, such as oil changes, lubrication, and minor adjustments. Furthermore, workers can record equipment failures to replace or repair worn-out parts before they cause system breakdowns (Walmohammadi et al., 2021). The primary objectives of preventive maintenance are to strengthen capital equipment, reduce failures in critical equipment, and minimize production losses due to equipment breakdowns (Dastkar et al., 2019).

Preventive maintenance, or maintenance aimed at preventing breakdowns, includes the following meanings: care and servicing by personnel to maintain equipment in satisfactory operational conditions through systematic inspections, identification, and correction of early failures before they occur or before they develop into significant faults. Equipment work to prevent failure or malfunction is a regular and routine action performed on the equipment to avoid its breakdown. Maintenance includes tests, measurements, adjustments, part replacements, cleaning, and specific actions taken to prevent errors from occurring (Gang et al., 2022).

The implementation of condition-based maintenance requires a system for data collection and a set of measurement tools to monitor the performance of machinery during operation. By continuously monitoring the operating conditions of machinery, abnormal conditions can be quickly identified, enabling timely corrective actions and, if necessary, stopping the machinery before a failure occurs (Sajedi Nejad et al., 2019). Common approaches for data collection include vibration monitoring, oil analysis, and ultrasonic testing. Based on data analysis, when a monitored parameter exceeds a specific threshold, components are repaired or replaced. This strategy is often used for rotating or reciprocating machinery such as turbines, centrifugal pumps, and compressors. (Fernandes et al., 2020). Predictive maintenance may significantly reduce production costs and improve quality, profit margins, and market share. However, coverage and data quality limitations lessen the effectiveness and accuracy of predictive maintenance strategies (Chen & Chen, 2019). A key factor in determining when and why maintenance is conducted is scheduling, which involves the availability of services, resources, or facilities. In contrast, condition-based maintenance is directly linked to the condition of the equipment rather than its age (Nazami et al., 2021)—the following section reviews related research studies conducted on the topic of the present study.

Mostafavi et al. (2021) conducted a study on Total Productive Maintenance (TPM) and the six significant losses in the industry, focusing on the pivotal role of TPM in supporting continuous improvement, such as Lean production, and implementing strategies for waste reduction. The study also examined the feasibility, implementation, and maintenance of TPM in the press shop of Saipa Company. For data collection, a standard audit checklist was used to evaluate the maintenance structure across seven categories, and a researcher-developed questionnaire was used to audit human resources in five areas: social and psychological factors, cultural and managerial aspects, economic factors, and physical aspects. After consulting with industrial and academic experts and ensuring the validity and reliability of the instruments, data analysis revealed that structural and human factors were absent for implementing TPM in the press shop.

Orjlo et al. (2019) aimed to investigate the impact of Total Quality Management (TQM) on organizational performance, with TQM acting as a mediator. After collecting the questionnaires, the obtained data were analyzed using the SPSS software and inferential statistical tests. The results of the pairwise comparison analysis indicated that the mean before the implementation of TQM showed a significant difference from the mean after the implementation of TQM. The mean after TQM implementation was improved, suggesting that the mediating role of TQM positively impacted organizational performance.

Mehrmanesh et al. (2019) investigated the role of Total Quality Management (TQM) in reducing quality costs. The research first discusses the literature on TQM and quality costs and then reviews previous studies on these concepts. The subsequent section examines the role of TQM in reducing quality costs and explores its mechanisms. The study's findings indicated that TQM can significantly reduce the incurred quality costs with its strategic and cultural tools, such as expanding quality functions, simultaneous engineering design experiments, and other tools.

Tezifeko et al. (2023) aimed to develop and measure a scale for evaluating teachers' attitudes toward quality management, incorporating online education elements. Nine hundred and forty-two teachers from Romania participated in the study. The exploratory factor analysis led to the identification of three main dimensions of the scale: (1) Communication and Alignment, (2) Needs and Opportunities, and (3) Training and Support. Teachers in managerial positions on quality assurance boards showed more positive attitudes toward the three components. Additionally, teachers with more teaching experience reported higher values in the "Needs and Opportunities" component. The findings are helpful for educational institutions, program designers, and policymakers in assessing teachers' attitudes toward quality management.

Talib et al. (2021) aimed to identify healthcare practices and improve healthcare services by adopting and implementing Total Quality Management (TQM) enablers in India. The paper presents a ranking model for implementing TQM in India to enhance performance. The study identifies 20 TQM enablers through a comprehensive literature review and expert opinions and then categorizes them into five main groups. The significance of these enablers is assessed using a newly developed multi-criteria decision-making method known as the Best-Worst Method (BWM). The study results showed that, among the five main categories of enablers, "Leadership-based enablers" and "Continuous Improvement-based enablers" are the most and least important, respectively. Similarly, among the 20 subcategories of enablers, "Quality leadership and the role of physicians" and "Conducting regular customer satisfaction reviews and quality audits" are the most and least essential sub-enablers, respectively.

Baro (2021) aimed to investigate the impact of Total Quality Management (TQM) factors on knowledge creation in organizations in Bangladesh. A quantitative research approach was used, with Structural Equation Modeling (SEM) applied for data analysis. The study found a significant positive relationship between leadership, employee empowerment, benchmarking, customer focus, information technology, knowledge creation, and the four conversion modes. In contrast, a significant negative relationship was found between continuous employee training and the knowledge creation process and three of the knowledge conversion modes.

The main objective of Total Productive Maintenance (TPM) is to maximize the effectiveness and productivity of equipment, eliminate all equipment losses, foster a sense of ownership among operators through training programs, and involve them in continuous improvement activities carried out by small groups consisting of production, engineering, and maintenance personnel. Each organization has its unique definition and perspective of TPM. However, in most cases, there are common elements across these definitions, which include asset scheduling strategy, resources, empowerment, planning, systems and procedures, measurements, and teams for continuous process improvement. This strategy integrates maintenance and quality principles through daily inspections by trained users, aimed at eliminating significant losses caused by downtimes, startup times, and production delays. Successful implementation of this strategy requires a high level of employee involvement. A shift in organizational culture is needed to implement TPM, which is time-consuming and carries the risk of failure. The core principles of TPM techniques include maintenance and repairs performed by the operators, scheduled maintenance, reduction in maintenance and repair costs, increased equipment efficiency, increased equipment availability, enhanced performance efficiency, and improved product quality.

Methodology

The research method used in this study is quantitative, aimed at expanding practical knowledge and addressing a specific scientific or social problem. Based on the need for hypothesis generation, the study is descriptive. In most research studies, the population under examination consists of the sample population the researcher wishes to study in terms of specific characteristics or variables of its units. The definition of the population must be comprehensive and exclusive. Thus, the definition should be framed to include all units under study in terms of time and location and ensure that units that should not be included in the study are excluded.

In this research, the target population consisted of the 425 employees of the Lordegan Petrochemical Company. Based on Cochran's formula, the total sample size was 222 individuals, and the sampling method used was simple random sampling.

A questionnaire was used to collect and distribute data among the sample group members. The questionnaire contained 34 specialized questions. Table 1 shows the classification of questions for each of the variables studied in the research.

Table 1. Classification of Questionnaire Questions

Variable	Number of Questions	Source
Total Quality Management (TQM)	10	Baird et al. (2021) & Prajogo & Sohal (2014), Chen & Chen (2019)
Total Productive Maintenance (TPM)	10	McKone et al. (2021)
Operational Processes	7	Zhu et al. (2018); Green et al. (2021) & Prajogo et al. (2012)

In this study, the variables are measured using a Likert scale questionnaire. To convert qualitative data into quantitative data, each response option is assigned a numerical value from 1 to 5, respectively. The data analysis method used in this study is quantitative, conducted through both descriptive and inferential statistics. The analysis aims to examine the relationship between the variables and generalize the results obtained from the sample to the entire population. In addition to estimating the population parameters from the sample data, hypothesis testing is another goal of statistical inference.

Kolmogorov-Smirnov Test: In non-parametric statistics, one method related to distribution testing is the Kolmogorov-Smirnov test**.** This test makes it possible to determine whether the population follows the specified distribution using a random sample from the statistical population. Additionally, the Kolmogorov-Smirnov (K-S) test can be used to examine the homogeneity between two populations.

KMO (Kaiser-Meyer-Olkin) Index: The KMO index is a measure of sampling adequacy that examines the partial correlations between variables and determines whether the shared variance of some underlying latent factors influences the variance of the research variables. The KMO index ranges from 0 to 1. If the value of this index is close to 1, the data is considered appropriate for factor analysis. On the other hand, if the KMO value is less than 0.7, the analysis results may not be suitable for the data in question.

Bartlett's Test: This test is used to ensure sampling adequacy. The Bartlett test checks whether the correlation matrix is an identity matrix (i.e., whether the correlation between variables is significant for factor analysis). The index ranges from 0 to 1. If the value of the index is close to 1, the data is considered suitable for analysis, and if it is lower than 0.7, the analysis results might not be appropriate (Sepahri & Shah Qalyan, 2018).

Additionally, this test is used to verify that the correlation matrix, which is the basis for the analysis, is not equal to zero in the population and ensures significant correlations between variables, making factor analysis appropriate.

Structural Equation Modeling (SEM): Structural equation modeling examines relationships among latent variables while simultaneously considering the observable variables. Latent variables are the underlying factors represented in a conceptual model, while observable variables are the indicators or questions used to measure these latent factors.

Goodness-of-Fit Indices: The goodness-of-fit indices, which appear in the program's output, compare the relative fit index to determine how well the model fits compared to the baseline model (which assumes independence). These indices include NNFI, NFI, and CFI. Except for the NNFI, all these indices range from 0 to 1, and the closer the value is to 1, the better the model fit.

The Lordegan Petrochemical Complex is located in the Falard region of Chaharmahal and Bakhtiari Province, approximately 55 kilometers from Lordegan city. The Lordegan Petrochemical Company was established in 2008, and due to its favorable access to water and gas resources, as well as its proximity to three national gas pipelines and availability of land with suitable topography for infrastructure development, it is strategically well-positioned. The products produced by this company include ammonia, with a daily production capacity of 2,050 tons, and urea, with a daily production capacity of 3,250 tons. The company is part of a network of petrochemical plants, including Kermanshah Petrochemical, Pardis Petrochemical, Shiraz Petrochemical, Khorasan Petrochemical, and Razi Petrochemical, which also produce urea and ammonia. However, the production capacity of Lordegan Petrochemical is less than twice that of Kermanshah Petrochemical and only one-third of the capacity of Pardis Petrochemical.

Findings

In inferential statistics, the researcher calculates sample statistics and then generalizes these statistics to population parameters using estimation or statistical hypothesis testing. Inferential statistical methods are applied to data analysis and hypothesis testing. The population parameter obtained through a census is considered the actual value, while the statistic derived from a sample of size N is referred to as a sample statistic. This study first examines the parameters related to the survey questionnaire, followed by the output from the Structural Equation Modeling (SEM) technique.

The questionnaire is the most commonly used tool for data collection, and it can be evaluated from various aspects and through different methods. Most conventional evaluation methods are based on classical test theory, where scales depend on moments such as means, variances, and covariances, which are sensitive to sample characteristics. Below are three essential aspects evaluated in this study.

In Bartlett's Test, the null hypothesis assumes that the variances of K populations are equal, while the alternative hypothesis indicates that at least two populations have unequal variances. Therefore, higher values (close to 1 and above 0.70) in the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy indicate that factor analysis is feasible for the data, and the data can be reduced to a set of latent (hidden) factors. Table 2 shows the statistical value for this test. As can be seen, the value is 0.907, which is an acceptable level for factor analysis.

Table 2. Sample Size Adequacy Test (KMO Test)

Statistic Value	Degrees of Freedom	Sig
0.907	351	0.000

The reliability of the questionnaire in the analysis of questionnaires related to statistical research is measured using a criterion to assess the validity of the responses provided in the items, known as Cronbach's Alpha. This index is sometimes also referred to as the alpha coefficient. The output of this measure is displayed in Table 3.

Table 3. Cronbach's Alpha

Variable	Cronbach's Alpha Value
Total Productive Maintenance	0.873
Plant Operations Process	0.881
Total Quality Management	0.859

Convergent validity is a quantitative indicator that measures the internal consistency and alignment of the items used to calculate a particular construct. In other words, when one or more characteristics are measured, the correlation between these measurements provides two essential validity indicators. If the correlation between the factor loadings is high, the questionnaire is considered to have convergent validity. This correlation is necessary to ensure that the test measures what it is supposed to measure. The Average Variance Extracted (AVE) and Composite Reliability (CR) must be calculated to assess convergent validity. Convergent validity is established when the Average Variance Extracted (AVE) is more significant than 0.50 and when Composite Reliability (CR) exceeds 0.70. Composite Reliability (CR) should exceed the Average Variance Extracted (AVE). Convergent validity will be confirmed if both conditions are met, as shown in Table 4.

Table 4. Convergent Validity

Variable	Average Variance Extracted (AVE)	Composite Reliability (CR)	Status
Total Productive Maintenance (TPM)	0.502	0.772	Confirmed
Plant Operations Process	0.530	0.842	Confirmed
Total Quality Management (TQM)	0.619	0.804	Confirmed

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Discriminant validity refers to the low correlation of the items of one latent variable with other latent variables. Accordingly, acceptable discriminant validity in a measurement model indicates that a construct interacts more strongly with its indicators than with different constructs. Table 5 shows the results of the questionnaire's validity.

Table 5. Questionnaire Validity

Variable	Maximum Shared Variance	Status
Total Productive Maintenance (TPM)	0.205	Confirmed
Plant Operations Process	0.230	Confirmed
Total Quality Management (TQM)	0.252	Confirmed

Table 6 shows the factor loadings for the questionnaire items. All factor loadings are more significant than 0.30, indicating that all items are confirmed and none need to be removed. The following figure displays the commonalities in the unrotated form. Communality for a variable is the squared multiple correlation for that variable using the factors. Therefore, the proportion of the variable's variance is estimated by the common factors extracted in the factor analysis. The initial column reports the commonalities before extraction, with all values equaling one.

Table 6. Factor Loadings of Questionnaire Items

Number	Initial	Extraction
V_2	1/000	0/395
V_3	1/000	0/548
V_4	1/000	0/487
V_5	1/000	0/439
V_6	1/000	0/556
V_7	1/000	0/365
V_8	1/000	0/413
V_9	1/000	0/504
V_{10}	1/000	0/585
V_{11}	1/000	0/443
V_{12}	1/000	0/406
V_{13}	1/000	0/435
V_{14}	1/000	0/444
V_{15}	1/000	0/407
V_{16}	1/000	0/447
V_{17}	1/000	0/447
V_{18}	1/000	0/518
V_{19}	1/000	0/545
V_{20}	1/000	0/608
V_{21}	1/000	0/492

Number	Initial	Extraction
V_{22}	1/000	0/599
V_{23}	1/000	0/457
V_{24}	1/000	0/350
V_{25}	1/000	0/526
V_{26}	1/000	0/440
V_{27}	1/000	0/452
V_{28}	1/000	0/598
V_{29}	1/000	0/468

Rows from 4 onwards have been removed because their Eigenvalues are less than one. The first block contains three columns related to the eigenvalues of the correlation matrix. The eigenvalue represents the variance in the total test explained by a specific factor. The total variance for each test is equal to 1. The eigenvalue for the first factor is 8.387. The eigenvalues for subsequent factors are listed in the Total column. The second column, labeled % of Variance, represents the percentage of variance explained by that factor from the total variance, calculated by dividing the eigenvalue of that factor by the number of tests. The five factors with eigenvalues greater than one account for only 48.166% of the total variance. The second block includes three columns showing the total coefficients of the unrotated factors.

Table 7. Total variance

Component	Total	Initial Eigenvalues		Extraction Sums of Squared Loadings		
		% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8/387	31/06	31/06	8/387	31/06	31/06
2	1/289	4/774	35/836	1/289	4/774	35/836
3	1/202	4/453	40/289	1/202	4/453	40/289
4	1/102	4/080	44/368	1/102	4/080	44/368
5	1/025	3/798	48/166	1/025	3/798	48/166
6	0/986	3/650	51/816			
7	0/957	3/545	55/361			
8	0/937	3/470	58/832			
9	0/913	3/382	62/214			
10	0/826	3/058	65/272			
11	0/796	2/948	68/221			
12	0/766	2/837	71/058			
13	0/715	2/650	73/708			
14	0/706	2/614	76/322			
15	0/671	2/484	78/805			

16	0/648	2/402	81/207			
17	0/617	2/286	83/493			
18	0/586	2/171	85/664			
19	0/570	2/113	87/776			
20	0/513	1/901	89/678			
21	0/486	1/799	91/477			
22	0/473	1/752	93/229			
23	0/433	1/603	94/831			
24	0/402	1/489	96/321			
25	0/383	1/418	97/738			
26	0/354	1/309	99/048			
27	0/257	0/952	100/000			

Table 8 shows the unrotated component matrix, which includes the factor loadings (factor scores) for each variable on the remaining four factors. Interpreting the factor loadings without rotation is not straightforward. Therefore, the factors are rotated to enhance their interpretability.

Table 8. Unrotated Component Matrix

Number	Component Matrix				
	1	2	3	4	5
V_2	0/560	0/000	-0/028	-0/089	-0/263
V_3	0/573	-0/337	-0/092	-0/120	-0/300
V_4	0/544	-0/350	0/265	0/055	0/060
V_5	0/571	0/097	-0/257	-0/200	-0/021
V_6	0/532	0/083	-0/521	0/078	0/066
V_7	0/578	-0/057	0/102	0/088	0/125
V_8	0/585	-0/070	-0/205	-0/018	0/146
V_9	0/574	0/200	-0/137	0/305	-0/180
V_{10}	0/534	0/319	0/216	-0/096	0/406
V_{11}	0/574	-0/012	-0/124	0/258	0/181
V_{12}	0/608	-0/134	-0/121	0/117	-0/121
V_{13}	0/543	0/295	0/326	0/037	-0/139
V_{14}	0/489	-0/232	0/138	0/242	-0/005
V_{15}	0/564	0/149	-0/116	-0/256	-0/021

Number	Component Matrix				
	1	2	3	4	5
V_{16}	0/560	0/254	-0/256	-0/216	-0/131
V_{17}	0/546	0/274	-0/079	-0/216	-0/131
V_{18}	0/527	-0/091	-0/014	0/440	0/266
V_{19}	0/543	0/295	0/326	0/037	-0/139
V_{20}	0/489	-0/232	0/138	0/242	-0/005
V_{21}	0/543	0/295	0/326	0/037	-0/139
V_{22}	0/571	0/097	-0/257	-0/200	-0/021
V_{23}	0/532	0/083	-0/521	0/078	0/066
V_{24}	0/578	-0/057	0/102	0/088	0/125
V_{25}	0/585	-0/070	-0/205	-0/018	0/146
V_{26}	0/574	0/200	-0/137	0/305	-0/180
V_{27}	0/571	0/097	-0/257	-0/200	-0/021
V_{28}	0/532	0/083	-0/521	0/078	0/066
V_{29}	0/578	-0/057	0/102	0/088	0/125

When examining the uniformity of the data, the null hypothesis assumes that the data follows a uniform distribution, which is tested at a significance level of 0.05. If the p-value is greater than or equal to the error level (0.05), there is no evidence to reject the null hypothesis. In other words, the data distribution will be uniform. When testing for normality, the null hypothesis assumes that the data follows a normal distribution at a 5% error level. For normality testing, the statistical hypotheses are formulated as follows: if the test statistic (p-value) is greater than or equal to 0.05, there will be no evidence to reject the null hypothesis. In other words, the data distribution is normal. The results of the Kolmogorov-Smirnov test are shown in Table 9. The values in the table indicate the test statistic, all greater than 0.05, confirming that the data is normal.

Table 9. Kolmogorov-Smirnov Test Results

One-Sample Kolmogorov-Smirnov Test				
		Factory operation processes	Comprehensive maintenance and repairs	Total Quality Management
N		202	202	202
Normal Parametersa,b	Mean	2/025	1/965	1/967
	Std. Deviation	0/5996	0/8854	0/6363
Most Extreme Differences	Absolute	0/108	0/198	0/130
	Positive	0/108	0/198	0/130
	Negative	-0/105	-0/151	-0/104

Test Statistic	0/108	0/198	0/130
Asymp. Sig. (2-tailed)	0/000	0/000	0/000

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.

Structural Equation Modeling (SEM) Fit

Structural equation modeling (SEM) is, in essence, a highly accurate multivariate analysis method that allows for the simultaneous testing of multiple equations. Covariance structure analysis, also known as SEM, is one of the primary methods for analyzing complex data structures. It is a novel approach to investigating causal relationships and is used to analyze multiple variables within a theoretical framework, showing how variables affect each other simultaneously. AMOS (Analysis of Moment Structures) graphically performs SEM, enabling rapid model definition and accurate computation. For a model to be considered valid, the factor loading should be greater than 0.6, while factor loadings smaller than 0.4 are considered too small and should be removed from the model. In this study, all sub-variables in the model are validated. As shown in Figure 1, the factor loadings in the model meet the criteria.

Table 10. Symbols used in the model

Variable	Symbol	Sub-variable	Symbol
Comprehensive Maintenance	NG	Maintenance Organization	N1
		Operator Participation	N2
		Aesthetics and Functional Order	N3
		Information Sequence	N4
Factory Operations Process	AK	-	-
Total Quality Management	KF	Quality Reporting	K1
		Product Innovation	K2
		Research & Development Management	K3
		Technology Management	K4

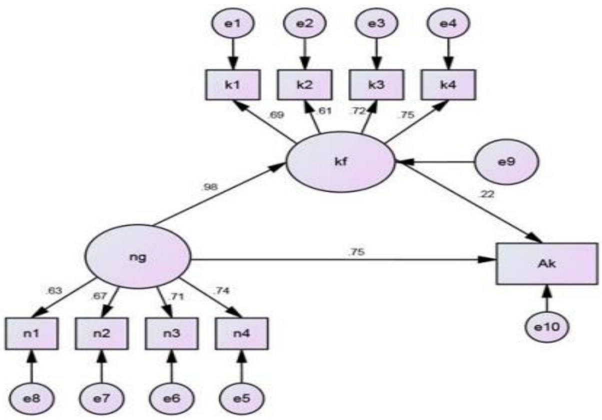

Figure 1. Graphical Representation of the Amos Output Model in Standard Mode

One of the primary goals of Structural Equation Modeling (SEM) is to assess the degree of fit between empirical data and the conceptual and theoretical model. Various fit indices and criteria are used to evaluate this fit, collectively referred to as *model fit indices*. In SEM, different indices are utilized to ensure the model's goodness of fit. In measurement models, the key question researchers aim to answer is whether the observed variables adequately measure the latent constructs or hidden variables. When the collected data support the research's conceptual model, the fit indices indicate a favorable model fit. Table 11 shows the model's goodness of fit indices. As can be seen, all indices indicate acceptable values, confirming the adequacy of the model's fit.

Table 11. Model Fit Indices

Index	Value	Status
Absolute Fit Indices		Confirmed
GFI (Goodness of Fit Index)	0.979	Confirmed
AGFI (Adjusted Goodness of Fit Index)	0.962	Confirmed
RMR (Root Mean Square Residual)	0.013	Confirmed
Comparative Fit Indices		Confirmed
NFI (Normed Fit Index)	0.971	Confirmed
CFI (Comparative Fit Index)	0.990	Confirmed
IFI (Incremental Fit Index)	0.992	Confirmed
Parsimonious Fit Indices		Confirmed
RMSEA (Root Mean Square Error of Approximation)	0.001	Confirmed

Discussion and Conclusion

The primary goal of Total Productive Maintenance (TPM) is to maximize the effectiveness and productivity of equipment, eliminate all machine losses, create a sense of equipment ownership among users through training programs and their involvement, and promote continuous improvement through small group activities involving production, engineering, and maintenance personnel. The present research was conducted to investigate the impact of implementing preventive maintenance systems on the productivity and efficiency of factory operations (case study: Lordegan Petrochemical Company). The descriptive results of the study are as follows: Over half of the sample population is male, accounting for 63%, while 37% of the sample is female. Age distribution shows that the highest proportion is in the age group over 36 years, constituting 52% of the sample. The second largest age group is 31-35 years, with 33%, followed by the 26-30 years group, which comprises 10%. The most minor proportion is in the 20-25 age group, accounting for 4%. Regarding educational level, the sample was categorized into four groups: below high school, high school diploma, bachelor's degree, and master's degree. Among the respondents, 36% held a bachelor's degree, while 49% had a master's degree. The educational level of respondents shows that the majority, 98 individuals, had a master's degree. According to the results obtained from the data, it is evident that Total Productive Maintenance (TPM) has a positive relationship with the factory operations processes, suggesting that implementing TPM practices, such as preventive maintenance, significantly enhances the efficiency and productivity of the factory's operational activities. The results also indicate that the involvement of well-trained personnel with appropriate educational backgrounds can contribute effectively to the success of TPM implementation. In conclusion, the study emphasizes the importance of implementing preventive maintenance systems and engaging workers at all levels of the production process. By doing so, organizations like Lordegan Petrochemical can achieve higher operational efficiency and maintain their competitive edge in the industry. The findings underscore the need for further research and adaptation of TPM strategies to improve the long-term performance of industrial plants.

Total Productive Maintenance (TPM), or Production-Oriented Maintenance, views maintenance as one of the key elements impacting an organization's production levels and revenue generation, thereby integrating an engineering economics perspective into the maintenance sector. Total Productive Maintenance is generally referred to as user-centered maintenance. This approach shifts from traditional maintenance methods by delegating certain maintenance activities to equipment and machinery operators. The technicians and the operators share responsibility for maintaining and servicing the equipment. These activities differ from other organizational tasks, typically managed and executed by a few employees. The new TPM activities involve all company personnel and have a revolutionary impact by introducing changes in machine maintenance methods, employee behavior, workplace culture, and working environments, which leads to structural reforms within the company, resulting in higher profitability. Given the advantages of this maintenance approach, necessary actions should be taken to introduce it to manufacturing institutions to increase their production capacity. The method should be properly justified for its implementation. This conclusion is consistent with Mostafavi et al.'s (2021) and Orjloo et al. (2019) studies. TPM positively influences Total Quality Management (TQM). Organizations are continually seeking ways to improve the productivity of interactions among individuals within their systems. One of the strategies to increase team performance within an organization is through Total Productive Maintenance (TPM). TPM is a comprehensive culture that seeks to increase responsibility and reduce waste (such as time losses and decreased quality) by engaging everyone directly or indirectly with the organization's equipment. Total Quality Management (TQM) involves senior management support, employee participation, continuous improvement, and customer focus. Among these factors, the most significant factor is customer focus, while employee participation holds the least weight. Information and data analysis related to quality are significantly correlated with quality performance, and there is a strong positive relationship between Total Quality Management (TQM) activities and quality performance. The findings of this research align with those of Mehrmanesh et al. (2019), Tezifeko et al. (2023), and Talib et al. (2021). Plant operations processes have a positive relationship with Total Quality Management (TQM). TQM encompasses processes and management systems to achieve customer satisfaction through empowering employees, achieving higher revenue, and reducing costs. TQM defines a pathway through which, in both stable and changing environments, organizations can achieve high-quality levels and superior management by applying various methods and techniques professionally and scientifically, along with continuous improvement and participation from all employees. Total Quality Management is a paradigm of business success globally because its implementation improves the organization's internal functions, gradually builds customer trust, and supports a chain of improvement reactions. Team management within TQM is essential not only for its implementation, development, and execution but also for its sustainability. TQM is a management philosophy and an operational business style aimed at achieving success. This result is consistent with Orjloo et al. (2019) and Baro (2021) findings. Total Quality Management (TQM) is a structured system that emphasizes the continuous improvement of all internal organizational activities. The ultimate goal of Total Quality Management is to improve the quality of products and services by enhancing human resources, processes, and available equipment while simultaneously reducing operational costs. Total Quality Management aims to bring about fundamental changes in the mindset of individuals, steering their thinking from past-oriented perspectives to future-focused ones and from individual attitudes to dynamic group efforts. Although Total Quality Management was initially designed and formulated for industrial purposes, it is a system through which organizations can control their products and services and the effects of these systems on their performance. These effects have been repeatedly tested and verified. This study attempts to provide a systematic perspective on the quality topic by measuring the mediating role of market orientation within an organization and identifying the combined effects of these two management approaches on organizational performance. The findings are consistent with the studies of Mostafavi et al. (2021), Tezifeko et al. (2023), and Talib et al. (2021). The overall results of the research indicate that Total Productive Maintenance (TPM) directly impacts the improvement of operational processes and the enhancement of organizational productivity. This system helps reduce equipment failures and increases availability, enabling more sustainable production and reducing unnecessary costs. Additionally, fostering a sense of ownership and participation among employees positively impacts organizational performance. The mediating role of Total Quality Management is also highlighted in this study. By strengthening the organizational culture and focusing on continuous improvement, Total Quality Management amplifies the positive effects of Total Productive

Maintenance (TPM). These findings demonstrate the importance of the synergy between these two approaches in improving organizational performance, and it can be considered a key strategy for the petrochemical industry and other manufacturing sectors. Based on the research findings, the following practical recommendations are provided for improving performance:

1. regular inspections should be conducted more frequently, and higher-quality materials should be used to prevent defects from leaks.
2. Review equipment and refine the preventive actions defined for the equipment.
3. Hold daily meetings with experts and managers to discuss any breakdowns.
4. Use auxiliary equipment to monitor the performance of machinery and equipment.

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