The Impact of Concurrent Engineering Technology on Total Quality, With Digital Transformation as A Mediating Variable in Jordanian Public Industrial Companies

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ABSTRACT

This study sought to evaluate how concurrent engineering technology, and its aspects influence total quality, using digital transformation as a mediating factor in Jordanian public industrial companies up to 2023. Utilizing the Amman Stock Exchange directory, it examined 46 companies across nine sectors, sampling 41 company. The focus was on senior and middle management employees (in departments like finance, production, quality, R&D, and IT), estimating 369 participants, with 315 responses retrieved after filling an electronic questionnaire analyzed through SPSS. Findings showed concurrent engineering's significance, especially in product, process, and supply chain design, and underscored digital transformation's impact. Recommendations include continuous training in concurrent engineering, quality management, and digital transformation, fostering a culture of improvement, and investing in digital tools like AI and data analytics to enhance processes and decision-making.

Keywords: Concurrent Engineering Technology, Total Quality, Digital Transformation, Jordanian Public Industrial Companies

Introduction:

The information technology and telecommunications revolution has driven entrepreneurial ventures from an industrial to a knowledge-based global society. This shift calls for flexible product development and the integration of innovative practices like concurrent engineering and total quality management. These approaches are crucial for improving competitiveness and expanding market presence, enabling businesses to adapt swiftly to changing demands.

leading companies therefor focus on lowering product costs and improving quality by employing concurrent engineering. They also work to shorten development cycles through digital transformation and total quality management (TQM). Digital transformation drives strategic initiatives that impact operations internally, by reshaping processes, and externally, by enhancing product presentation and expanding market reach. This combined approach allows businesses to meet strategic goals with greater efficiency and cost-effectiveness (Mar'i, 2023).

This study thus seeks to explore the impact of concurrent engineering technology on total quality, considering the role of effective digital transformation within Jordanian public industrial companies.

Study Problem

The study explores challenges faced by Jordanian industrial companies in sustaining competitiveness and expanding market share, particularly against large multinational corporations. To address this, these companies have implemented total quality management (TQM) standards and embraced modern techniques like concurrent engineering and digital transformation to improve product quality. This research aims to examine how concurrent engineering and its aspects influence TQM and to assess whether digital transformation enhances these effects, providing Jordanian companies a stronger competitive edge.

Study Objectives

The study seeks to achieve the following objectives:

1. To provide a philosophical and scientific framework for modern techniques, such as concurrent engineering and digital transformation, that support continuous improvement in industrial products.
2. To identify the impact of concurrent engineering on total quality and to assess the extent to which digital transformation enhances this impact.
3. To inform industrial companies of the findings, which may assist decision-makers in these organizations in improving competitiveness by enhancing product quality through the use of these techniques.

Importance of the Study

The significance of this study lies in the following points:

1. This research contributes intellectually and scientifically by linking various industrial techniques within Jordanian industrial companies, providing insights into the relationship between competitive capability and product quality.
2. It fills a unique gap in the field by investigating the impact of modern technologies on dependent variables that have not been extensively explored by previous studies.
3. The study highlights the need for industrial companies to shift from traditional methods in managing production processes to more advanced technologies capable of better achieving their strategic goals.

Study Hypotheses

To achieve the research objectives and answer the research questions, the following hypotheses were formulated:

- Main Hypothesis H01: There is no statistically significant impact at the significance level ($\alpha \leq 0.05$) of concurrent engineering and its dimensions (product design, process design, and supply chain design) on total quality management and its dimensions (top management commitment, employee participation, and continuous improvement) in Jordanian public industrial companies.
    - Sub-Hypothesis H01.1: There is no statistically significant impact at the significance level ($\alpha \leq 0.05$) of product design on total quality management in Jordanian industrial companies.
    - Sub-Hypothesis H01.2: There is no statistically significant impact at the significance level ($\alpha \leq 0.05$) of process design on total quality management in Jordanian public industrial companies.
    - Sub-Hypothesis H01.3: There is no statistically significant impact at the significance level ($\alpha \leq 0.05$) of supply chain design on total quality management in Jordanian public industrial companies.
- Main Hypothesis H02: Digital transformation does not contribute to enhancing the impact of concurrent engineering and its dimensions (product design, process design, and supply chain design) on total quality management and its dimensions (top management commitment, employee participation, and continuous improvement) at the significance level ($\alpha \leq 0.05$) in Jordanian public industrial companies.

Study Methodology

The study employed a descriptive-analytical approach to achieve its objectives, answer the research questions, analyze data, and test its hypotheses.

Study Population and Sample

The study's population comprised Jordanian public industrial companies listed on the Amman Stock Exchange as of 2023, covering 46 companies across nine sectors. From this population, a sample of 41 companies was selected, following the sampling guidelines from Sekaran & Bougie's statistical tables (2016).

Targeted Analysis Unit

The study targeted senior and middle management employees—specifically executive managers and department heads in finance, production, quality, research and development, and information technology—across the selected public industrial companies. This group comprised approximately 369 employees. An electronic survey link was distributed via social media to reach participants, yielding 315 valid responses for analysis. The demographic and professional characteristics of the respondents are summarized in the table below.

Table (1): Respondent Data Analysis

Variable	Category	(n=315) Repeats	Percentage
Academic Qualification	BSc	169	53.7
	Diploma	59	18.7
	MSc	73	23.2
	PhD	14	4.4
Years of Experience	Less than 5 years	58	18.4
	From 5 years to less than 10 years	115	36.5
	From 10 years to less than 15 years	90	28.6
	From 15 years to less than 20 years	34	10.8
	20 years or more	18	5.7
Scientific Specialty	Accounting	69	21.9
	Business Administration	92	29.2
	Information Technology	89	28.3
	Other	65	20.6
Job Title	Executive Director	15	4.8
	Department Manager	132	41.9
	Section Head	168	53.3
Total		315	100

Table (1) reveals that 53.7% of respondents hold a Bachelor's degree, while 27.6% have a Master's or Doctorate, indicating a well-qualified sample. Most respondents (36.5%) have 5 to less than 10 years of

experience, highlighting significant practical expertise. A balance of scientific specializations is also present, ensuring diverse skills within the companies. Additionally, 53.3% of participants are section heads, reflecting a proportional distribution across the organizational hierarchy. These factors suggest the sample's strong competencies and alignment with the industry's administrative structure.

Reliability Testing of the Study Instrument

The Cronbach's Alpha Coefficient assesses the reliability of the study instrument by measuring the internal consistency among its items. A Cronbach's Alpha value of 0.70 or above signifies high reliability, confirming that the instrument is dependable and appropriate for statistical analysis. The following table displays the study instrument's reliability test results.

Table (2): Results of the Reliability Test of the Study Instrument

Number	Variable	# of paragraph	Alpha's value
1	Product Design	5	0.706
2	Process Design	5	0.819
3	Supply Chain Design	4	0.769
	Concurrent Engineering	14	0.879
4	Top Management Commitment	5	0.818
5	Employee Participation	5	0.842
6	Continuous Improvement	5	0.857
	Total Quality Management	15	0.907
	Digital Transformation	11	0.861

The values in Table (2) show strong stability and reliability for the study instrument, with all Cronbach's Alpha values above 0.70—ranging from 0.706 for "Product Design" to 0.907 for "Total Quality Management."

To evaluate the correlation among independent variables and detect multicollinearity, the Variance Inflation Factor (VIF) and Tolerance Factor were tested. VIF values over 10 and Tolerance values below 1

suggest multicollinearity issues (Gujarati, 2004). The following table provides the correlation values for the explanatory variables.

Table (3): Correlation Values Among Explanatory Variables

Concurrent Engineering	VIF	Tolerance Factor
Product Design	**1.474**	**0.679**
Process Design	**1.905**	**0.525**
Supply Chain Design	**2.049**	**0.488**

It is evident from Table (3) that there are no high linear correlations among the explanatory (independent) variables, as all Variance Inflation Factor (VIF) values were less than 10, and the Tolerance values were less than 1.0.

Theoretical Framework

According to Smith, concurrent engineering represents the most effective strategy for addressing product development challenges within manufacturing. The success of this approach is shaped by three key elements: technological innovation, product complexity, and significant economic factors (Makinen, 2011). As a result, many American industrial firms have adopted precise methods for product and process development, giving rise to concurrent engineering. This methodology is regarded as a manufacturing philosophy that systematically combines design efforts with various processes throughout the product life cycle, with teamwork serving as a fundamental component of this strategy (Fine et al., 2005).

As noted by (Dongre et al. 2015), concurrent engineering is a method that emphasizes simultaneous execution of different stages of product design, which not only shortens the time to market but also reduces costs and enhances the competitive edge of businesses. Similarly, (Bas et al. 2021) view concurrent engineering as a strategic approach that facilitates various benefits, including innovation, time efficiency, and cost reductions in a well-balanced way.

Objectives of Concurrent Engineering

Concurrent engineering achieves many objectives, the most prominent of which are:

Customer Focus: It aims to improve quality levels, reduce costs, increase profit margins, and lower product development costs.

Reduction of Design, Assembly, and Manufacturing Time (Al-Falahi, 2019).

Lower Overall Product Costs through innovation and excellence in utilizing organizational resources, cost control, and minimizing costs (Belay, 2013).

Achieving Competitive Advantage by realizing advantages related to reducing time, lowering costs, improving product quality, and enhancing responsiveness and flexibility to customers (Tayal, 2012).

From the above, the core concept of concurrent engineering embodies integration and cooperation among stakeholders in the production process (suppliers, design engineers, and organizational customers) throughout the product development cycle by working as a team during the design phase. This effectively contributes to product development, improves its quality, and provides sufficient capacity to reduce costs related to rework in later stages of the production process Al-Mousawi, 2013).

Concept of Total Quality Management (TQM)

Total Quality Management (TQM) is considered a modern management philosophy that focuses on a set of contemporary concepts, combining administrative instruments, innovative efforts, and specialized technical skills aimed at enhancing performance and sustaining continuous development and improvement (Idris et al., 2012). Many researchers consider TQM one of the most critical factors in achieving competitive advantages, as the increasing demand for better quality is one of the main customer requirements, making TQM the primary tool for achieving competitiveness and providing competitive advantages to organizations (Amansour, 2012). It is worth noting that the application of TQM concepts and principles and the development of performance have become important priorities for organizations in all advanced industrial countries, such as Japan, the United States, and European nations (Hassan et al., 2013).

(Dassanayak 2014) identifies six principles of Total Quality Management:

- Customer Focus: Maintaining a close relationship with current and potential customers.
- Good Leadership: Creating a motivating work environment that allows employee participation in planning, goal setting, and decision-making.
- Employee participation: Engaging employees at various organizational levels in the process of improving organizational performance.
- Scientific Approach: Applying TQM strategies effectively to improve operational efficiency and enhance performance within the organization.
- Continuous Improvement: Adopting this principle ensures the continuity of organizational performance and the effective and timely execution of duties and tasks.

- Mutual Benefits: Collaborating with other parties, such as investors and suppliers, is crucial for developing competitive advantages and maintaining relationships that contribute to production and performance enhancement.

Importance of Implementing Total Quality Management (TQM)

The importance of applying Total Quality Management (TQM) is embodied in its role as one of the most critical stages of improvement in organizations, leading to customer satisfaction and meeting their needs while fulfilling their desires at lower costs, increasing profit levels, and achieving competitive advantages in organizations (Bin Naflah et al., 2006).

Concept of Digital Transformation

The Concept of Digital Transformation

This pioneering concept emerged from the ideas and applications of artificial intelligence, as entrepreneurial companies rely on its use within the boundaries of the digital applications they implement. According to (Al-Rawashdeh et al. 2024) and (Malkawi et al. 2023), there are various perspectives on defining the concept of digital transformation, all stemming from advanced technological ideas, as noted by (Brook & McCormac .2020).digital transformation refers to technological changes that facilitate new educational and operational models, thereby altering corporate business models and strategic directions. This transformation necessitates innovative leadership across all levels to effectively plan, implement, and adopt an integrated technological system driven by data analytics. The digital approach becomes the method through which companies incorporate innovation into every facet of their operations, aiming to enhance effectiveness and improve performance across diverse processes and services.

The aspects of digital transformation lie in enhancing the integration of technology and business and facilitating strategic decision-making based on accurate, data-supported insights. Digital transformation is essential for companies to adapt to rapid developments in the digital age and to fully leverage the new opportunities presented by digital technologies (Garzoni et al., 2020).

Thus, it is the process of using digital technologies to create new or existing business management processes, organizational cultures, and customer experiences to meet changing business and market needs. Reorganizing business in the digital age is a digital transformation (Peter et al., 2020).

(Ghrio,2022) defines digital transformation as the process of converting information and data from analog systems to digital systems. (Ahmed,2023) believes that digital transformation can be understood through two main concepts: the first is a broad concept that includes all activities related to digital content, which encompasses activities related to goods, services, communications, and information technology.

Importance of Digital Transformation

The importance of digital transformation lies in meeting customer needs and desires and accurately understanding their requirements. This helps reach a broad customer base across the globe without spatial or temporal limitations, while also increasing the detection of fraud and risk management through the use of artificial intelligence applications as an effective security shield. Thanks to digital transformation, some items of general and administrative expenses can be eliminated, contributing to a reduction in overall costs (Malar et al., 2019, p. 18).

Objectives of Digital Transformation

The objectives of digital transformation are embodied in Nicoletti's (2021) viewpoint as follows:

1. Improving the Quality of Information and Data: Enhancing the quality of services provided to various users and decision-makers.
2. Interactivity in Document Management: Managing documents within companies according to their size and nature of work.
3. Increasing Efficiency and Effectiveness: Saving time in executing necessary operations for any activity beneficial to the company.
4. Absolute Confidentiality and Information Security: Utilizing modern technologies to protect against breaches.
5. Enhancing Competitive Advantage: Focusing on core competencies and overcoming weaknesses.
6. Innovating Smart Systems: Creating easy and convenient systems for information users specific to the company.

Dimensions of Digital Transformation

Digital transformation includes the following dimensions:

1. Technology: This is the primary requirement for initiating digital transformation. It encompasses a wide range of needs such as data, computers, mobile devices, cloud storage, social media, big data, artificial intelligence, the Internet of Things, software, cybersecurity, embedded devices, and applications (Nazari & Musilek, 2023).
2. Processes: This refers to the set of tasks necessary for digital transformation, including strategies, business models, operational models, business activities, new services, operational processes,

coordination mechanisms, products, organizational culture, and organizational structure (Nazari & Musilek, 2023).

3. Individuals: They are the core of digital transformation, representing its foundation and the target audience to be satisfied. This group consists of a diverse mix of individuals who may hold multiple positions at once, including: customers, executives, employee talents/workforce/individuals, managers, suppliers, owners, competencies, stakeholders, and partners (Nazari & Musilek, 2023).

Characteristics of Digital Transformation

Digital transformation offers numerous benefits to customers, organizations, and various stakeholders. Among the most important characteristics of digital transformation are (Hasan, 2023):

1. Significant Dependence on Intangible Assets: This includes intellectual property, technologies, software, and algorithms, with a need to encourage customer and user participation in creating data value. Digital interaction platforms are used to understand and analyze customer behaviors to increase revenues.

2. Provision of Free Services to Consumers: This is a strategy adopted by many entrepreneurial digital organizations, as these platforms enable interaction between sellers and buyers.

3. Wide Reach Achievable Without Physical Presence: Organizations benefit from using internet networks and platforms to establish cross-border relationships with customers in distant locations, without the need for a permanent physical presence in those countries.

4. Entrepreneurial Digital Organizations: Such as e-commerce platforms, online advertising, and cloud computing, show a trend towards monopoly due to network effects, the massive volume of data, usage constraints, and the complexity of multi-faceted systems.

Data Analysis and Hypothesis Testing

Description of Study Variables

Table (4) shows the results describing the study variables using descriptive statistical measures. The values indicate a high relative importance of the variable of concurrent engineering in Jordanian industrial companies, with a mean of (4.441) and a standard deviation of (0.552). The relative importance of all dimensions of concurrent engineering was also high, with the following order of their means: Product Design (4.660), Supply Chain Design (4.410), and Process Design (4.291).

The values also indicate a high relative importance of the Total Quality Management (TQM) variable in Jordanian industrial companies, with a mean of (4.492) and a standard deviation of (0.538). All dimensions of TQM showed high relative importance, with the following order of their means: Continuous Improvement (4.654), Top Management Commitment (4.581), and Employee Participation (4.289).

Additionally, the values indicate a high relative importance of the Digital Transformation variable, with a mean of (4.447) and a standard deviation of (0.501).

Table (4): Description of Study Variables

Number	Variable	Mean	Standard deviation	Rank	Relative importance
1	Product Design	4.660	0.525	1	High
2	Process Design	4.291	0.599	3	High
3	Supply Chain Design	4.410	0.603	2	High
	Concurrent Engineering	4.441	0.552	-	High
4	Top Management Commitment	4.581	0.537	2	High
5	Employee Participation	4.289	0.688	3	High
6	Continuous Improvement	4.654	0.521	1	High
	Total Quality Management	4.492	0.538	-	High
	Digital Transformation	4.447	0.501	-	High

Results of Hypothesis Testing

Results of Testing the First Main Hypothesis H01

There is no statistically significant impact at the significance level ($0.05 \geq \alpha$) of concurrent engineering and its dimensions (Product Design, Process Design, and Supply Chain Design) on Total Quality Management and its dimensions (Top Management Commitment, Employee Participation, and Continuous Improvement) in public shareholding industrial companies in Jordan.

Table (5): The Relationship and Impact of Concurrent Engineering on Total Quality Management

	Non-standardized coefficients	Standardized coefficients

Independent Variable	B	Standard Error	β	T	Sig. T
Product Design	**0.267**	**0.047**	**0.261**	**6.695**	**0.000**
Process Design	**0.391**	**0.047**	**0.435**	**8.355**	**0.000**
Supply Chain Design	**0.161**	**0.048**	**0.180**	**3.343**	**0.001**
R			0.747		
R^2			0.557		
F			130.551		
Sig. F			0.000		

Dependent Variable: Total Quality Management

The values in Table (5) indicate the relationship of concurrent engineering and its effect on Total Quality Management in public shareholding industrial companies in Jordan. It was found that concurrent engineering is strongly and positively related to Total Quality Management (R = 0.747), explaining (55.7%) of the variation in Total Quality Management (R^2 = 0.557). Additionally, its impact was statistically significant on Total Quality Management (F = 130.551, Sig.F = 0.000). Based on the above, it is clear that: "There is a statistically significant impact at the significance level ($0.05 \geq \alpha$) of concurrent engineering and its dimensions (Product Design, Process Design, and Supply Chain Design) on Total Quality Management and its dimensions (Top Management Commitment, Employee Participation, and Continuous Improvement) in public shareholding industrial companies in Jordan."

Results of Testing Sub-Hypotheses

Sub-Hypothesis 1 H01.1

There is no statistically significant impact at the significance level ($0.05 \geq \alpha$) of Product Design on Total Quality Management in Jordanian industrial companies.

It is evident from Table (5) that Product Design is positively related to Total Quality Management (B = 0.267) and that its impact is statistically significant on Total Quality Management (T = 5.695, Sig.T =

0.000). Based on the above, it is clear that: "There is a statistically significant impact at the significance level (0.05 ≥ α) of Product Design on Total Quality Management in public shareholding industrial companies in Jordan."

Sub-Hypothesis 2 H01.2

There is no statistically significant impact at the significance level (0.05 ≥ α) of Process Design on Total Quality Management in public shareholding industrial companies in Jordan.

It is evident from Table (5) that Process Design is positively related to Total Quality Management (B = 0.391) and that its impact is statistically significant on Total Quality Management (T = 8.355, Sig.T = 0.000). Based on the above, it is clear that: "There is a statistically significant impact at the significance level (0.05 ≥ α) of Process Design on Total Quality Management in public shareholding industrial companies in Jordan."

Sub-Hypothesis 3 H01.3

There is no statistically significant impact at the significance level (0.05 ≥ α) of Supply Chain Design on Total Quality Management in public shareholding industrial companies in Jordan.

It is evident from Table (5) that Supply Chain Design is positively related to Total Quality Management (B = 0.161) and that its impact is statistically significant on Total Quality Management (T = 3.343, Sig.T = 0.001). Based on the above, it is clear that: "There is a statistically significant impact at the significance level (0.05 ≥ α) of Supply Chain Design on Total Quality Management in public shareholding industrial companies in Jordan."

To rank the impact of the dimensions of concurrent engineering on Total Quality Management, stepwise regression analysis was used.

Table (6): Ranking the Impact of Dimensions of Concurrent Engineering on Total Quality Management

Model	Concurrent Engineering	B	T	Sig. T	R^2	F	Sig. F
First	Product Design	0.614	16.590	0.000	0.468	275.228	0.000
Second	Process Design	0.318	7.077	0.000	0.541	184.233	0.000
Third	Supply Chain Design	0.161	3.343	0.001	0.557	130.551	0.000

The values in Table (6) indicate that Process Design has the most significant impact on Total Quality Management, explaining (46.8%) of the variation in Total Quality Management ($R^2 = 0.468$). With the inclusion of the Product Design variable in the regression model, the explanatory power increased by (7.3%) ($R^2 = 0.541$). Furthermore, adding the Supply Chain Design variable to the regression model, which already included Process Design and Product Design, resulted in an increase of (1.6%) in explanatory power ($R^2 = 0.557$).

Results of Testing Main Hypothesis Two H02

There is no contribution of digital transformation to enhancing the impact of concurrent engineering and its dimensions (Product Design, Process Design, and Supply Chain Design) on Total Quality Management and its dimensions (Top Management Commitment, Employee Participation, and Continuous Improvement) at the significance level ($0.05 \geq \alpha$) in public shareholding industrial companies in Jordan.

Table (7): The Role of Digital Transformation in the Impact of Concurrent Engineering on Total Quality Management

Concurrent Engineering	First Model			Second Model		
	B	T	Sig. T	B	T	Sig. T
Product Design	0.267	5.695	0.000	0.162	3.185	0.002
Process Design	0.391	8.355	0.000	0.288	5.689	0.000
Supply Chain Design	0.161	3.343	0.001	0.089	1.807	0.072
Digital Transformation				0.323	4.546	0.000
R^2	0.557			0.585		
ΔR^2	0.557			0.028		
ΔF	130.551			109.271		
Sig ΔF	0.000			0.000		

Dependent Variable: Total Quality Management

The values in Table (7) indicate the moderated role of digital transformation in the impact of concurrent engineering on Total Quality Management in public shareholding industrial companies in Jordan, according to two models. The results of the first model showed a statistically significant impact of the combined dimensions of concurrent engineering on Total Quality Management ($\Delta F = 130.551$, Sig $\Delta F = 0.000$), explaining (55.7%) of the variation in Total Quality Management ($R^2 = 0.557$).

In contrast, the results of the second model highlighted the moderated role of digital transformation. Its inclusion in the regression model resulted in an increase of the coefficient of determination R2R²R2 by (2.8%) ($R^2 = 0.585$, $\Delta R^2 = 0.028$), and this percentage is statistically significant ($\Delta F = 109.271$, Sig $\Delta F = 0.000$). The value of ($B = 0.323$) for digital transformation, with a significance level of ($SigT = 0.000$), confirms the differing significant impact of the dimensions of concurrent engineering on Total Quality Management based on variations in digital transformation. Based on the above, it is evident that: "Digital transformation contributes to improving the impact of concurrent engineering with its dimensions (Product Design, Process Design, and Supply Chain Design) on Total Quality Management with its dimensions (Top Management Commitment, Employee Participation, and Continuous Improvement) at a significance level of ($0.05 \geq \alpha$) in public shareholding industrial companies in Jordan."

Results and Recommendations

Results

The analysis outcomes and hypothesis testing indicated the following results:

1. The significant emphasis on concurrent engineering and its dimensions—Product Design, Process Design, and Supply Chain Design—within Jordanian industrial companies highlights a growing awareness and comprehension among management about the critical role of concurrent engineering. This approach is recognized as a vital strategy for enhancing competitiveness, improving operational efficiency, reducing costs, speeding up development processes, boosting the quality of products and services, and more effectively meeting customer expectations.

2. The significant emphasis on Total Quality Management (TQM) within Jordanian industrial companies indicates a heightened awareness and understanding among management of its essential role in achieving operational excellence, superiority, and sustainability. TQM is viewed as a vital tool for competitive advantage, offering the framework and processes needed to effectively address the increasing and continuous demands of customers. It enables improved productivity, waste reduction, enhanced quality of products and services, and creates a supportive environment that fosters creativity and innovation within the organization.
3. The high level of relative importance of digital transformation in Jordanian industrial companies indicates an increased awareness and understanding among the management of industrial companies regarding the significance of keeping pace with technological advancements. This includes investing in improving efficiency, productivity, competitiveness, and cost savings, as well as understanding and effectively meeting customer needs.

4. A significant statistical relationship exists between concurrent engineering and Total Quality Management in public shareholding industrial firms in Jordan. This emphasizes the critical role of concurrent engineering in improving the integration and simultaneous coordination of processes, which leads to enhanced quality and efficiency while reinforcing the principles and goals of Total Quality Management.
5. There is a statistically significant impact of product design, process design, and supply chain design on Total Quality Management in public shareholding industrial companies in Jordan. This emphasizes the importance of effective integration among these elements and their positive interaction in achieving outstanding performance, improving quality, meeting specified goals, increasing operational efficiency, reducing waste, and generating customer satisfaction.
6. Process design is recognized as a crucial element of process engineering that significantly impacts Total Quality Management in industrial companies in Jordan. This importance is linked to the ability of process engineering to improve overall performance, align with the company's strategic objectives, and boost customer satisfaction. It aids in enhancing operational efficiency by minimizing waste, increasing productivity, and optimizing the use of resources. Furthermore, it guarantees the timely delivery of high-quality products and services at competitive prices, steering operations toward achieving strategic goals and establishing a framework for ongoing improvement through consistent review, analysis, and refinement of processes. This continual progress fosters greater customer satisfaction and loyalty, enhancing the company's capacity to fulfill customer needs and expectations, ultimately resulting in improved quality of products and services.
7. Digital transformation plays a crucial role in amplifying the influence of concurrent engineering—encompassing product design, process design, and supply chain design—on Total Quality Management, which includes dimensions such as Top Management Commitment, employee participation, and continuous improvement, with a significance level of ($0.05 \geq \alpha$) in public shareholding industrial companies in Jordan. This highlights the vital role of digital transformation in improving communication and coordination among teams, steering them towards achieving Total Quality Management objectives. It provides precise and analyzable data that facilitate process enhancement and product development, encourages a customer-centric approach by addressing their needs and expectations, and supports ongoing improvement and innovation efforts. Ultimately, this leads to enhanced quality and efficiency in Total Quality Management.

Recommendations

Based on the previous results, the research proposes the following recommendations:

1. Continuous Training Programs: The management of Jordanian industrial companies should conduct continuous training programs for employees to improve their skills in the areas of concurrent engineering, total quality management, and digital transformation. Workshops and training courses should also be organized on the latest technologies and methodologies in these fields.
2. Adopting a Culture of Continuous Improvement: The management of Jordanian industrial companies should adopt a culture of continuous improvement and encourage employee participation in the continuous and effective updating and development of processes and products.
3. Enhancing Integration and Coordination: The management of Jordanian industrial companies should provide all necessary procedures to enhance integration and coordination among all departments of the company, and identify key performance indicators that ensure the achievement of set goals and the continuous improvement of performance and quality.
4. Increasing Investment in Technology: The management of Jordanian industrial companies should direct efforts toward increasing investment in technology and digital tools that support concurrent engineering and total quality management, such as artificial intelligence and predictive and analytical tools, and utilize them to improve processes and make strategic decisions.

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