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Proposed Geometric Model for Measuring Total Quality Principles and their Role in Promoting Sustainable Manufacturing: A Case Study at Al-Kufa Cement Factory

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Abstract: The present study aims to determine and assess the effects of implementing TQM principles on enhancing sustainable manufacturing, encompassing three dimensions of sustainable manufacturing and seven key aspects of TQM. The research question that emerged was whether it was crucial to construct and test a model that combined these two principles of the modern industrial workplace. The Kufa Cement Factory was selected as the study site, with a research population of 144 workers. We sent out 120 questionnaires, and 116 were returned with the necessary information to be utilized. The study employed descriptive, analytical, and quantitative methods, with SEM (AMOS V.26) serving as the primary statistical tool, and reliability and descriptive analysis were conducted using SPSS V.26. The statistical results confirmed the strong and significant influence of TQM principles on sustainable manufacturing. However, there were shortages in the dimensions of process management implementation and information and analysis, as interest in the economic dimension was the least favorable. The most vital recommendation is to implement a comprehensive program of digital transformation to address issues with administrative and operational readiness, and to enhance long-term economic performance through data-driven improvements.

Keywords: Total Quality Management concepts, sustainable production, and the Al-Kufa Cement Plant are key terms.

Introduction

The rapidly changing world around the globe leads to a quick transition in the perception of the concept of industrial production. Currently, the time has gone when we could strictly focus on profit and the ideas of the marketplace economy. It is necessary to consider the environment, improve our society, and make production systems more sustainable. Overall, sustainable manufacturing ensures a balance between the economic aspects of production and its environmental and social components. It is achieved through increasing the efficiency of resource utilization, reducing emissions, and minimizing waste. Therefore, the current research aims to present an integrated model of quality and sustainability management systems in industrial production.

Total Quality Management is essential as one of the important parts of the shift toward sustainable production and its principles. The main pillars of TQM, which include full participation, focusing on the client, and continuous improvement, help ensure that sustainable practices are applied at every step of the production process. TQM can be used not only to improve products but also to enrich processes, reduce waste, and stimulate thinking. Nevertheless, we need to develop a safe engineering model that can link these two main ideas in industrial production, meaning overall production improvement and the practice of sustainable manufacturing. It allows the industrial organization to establish an innovative production system that is far more efficient and safer for the environment and future generations. Having formulated our goals and questions, we have divided the research into four parts. The first part discusses the scientific method employed in the research, the second part outlines the theoretical framework used, the third part examines the practical aspects of the study, and the fourth part presents the results and recommendations made by the researchers.

1- Scientific research methodology

1-1- The study problem

The topic of the study is the discrepancy between the theoretical high of the Total Quality Management and Sustainable Manufacturing and the effectiveness of their integrated implementation inside the tested laboratory. Although the overall extent of implementing TQM principles is at a relatively high level, a substantial portion of this implementation is weakened by the lack of presence in significant areas for improvement, such as process management, information, and analysis. This unfortunate tendency of the laboratory's performance unjustifiably enjoyed the maximum extent of the environmental dimension's peaks, while the economic and social extents reached their minimum. The purpose of this study is to determine the nature of TQM's impact on sustainable manufacturing and to identify the most effective approaches to eliminate the specified weaknesses and achieve overall balance.

1-2- The Questions of the Study

To what extent are the people in the community living near the laboratory under discussion aware of and receptive to the overall quality management concepts? Are the people in the given community aware of the formal extent and receptive to the available extent of the overall quality concepts in the studied laboratory?

To what extent does technology exist for the implementation of the total quality management principles in the sustainable manufacturing process in the current laboratory? How far-reaching is the impact of the available technology for the total quality management principles on the implementation of the sustainable manufacturing process inside the studied laboratory?

How far do the sustainable manufacturing details in the tested laboratory allow the achievement of the TQM's goals in the process of manufacturing it in ways that are good for nature? What kind of impact do the TQM's rules have on the laboratory's ability to implement sustainable manufacturing in the tested laboratory?

What are the key components of the comprehensive engineering model that combines sustainable management and production to produce goods described in environmentally efficient ways inside the same laboratory? What are the key fundamentals of a TQM and SM comprehensive engineering model to deliver goods in an ecologically efficient way within the same laboratory?

1-3- Importance of the Research:

The importance of this research assumes a dual character, combining theoretical significance in the field of management with direct practical relevance for administrative leadership at all levels of the Kufa Cement Factory.

1-3-1- The practical importance (for the Kufa Cement Factory)

The practical significance of the research lies in its provision of a clear methodological framework for the upper and middle management at Al-Kufa Cement Factory, linking the application of Total Quality Management principles with the achievement of sustainable manufacturing goals. The study also provides a correct diagnosis of strengths and weaknesses in the application of quality, enabling managers to direct limited resources to the dimension that has the greatest impact on enhancing economic efficiency and reducing environmental emissions. This analysis also helps management come up with sustainable strategies for ensuring they remain competitive in a changing business environment.

1-3-2- Theoretical and Scientific Importance

The theoretical significance of this study lies in its contribution to the integration of two modern management approaches, namely TQM and sustainability, within a single structural model. The study's contribution to the literature lies in its separate testing of the impact of each of the seven dimensions of TQM on three dimensions of sustainable manufacturing. This detailed examination of the existing problems in company development is of great interest to academic researchers. It opens up the way for further research on integrating operational activities and corporate responsibility into environmental and social problems in major industry fields, such as the cement industry.

1-4- Research Objectives:

The research objectives can be summarized as follows:

- ✓ To investigate the current situation and apply sustainable manufacturing approaches in the considered lab.
- ✓ To assess the influence of factors incorporated in Total Quality Management on the achievement of the dimensions of sustainable manufacturing
- ✓ To develop the integrated engineering model that will provide for the incorporation of specific TQM factors and conditions of sustainable manufacturing.
- ✓ To assess whether the implementation of the proposed model will result in the improvement of the overall performance of the considered lab.

1-5- Research Model

A hypothetical engineering diagram was constructed to illustrate the relationship between TQM principles and sustainable manufacturing. It was formulated based on existing literature and includes the following:

1. **Independent Variable (X):** This represents the dimensions of TQM principles (leadership (top management), strategic planning, customer focus, resource focus, process management, information, analysis and improvement, and quality outcomes).
2. **Dependent Variable (Y):** This represents the dimensions of sustainable manufacturing (economic dimension, social dimension, and environmental dimension). As shown in Figure 1 below:

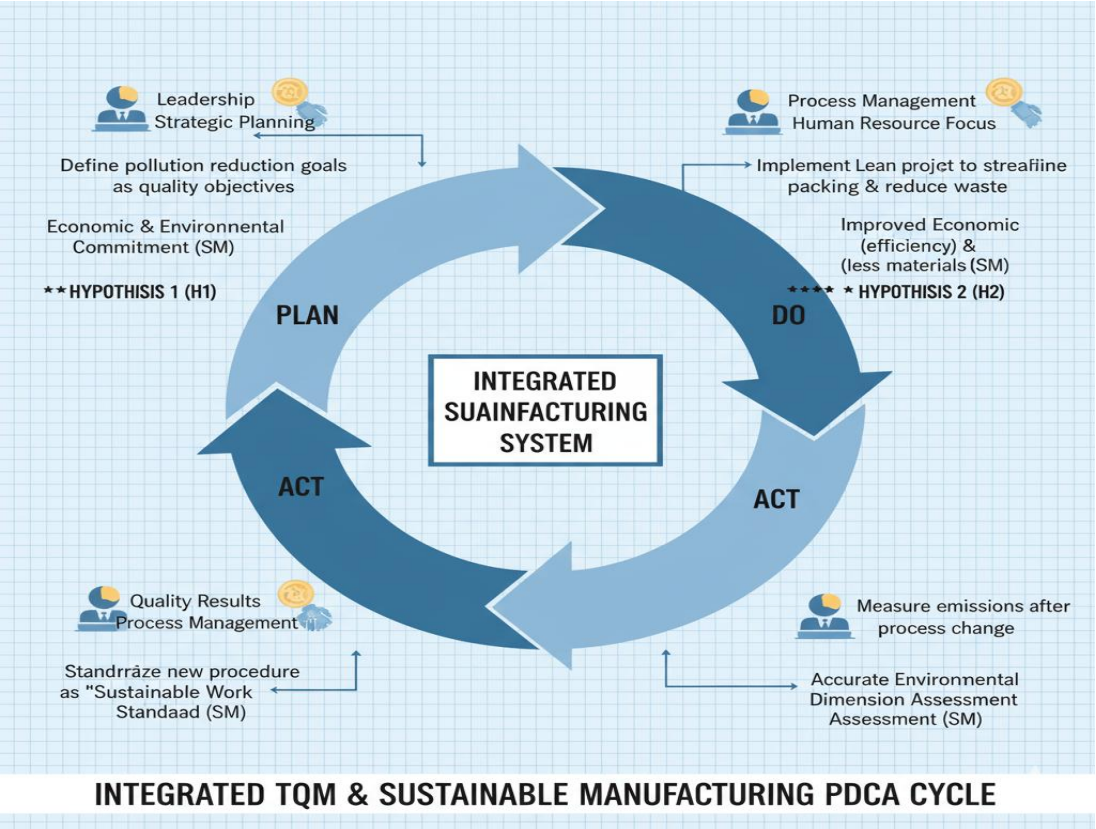

Figure 1: Hypothetical Engineering Model of the Study

Source: Prepared by the researcher based on the literature

1-6- Research Hypotheses

Based on the hypothetical engineering model, the following hypotheses were formulated:

- The first primary hypothesis (H1) states: "There is no statistically significant effect between the independent variable, Total Quality Management principles, and the dependent variable, Sustainable Manufacturing." The following sub-hypotheses are derived from this:
- ✓ (H1-1) There is no statistically significant effect between the dimensions of Total Quality Management and the economic dimension.
- ✓ (H1-2) There is no statistically significant effect between the dimensions of Total Quality Management and the social dimension.
- ✓ (H1-3) There is no statistically significant effect between the dimensions of Total Quality Management and the environmental dimension.

1-7- Research Population and Sample:

The appropriate selection of the study location and the studied population is one of the essential aspects that ensures the accuracy and validity of the results. In testing the study hypotheses, the Kufa Cement Plant is considered one of the essential plants in the Ministry of Industry, due to its central role in supporting the national economy. The number of administrative leaders at all administrative and technical levels (department head, division head, unit head) in the studied plant is 144, as determined by the design and selection of the sample size using ready-made tables that show the sample size (Margen & Krjera, 1970, p. 608). Based on this, it appeared that the optimal sample size is at least 104 managers. Therefore, (120) questionnaires were distributed to a random sample, and after (116) questionnaires were returned, it was found that the number of questionnaires valid for statistical analysis was (116), which is the number that meets the requirement of representing the population well, with a response rate of (98%). The following table shows the demographic factors of the respondents.

Table (1) Description of the respondent sample

Classification variables	Category	repetitions	Percentage
Gender	Male	82	70.7%
	Female	34	29.3%
	Total	116	100.0%
Educational attainment	Diploma	14	12.1%
	Bachelor's	58	50.0%
	Master's	26	22.4%
	PhD	18	15.5%
	Total	116	100.0%
Length of service	Less than 5 years	16	13.8%
	6-10 years	41	35.3%
	11-15 years	35	30.2%
	16 and over	24	20.7%
	Total	116	100.0%
Job specialization	Unit Head	62	53.4%
	Section Head	44	37.9%
	Department Head	10	8.6%
	Total	116	100.0%

Source: Prepared by the researchers.

The table above shows the following:

The gender variable data showed that the majority of the sample are males, which are 82 individuals, representing 70.7%. In contrast, the least proportion is among females, who account for 29.3% (34 individuals). Therefore, in this case, there is a higher representation of males in the industrial production environment under study at Kufa Cement Plant, compared to females. This might be dictated by the nature of the work, where males are more attracted to industrial work than females. Concerning the level of education, the data showed that the highest proportion belongs to the bachelor's degree level, which accounts for exactly half of the sample, that is, 58 individuals or 50.0%.

In contrast, the diploma level has the lowest representation, at 12.1% (14 individuals). From the data, it is clear that the sample has a high level of education, as the majority hold at least a bachelor's degree. Consequently, this indicates that the sample has a sufficient number of qualified personnel who may be actively involved in management and quality programs. The length of service data shows that the largest category within the sample is the experience level of 6 to 10 years, which accounts for 35.3%, representing 41 individuals. As such, the majority of managers have relatively more extensive and higher-level experience.

On the other hand, samples with less than 5 years of work experience account for 13.8% with 16 individuals. This depicts a relatively stable work environment, and the full sample has enough practical and work experience to draw and base precise evaluations of the TQM and SM concepts. The job specialization variable indicates that the most common category within the sample is unit manager, accounting for 53.4% (62 individuals). Therefore, the sample used for this dataset is evident in that it comprises mid-level supervisory and executive categories responsible for the day-to-day operation of the unit. The least represented category is the department head, which accounts for 8.6% (10 individuals). From this point, the data show that the majority of the sample data used is from the management group, which has direct contact with the processes and activities under review, specifically quality and sustainable production.

1-8- Statistical Tools:

Several readily available statistical methods and models were employed, in line with the research objectives. These include:

Statistical Software Used:

A. The study used a set of statistical software programs to analyze the data, namely:

- Excel 2007 for extracting the primary data.
- SPSS version 26 for various statistical analyses.
- AMOS version 26 for structural equation model analysis and path analysis.

Statistical Methods Used:

B. The statistical methods used in the study included the following:

- Arithmetic mean: to measure the average of participants' responses.
- Standard deviation: to measure the dispersion of responses.
- Relative importance and ranking of importance: to assess the importance of the study variables.
- Cronbach's alpha coefficient: to measure the reliability of the measurement instrument.
- Interpretation coefficient (R^2): to determine the proportion of variance explained in the dependent variable.
- Normality test: to verify the distribution of the data.
- Simple regression analysis: to model the relationship between the variables.
- Structural Equation Model and Path Analysis: To analyze complex relationships between variables.

1-9- Measures and Their Coding

The measures listed in the following table were adopted because they are suitable for the study environment and sample, and were agreed upon by most reviewers and specialists. The main variables and sub-dimensions were also coded for ease of use in statistical software, as shown in the following table:

Table No. (2) Variables and Their Dimensions According to the Adopted Measure

Variables	Dimensions	Coding
Total Quality Principles X	Leadership (Top Management)	X1
	Strategic Planning	X2
	Customer Focus	X3
	Resource Focus	X4
	Process Management	X5
	Information, Analysis, and Improvement	X6
	Quality Outcomes	X7
Sustainable Manufacturing Y	Economic Dimension	Y1
	Social Dimension	Y2
	Environmental Dimension	Y3

The researcher prepared the source based on the literature mentioned in the table.

2- Literature Review

2-1- The Concept of Total Quality Management

There are no universally accepted definitions of Total Quality Management among researchers and thinkers. However, we will highlight the most prominent of these definitions (Al-Harahsheh, 2011), which was the first attempt at a definition by the British Quality Foundation. They defined it as "the management philosophy of an organization that recognizes and achieves all customer needs in addition to achieving project objectives." Al-Habib (2019) explained it as a comprehensive management system that focuses on improving and enhancing the organization's products, encompassing all activities through inputs, processes, and outputs. However, the most accurate definition is the one that clarifies the meaning of the three words that make up the term:

- Management involves developing the organizational capabilities of administrative leaders to foster a culture of continuous improvement, thereby maintaining a high level of performance.
- Quality: This means meeting customer requirements for the services and goods provided by the organization and continuously striving to provide a higher level of quality than expected.
- Comprehensive: This means involving all elements of the work process to identify customer needs at every stage and for all employees, and to exert collective efforts to achieve the goals.

Quality is a strategy that all organizations strive to implement to achieve their organizational goals, while also establishing a competitive advantage in business environments (Al-Khatib, 2018).

2-2- The importance of Total Quality Management and its objectives

The importance of Total Quality Management can be observed through its direct impact on the consumer and the satisfaction of their needs, as well as on the product and its ability to stand out. Additionally, it impacts the perfection of goods and their enhanced character. Total quality management is a series of procedures aimed at achieving highly productive service performance, ensuring it meets the utmost satisfaction of the consumer. The importance of Total Quality Management can be seen through the following central points:

1. Reducing consumer complaints regarding the products offered and the resulting reduction in costs.
2. Reducing quality costs.
3. Increasing market share, as Total Quality Management has contributed significantly to the growth of productive and service organizations.
4. Reducing workplace accidents.
5. Contributing to increased customer satisfaction.
6. Contributing to increased production efficiency and profits.

Richard Farman identified the objectives of Total Quality Management (TQM) as follows:

1. Focusing on market needs and translating those needs into actionable descriptions.
2. Achieving higher performance in all areas.
3. Simplifying quality performance procedures.
4. Continuous review to address losses and waste.
5. Focusing on competition and developing its strategies.

Continuous and endless improvement (Abu Nasser 2008: 321). Furthermore, there is a set of objectives that organizations strive to achieve by adopting the TQM approach, which are as follows:

1- **Achieving profitability and competitiveness:** Continuous quality improvement is a key indicator of increased sales, which in turn leads to a higher market share, greater profitability, and enhanced competitiveness.

2- **Achieving customer satisfaction:** TQM contributes to identifying both current and potential customers, then determining their needs and desires to meet them, while also retaining current customers and attracting new ones.

3- **Increasing organizational effectiveness:** Quality is the responsibility of all employees in the organization; therefore, it places great emphasis on teamwork, continuous improvement, and empowering them to solve production problems. Operational and improving organizational and operational relationships among them (Agency, V1, 18 August 2000, p. 8).

2-3- Dimensions of Total Quality Management:

1- Leadership (Top Management Commitment)

Top management determines the organization's direction by adopting a general vision, making informed future decisions, and designing organizational structures that define responsibilities, relationships, and authorities. It also determines organizational communication methods, leadership styles that influence employees, and motivational techniques to achieve goals and control employee behavior by fostering organizational culture. It provides a firm basis and a great start for Total Quality Management implementation when top management takes the lead in terms of providing focused suppliers. The organization cannot effectively apply in this area without the top management of the supplier specializing in this area. However, top management is not only a supplier; it is also a specialist. This is also a definition of the highest priority for the entire organization, initiating the implementation process and enabling a deep and practical understanding of quality reality, control of its principles, and management of technologies across all areas of the organization (Slack et al.). (al, 2010:506)

2- Strategic Planning:

Strategic planning is a methodology that determines what an organization should achieve and how it will achieve it. Thus, the adoption of human resource management ensures high performance. This approach ensures a competitive advantage to organizations. It is given that the work environment is always rapidly changing; therefore, organizations must carefully implement changes accordingly. The adoption of human resource management assists in the integration of strategic planning. It also promotes the use and incorporation of Total Quality Management in this integration. The coordination of TQM programs ensures that employee participation in the plan is made easy, allowing an organization to achieve the expected results. The link between TQM and strategic planning does not occur during the implementation phase but begins from the moment of formation (Dean & Evans, 1994:1). This means that the alignment between the degree of TQM implementation and the organization's adopted strategy helps the organization achieve a good market share and a high competitive advantage.

3- Focusing on the Customer.

This means meeting the expectations and needs of potential and current customers through a comprehensive understanding of those needs, and then delivering value to them, while also achieving the expected results of the process. Customer satisfaction helps foster customer loyalty to the organization, leading to increased profitability (Dahlgaard, 2015, p. 114). The primary goal of implementing Total Quality Management (TQM) is to achieve customer satisfaction, which has a direct impact on organizational performance (Mehra & Ranganathan).

4- Focus on Human Resources:

Human resource departments are central in any organization implementing TQM activities. They are responsible for initiating organizational details, as human factors can have a profound and significant influence on the change process. In conducting an organizational analysis, the human resource department compares the needs and designs and presents a training program that reflects the organization's long-range mission. Human resource management is an essential facilitator for implementing the process of philosophy and TQM principles. It also serves to channel an organization's culture in creating change that can be made supportive and rewarding as TQM Zen can be reinforced. Synergy in implementing TQM activities can be harnessed by focusing on consistent human resource management activities throughout the change process. In addition, teamwork and harmonization are critical in human resourcing, connecting functions, levels, training suppliers, training customers, and training line managers towards the achievement of quality by solving quality problems together, with satisfaction as the expected outcome. Furthermore, teamwork entails high-level cooperation and increased information sharing through the substantive implementation of key players within the organization.

5- Process Management:

Wijngaard, Waszink, and Zhang defined process management as a series of systematic measures and activities that utilize resources and transform inputs into outputs, thereby reducing possible errors in the operational process. The importance of process management for the organization is evident in the interconnectedness of such an operational system. Improving one's performance will lead to better results in another. Thus, the implementation of Total Quality Management programs is fundamental for improving the value of these processes and increasing productivity throughout the entire organization. Moreover, the implementation of TQM programs also raises the level of service and product quality. Appropriate statistical methodologies should be used, and the results of the evaluation of the processes should serve as a source of knowledge for the process. By understanding the changes and insights required, process engineering and design ensure that overall organizational performance continually improves. The major prerequisite of successful TQM program implementation is an internal, process-oriented environment designed to overcome obstacles and difficulties in measuring and evaluating the efficiency and effectiveness of the applied and need-to-be-implemented procedures and processes. Thus, process management is one of the key principles of Total Quality Management.

6- Information, Analysis, and Improvement:

When it comes to measuring quality, it is essential to collect data to maintain the current quality and continually improve it. Hence, an organization cannot accurately determine if its products and services exhibit the desired quality or require improvements without measuring both the initial state and the subsequent state after the quality improvement process. This primarily involves preparing reports and collecting high-quality data through monitoring and documentation. This also refers to regular feedback and learning about how to identify waste and damage in the production process, as well as how to support and sustain the employees' information. The tendency towards continuous improvement, process monitoring, and defect analysis enables the organization to stay competitive in the market. Data collection became less time-consuming because the proliferation of IT has made it easier to conduct subsequent analysis much faster and more accurately.

Thus, there is no doubt that one of the methods for gathering and sometimes recording ideas, and then working on them during employee meetings, is the use of information technology applications. The necessary information and ideas may come from the World Wide Web or other groups, associations, and newsgroups. Such information can be vital for improving the quality of the product. This includes quality costing and effective ways to utilize it. It is, therefore, extremely important to provide managers and employees with the necessary feedback that will

help them understand how and when data should be measured and made available. (Martinez 1999:15)

7- Quality Results:

Implementing Total Quality Management enables organizations to achieve improved operational outcomes, build stronger employee relationships, attain greater satisfaction and loyalty, increase market share and profitability, reduce costs, and achieve better economic performance, as well as implement process and product innovation. The results of TQM affect outcomes, both directly and indirectly, through the policies, strategies, resources, and processes of organizations (Calvo-Mora, 2020:2304).

2-4- The Concept of Sustainable Manufacturing:

Sustainable manufacturing is rooted in the broader concept of sustainable development. The latter emerged in the 1980s as a response to rising environmental awareness, business growth and expansion, and international economic trade (Abubakr et al., 2020:2). Manufacturing is at the core of creating essential materials and products that enable everyday activities, which in turn affect human health and safety. It represents a new industrial way of conducting business and creating value, attracting many companies worldwide into innovations and drives that assist in creating a safer environment, ensuring competitive advantages, and reducing risks, by investment, customers, profits, and eventually trust(Ahmad & W., 2018:3). A comprehensive balance between supportive practices and policies that convey or support diverse environmental, social, and economic objectives must be achieved. At the same time, a balance must be maintained between achieving societal goals and those of manufacturers. Accordingly, sustainability is a revolution set to be implemented in manufacturing processes in the 21st century. The sustainable manufacturing revolution necessitates a transition from a demand for solely economic performance: “Decision-making must take a far broader perspective to meet the requirements of the economic and social environment, going from a product lifecycle point of view to an organismic lifecycle perspective”(Abdul-Rashid et al., 2017, p. 3). This approach aims to achieve an optimal flow of semi-permanent materials, which can be utilized across multiple lifecycle processes to produce high-quality recycled materials. Sustainable manufacturing is one such broad concept that has evolved, combining the fundamental principles of sustainability. According to Abubakr et al., attaining sustainability in production and operations within the process of manufacturing, and refining products based on their useful lifecycle is a fundamental approach to enhancing financial performance and abiding by the rules and requirements of a broad form of cultural, social, and economic sustainability, which involves recovering products, minimizing the need for redesign, recycling, and reusing products, ultimately delivering products beneficial to human health and the environment in general, thus efficaciously contributing to enhancing human life and, as a result, the global economy(Dassisti et al., 2012).

2-5- The Importance of Sustainable Manufacturing:

The importance of sustainable manufacturing and its associated strategies cannot be overstated, as this approach enables the addressing of social, environmental, and economic problems. Moreover, it helps reduce the environmental impact of industrial processes; for example, it helps reduce gas emissions and contributes to natural resource conservation. In addition, it focuses on improving the efficiency of resource utilization, such as raw materials and energy, which helps enhance the production process and reduce costs. Furthermore, it can help improve the economic sustainability of factories, as costs are reduced and the reputation of organizations and their social responsibility practices are enhanced. Finally, sustainable manufacturing can help innovate in the field of manufacturing and improve processes, as water, materials, and energy are scarce and cannot be replenished. The global economic crisis of the last several years raised numerous questions about whether existing businesses and business practices should be followed and why they have not reduced their negative impact. Therefore, there is considerable pressure

on the practice of sustainable manufacturing from investors, suppliers, competitors, customers, organizations, governments, employees, and regulators (AlShahwani & Raad, 2021:50).

2-6- Sustainable Manufacturing Objectives:

Sustainable manufacturing is a type of manufacturing that plays a significant role in the success of the production process and the achievement of outstanding goals, making the economic unit a leader in its field compared to its counterparts. Sustainable manufacturing seeks to achieve four main objectives:

1. Reducing energy consumption
2. Reducing solid waste
3. Reducing water consumption
4. Reducing emissions resulting from industrial processes.

With that being said, I can conclude that there is such a thing as a competitive superiority of an economic unit, which it achieves through the continuous improvement of industrial processes and enhancing its product efficiency. Additionally, an ongoing program of improving all unit activities, from transportation and production to supply chains and waste disposal, leads to increased revenue and a better living standard for community members. This, in turn, gives the economic unit a unique standing as compared to its rivals (Carley et al., 2014, p. 8).

2-7- Dimensions of Sustainable Manufacturing:

Sustainable manufacturing encompasses three primary dimensions: economic, social, and environmental. These dimensions must be interconnected and integrated to achieve economic improvement and social well-being. Maintaining the essential components of long-term life through the use of modern technologies encompasses the following dimensions:

1. **The Economic Dimension** is a fundamental objective in production and industrial environments. It is essential in all production and industrial processes, as without it, work and wealth creation for all contributing individuals would cease to exist. Sustainable production and manufacturing contribute to cost reduction through the use of sustainable manufacturing practices and the optimal use of technologies (Al-Saray, 2017:51). This dimension requires the optimal and highly efficient use of available economic resources to raise the standard of living for individuals, improve social conditions, and ultimately achieve a decent standard of living by reducing costs, energy, and production inputs, thus realizing added value (Saleh, 2019:19).
2. **The Social Dimension:** The social dimension can be defined as the individual's right to live in a clean environment through the practice of all activities, in addition to their right to natural resources and social and environmental services. This is to be utilized in a way that fulfills both basic and supplementary needs, thereby raising the standard of living for future generations. (Yilmaza & Bakis, 2015:2256) This dimension encompasses essential requirements, including housing, employment, health conditions, education, and cultural activities, in the long term (Widok & Wohlgemuth).
3. **The Environmental Dimension:** This dimension involves evaluating the environmental impacts of production and manufacturing processes. In other words, it requires the reduction of waste, pollutants, and other harmful toxic gases by maximizing production and using all resources and assets efficiently. This is necessary to minimize the depletion of environmental resources for future generations and to reduce environmental damage by supporting nature with sustainable and biodiverse activities (Al-Saray, 2017:52). We can say that this dimension particularly raises the willingness to adopt a socially upscale production method rather than the conventional manufacturing one. The dimension is related to the enabling capabilities of natural and environmental properties to meet the requirements. (Al-Roumi, 2018:35).

3- Practical Aspect

3-1- Tests for scale reliability and normal distribution:

The testing phase for quantitative measurement properties was crucial for ensuring the validity and reliability of the results obtained. This was achieved by verifying whether the measuring instrument could indeed measure the concepts and that the results were consistent. In this case, the authors established that Cronbach's alpha was among the most important measures of internal consistency. The instrument was found to be highly reliable, with reliability coefficients for all dimensions ranging from 77.98% for the Economic concept to 91.76% for the Environmental concept. In both cases, these values were very high, confirming that all indicators in the dimensions are relatively coherent and highly interconnected. All these values were higher than the allowed minimum level (70%) and confirmed the reliability of the measurement instrument, as well as the validity and quality of the data used in the current and further statistical analyses. It was equally important to verify that the data met the conditions for implementing parametric analysis, first of all, the condition of normality. It was assessed by calculating the skewness and kurtosis indices. The former indices were modest, ranging from 0.654 to 1.417, and, importantly, all were positive, indicating that these distributions have relatively low values in the samples. They were the only values that were well below the maximum permissible level (|2|).

In contrast, the kurtosis values all had negative values, ranging from −0.565 to −1.602. That is, they are infinitely flatter than the normal distributions, but within the permissible statistical limits. Therefore, the data met the qualifications and had the capacity for implementing parametric statistical tests, such as correlation and regression, allowing for valid conclusions about hypothesis testing to be drawn from this data.

Table (3) Reliability coefficient and normal distribution for dimensions and items

Variables	Dimensions	Number of paragraphs	stability coefficient	Skewness	Kurtosis
Total Quality Principles	Leadership (Top Management)	3	87.43%	1.123	-1.209
	Strategic Planning	3	91.19%	1.417	-1.001
	Customer Focus	3	90.76%	1.095	-1.287
	Resource Focus	3	89.32%	1.193	-0.878
	Process Management	3	84.65%	0.897	-0.996
	Information, Analysis, and Improvement	3	91.08%	0.654	-0.565
	Quality Outcomes	3	79.99%	1.329	-1.432
All sections of the dimensions of the principles of total quality management		21	87.77%	1.101	-1.053
	Economic dimension	3	77.98%	1.308	-1.213
	Social dimension	3	87.35%	1.056	-1.143
	Environmental dimension	3	91.76%	1.063	-1.602
All aspects of sustainable manufacturing		9	85.70%	1.142	-1.319

"The source was prepared by the researcher using the SPSS program."

3-2- Descriptive Analysis of Sample Responses

This section describes the study results by reviewing the opinions and preferences of the employees (in the studied laboratory) in the study sample of 116 respondents. It determines the level of agreement regarding the suitability of the measurement instrument items to them by focusing on descriptive statistical analyses, namely, (arithmetic mean, standard deviation, relative importance, coefficient of variation, and level and direction of response) for each item of the variables under study. Therefore, to measure the level and direction of response, a five-point

Likert scale can be used to extract the categories that allow for assessing the level and direction of the study sample's response to the study items. This is done by determining the range (5 - 1 = 4), then dividing the range by the number of categories (5) (4/5 = 0.80), and finally adding (0.80) to the lower limit.

The relative importance is measured by dividing the lowest and highest scores in the categories of response level and direction by the highest score on a five-point Likert scale (5). Table 4 illustrates the degree of preference for response level and direction.

Table (4) Criteria for the availability of study variables

Categories	Level of relative importance:	Direction of response	Categories	Answer level:
0.36 – 0.01	Very weak	Disagree	**1.80 – 1**	Very low
Greater than 0.36 – 0.52	Weak	Disagree	**2.60 – 1.81**	Low
Greater than 0.52 – 0.68	Moderate	Neutral	**3.40 – 2.61**	Medium
Greater than 0.68 – 0.84	Good	Agree	**4.20 – 3.41**	High
Greater than 0.84 – 1	Excellent	Strongly Agree	**5 – 4.21**	Very high

Akadiri O. P. (2011), Development of a Multi-Criteria Approach for the Selection of Wolver Hampton, U.K.

The dimensions were arranged and preferred based on the value of the lowest coefficient of variation, as an interpretation of a 30% coefficient of variation is acceptable in social studies according to (Field, 2017), as this indicator is an indication of the highest levels of consistency and coherence in the responses of the sample members selected by the laboratory under study to evaluate the main dimensions and variables.

1- The variable of Total Quality Management principles: -

At the variable level, Table 5 indicates that the total application of TQM principles within the organization is high. The mean is 3.53, and the relative importance is 70.6%. This indicates that the managers tend to agree on the application of the core principles of TQM. However, the coefficient of variation of 20.2% implies moderate variability in the respondents' answers concerning the extent of application. This implies that the level of commitment to these principles varies between the departments and the different divisions within the organization. :

- ✓ The leadership dimension (top management) ranked third with a high level. It had the mean scores of 3.62 and a relative importance of 72.4%. This is a higher application level, meaning that the respondents agree with the premise that the top management "is committed to adopting TQM by defining visions, allocating resources to bring about the vision, and supporting the initiatives as a part of the total organization's process". Leadership embodies the fundamental requirement for the success of a company's program and its perpetuation. Leadership as a skill is the primary means and lever for creating and enhancing the culture of quality in the company.
- ✓ The strategic planning dimension ranked fourth, with high mean scores of 3.57 and a relative importance of 71.4%. Here, the organization applies the medium application level. This indicates that the company is confident that quality objectives should be key components in its strategic plans. The medium rank implies that the quality objectives may not be fully integrated into the organization's strategic direction or should be enhanced systematically.

- ✓ The customer's focus dimension had the highest mean among the Respondents. The dimension had a mean of 3.73, a relative importance of 74.6%, and a high level of response. It reveals that it goes out of the box in its philosophy, relying on the principle that the satisfaction of this very customer is the main measure of the quality of the goods. The low coefficient of variation is indicative of the high probability that the value was quite important for the managers, reaching 15.4%.
- ✓ The focus on resources takes fifth place, with high levels, a mean rating of 3.53, and a relative importance of 70.6%. It consists of an acceptable level indicating the organization's interest in the development and training of its human resources, as well as creating all the appropriate conditions for them to accomplish these tasks within the required quality standards. However, the elevated coefficient variation of 21.2% suggests the divergence in the efficiency of the training and enabling programs implemented. The level of perceived active participation by managers may also vary.
- ✓ The dimension of process management had the lowest scores among the principles, ranking seventh with a mean of 3.24 and a response level of middle. This is a crucial signal, as process management is the heart of continuous improvement, performance control, and efficiency. A neutral response shows that there are some problems or complications in the application of systematic tools for process control and waste reduction. These can be a barrier for the organization to achieve higher levels of quality and efficiency.
- ✓ Information, analysis, and improvement was sixth, scoring moderate with an average of 3.33. Although it is common knowledge that any decision-making process must be data-driven, an average level may indicate systemic weaknesses in data collection, performance, and methodology. Alternatively, the weakness of quality data analysis results hinders support for the QAPI continuous improvement cycle. The latter may lead to an organizational inability to identify root causes properly. Additionally, it makes it impossible to direct and vision-directed targeted organizational performance improvement efforts.
- ✓ Quality outcomes ranked second on the list, with an average high level of importance, yielding an average score of 3.68. It shows that the total application of Quality Management principles has a positive impact on both the level of quality of products for the final customers and their overall cost. It also positively impacts the company's operational performance. At the outcome level, it shows that managers can trace a link between the quality efforts and the final results that meet customer satisfaction. It contributes to the overall achievement of the organization's vision, which is founded on an initial strategic approach that relies on quality-effective solutions.

Table (5): Summary of descriptive indicators for the dimensions of the Total Quality Management principles variable.

	Dimensions of the Total Quality Management	arithmetic mean	standard deviation	Direction of response:	relative importance	Answer level:	C.V	Sequence
1	Leadership (Top Management)	3.62	0.665	Agree	72.4%	High	18.4%	3
2	Strategic Planning	3.57	0.692	Agree	71.4%	High	19.4%	4
3	Customer Focus	3.73	0.576	Agree	74.6%	High	15.4%	1
4	Resource Focus	3.53	0.748	Neutral	70.6%	High	21.2%	5
5	Process Management	3.24	0.886	Neutral	64.8%	Medium	27.3%	7
6	Information, Analysis, and Improvement	3.33	0.804	Agree	66.6%	Medium	24.1%	6
7	Quality Outcomes	3.68	0.614	Agree	73.6%	High	16.7%	2

Total Quality Management (TQM) Principles Variable	3.53	0.712	Agree	70.6%	High	20.2%	

"The source was prepared by the researcher using the SPSS program."

2- Sustainable manufacturing variable

Table (6) mainly shows the results of the overall level of the realization of the application of the concept of sustainable manufacturing in the factory, with a mean of (3.37), with the relative importance score equally (67.4%). That is, a significant number of managers generally agree that the factory applies the concept of sustainability. However, the coefficient of variation at (22.3%) shows a moderate distribution of opinions among workers, indicating that the implementation work is not uniform throughout all the plant's departments and that the effectiveness of combining the three dimensions must be increased.

- In the environmental dimension, which realized the highest rank, the general level of realization is high, as the mean came at (3.74) and the relative importance score at (74.8%). This result demonstrates that the plant places great emphasis on mitigating the environmental impacts resulting from its operations, which is both expected and essential in the cement manufacturing industry. As evident in the result, when the desire to achieve goals of sustainability by reducing emissions and waste, efforts in this field will be significant, and the low value of the standard deviation (0.666) indicates that there is a high degree of consensus among workers in the plant according to their satisfaction with the work of this paragraph.
- In the social sphere, which came in second place, the level of realization is moderate, as the mean score equals 3.25 and the relative importance score is 65.0%. Thus, it indicates that the factory agreed with workers 'general agreement toward the impact of plants' operations on the safety and health of workers, improving the conditions of their job, and preserving the environment. This medium-weak mean should be strengthened and restored because it implies that the factory's work in the social good workers and providing a clean and unsaturated environment, which each person has the right to, is still at a moderate rate and does not reach the high rate necessary for attracting workers 'interests and aspirations and gaining the continuation of the society's confidence in the factory.
- In the economic dimension, which came in last place, realization was also the least moderate, with a mean score of 3.12 and a relative importance score of 62.4%. This indicates that the collective opinion of workers aligns with the general trend regarding the factory's role in achieving the goals of optimal resource utilization, cost reduction, and increased financial efficiency, which is necessary within the framework of sustainable manufacturing. However, the low implementation of this dimension, which is essential for wealth access and business development, is evident and must be addressed because of its immediate remedy: trimming costs and development projects.

Table 6: Summary of descriptive indicators for the dimensions of the sustainable manufacturing variable.

	Dimensions of the Sustainable Manufacturing Variable	arithmetic mean	standard deviation	Direction of response:	relative importance	Answer level:	C.V	Sequence
1	Economic Dimension	3.12	0.852	Neutral	62.4%	Average	27.3%	3
2	Social Dimension	3.25	0.734	Neutral	65.0%	Average	22.6%	2
3	Environmental Dimension	3.74	0.666	Agree	74.8%	High	17.8%	1

The Sustainable Manufacturing Variable	3.37	0.751	Agree	67.4%	High	22.3%	

"The source was prepared by the researcher using the SPSS program."

3-3- testing the study hypotheses

The first main hypothesis (H1): "The main and Null hypothesis states: (There is no statistically significant effect of applying Total Quality Management principles in sustainable manufacturing)."

A method sometimes referred to as structural equation modeling was used to measure the strength of the correlation and the extent to which an item belongs to the dimension it was designed to measure. Therefore, structural equation modeling is a fundamental approach to confirmatory factor analysis, which attempts to cope with a large set of variables and reduces them to a smaller set by detecting the extent to which an item belongs to the dimension it was designed to measure. The variables of the study must be evaluated according to quality criteria of conformity to facilitate the interpretation of confirmatory factor analysis. The following table explains the indicators of quality conformity based on structural equation modeling.

Table (7) Conformity Quality Indicators according to the Structural Modeling Equation

Rules	Index
Less than (0.05) Good, less than (0.02) Compliant, greater than (0.05) Rejected	*Ratio between (x2) value and degrees of freedom (CIMN/df)*
Value range between (0) - (1), Acceptance rule: greater than (0.90), greater than (0.95) Compliant	*Quality of Fit Index (GFI)*
	Comparative Fit Index (CFI)
	Tucker Lewis Index (TLI)
Less than (0.05) Compliant, values between (0.05 - 0.08) Good, values between (0.10 - 0.08) Average, values greater than (0.10) Rejected.	*Root Mean Square Error of Rounding (RMSEA)*
Greater than 0.40	*Item Saturation Rate*

"The source was prepared by the researchers based on Hair et al. (2010)"

According to the structural model, whose reliability and plausibility were verified, the quality assessment criteria reached higher values than the required indicators stipulated by Hair et al. (2010). The results of the main hypothesis test H_1 confirm the ability to use the proposed engineering model effectively. A more robust, statistically significant positive relationship was established between the TQM and SM overall dimensions through structural analysis. It means that the quality becomes a strategic prerequisite for sustainability in an industrial environment. If a factory adheres to the principles of TQM, aggressive and careful work on sustainable outcomes in terms of quality assurance makes these outcomes almost inevitable. The standardized value amounted to 0.654, which means that any step taken by an organization to improve its TQM results in an approximate 65% increase in manufacturing sustainability achievements across the three spheres of the given concept. It is an extremely strong relationship with a significance level of 0.000 and the critical level of more than 10.111. To put it short, the null hypothesis may be ignored, and it is indispensable to accept TQM as the methodology for greening. It happens because the techniques for the latter one clarify the strong effect of TQM. Continuous improvement and the associated reduction of waste are not limited to minimizing product defects; they also encompass the optimization of processes and the elimination of unnecessary activities. They are the main source of reducing staff errors, as well as energy and raw material consumption. This approach guarantees the provision of economic efficiency, which includes the ability to increase productivity and reduce costs. The result is a reduction in pollutant emissions,

achieved through a decrease in the use of natural resources during the production process. Moreover, according to TQM, types of enterprises with the most waste in the world do not allow for measuring the main tools and mechanisms, including information for management, analysis, and indicators. The improvement requires a precise measurement system to govern sustainable achievements. Emissions of toxic substances, energy consumption, and the generation of hazardous waste must be monitored more frequently than once or twice a year. Decisions are made every time a cause of divergence or an adverse trend is detected. The data quality index, or GFI, was 1.00, and the RMSEA was 0.068, only 0.062 above the mean for the best acceptable range. In this case, the variance of sustainable manufacturing is 60.8%. This high percentage suggests the very significant role of quality in achieving most. The sustainability goals can be explained.

The remaining 39.2%, or more than a third, comes from technology, market demand, and government regulation, making TQM the most effective organizational tool for efficiently incorporating corporate sustainability into operational strategies.

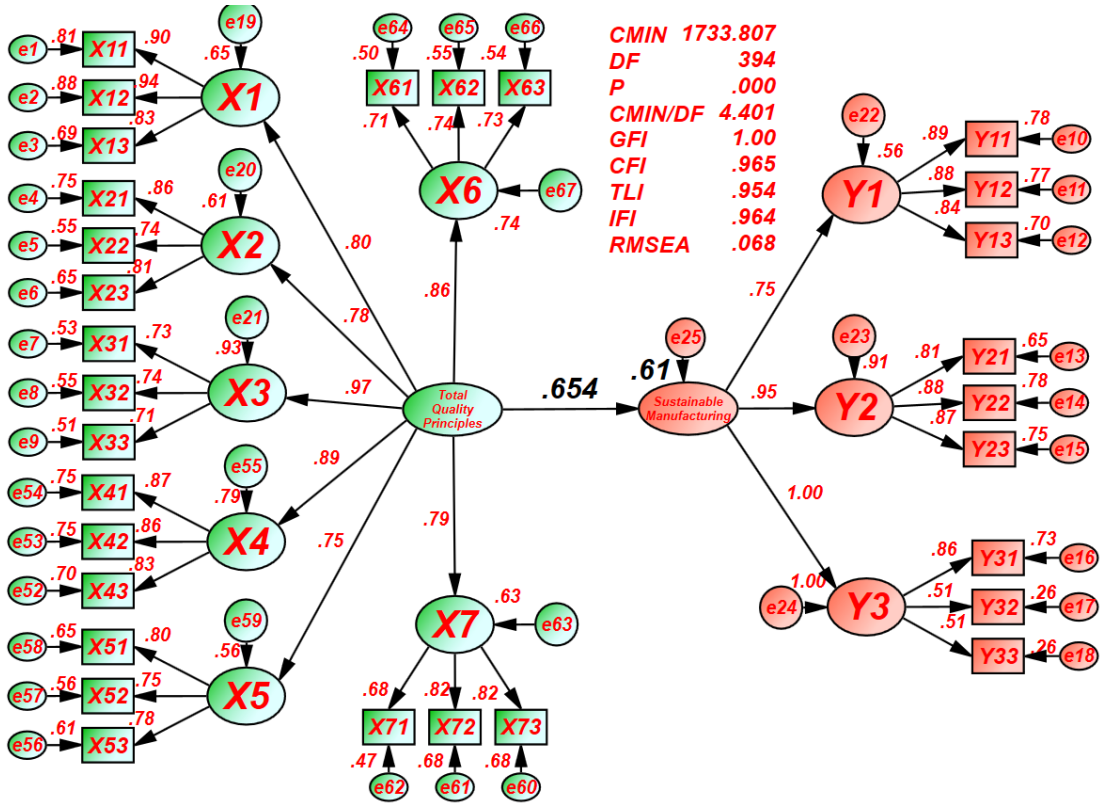

Figure (2) The structural model for applying the principles of total quality management in sustainable manufacturing

Source: Prepared by researchers based on the outputs of the statistical package "AMOS.V.26".

Table 8: Final results of the direct impact between the principles of total quality management and sustainable manufacturing.

Path			*Standardized assessment*	*standard error*	*Critical value*	*R2*	*Sig.*
Total Quality Principles	*<--*	*Sustainable manufacturing*	*0.654*	*0.065*	*10.111*	*60.8%*	*0.000*

Source: Prepared by researchers based on the outputs of the statistical package "AMOS.V.26".

"The Following Sub-Hypotheses Stem From The Main Hypothesis":

First: The impact of TQM principles on the economic dimension (Hypothesis H_(1.1)

Table (9) The impact of TQM principles on the economic dimension

The path			(β)	(C.R.)	(Sig.)	Note
Quality Results	→	*Economic dimension*	*0.077*	*1.55*	*0.121*	*Not significant*
Information and Analysis	→		0.150	3.10	0.002	Significant
Customer Focus	→		*0.093*	*1.98*	*0.048*	*Significant*
Resource Focus	→		0.051	1.22	0.223	Not significant
Process Management	→		*0.315*	*6.40*	*0.000*	*Most influential*
Leadership	→		0.085	1.89	0.059	Not significant
Strategic Planning	→		*0.112*	*2.15*	*0.031*	*Significant*

"The source was prepared by the researcher using the SPSS program."

The statistical results show that all TQM dimensions have a significant positive impact on the economic dimension of sustainable manufacturing. The most influential dimension was process management, demonstrating a standardized value of 0.315 and a high level of significance. Such a strong relationship seems quite natural due to the very essence of economically sustainable manufacturing. On the one hand, it is most directly related to efficiency, and on the other hand, it is described in terms of process management. As a quality management practice, TQM has become a tool to achieve efficiency by applying continuous improvement methodologies, such as Lean, which strives to minimize waste, defects, and cycle time. Each step in simplifying processes and the efficient use of time results in the optimal use of materials and energy. Thus, the reduction of operating costs, mainly linked to materials and required energy, combined with a constant increase in productivity, achieves economic sustainability. At the same time, dimensions such as strategic planning, information, and analysis also exhibit significant effects. On the one hand, this can be explained by the realization that process management is responsible for having clear economic goals for sustainability and measuring them with data. Nevertheless, on the other hand, the only dimensions that did not show a significant effect are the leadership and quality outcomes. Their effect is probably indirect, meaning that they realize their influence through process management.

Second: The effect of TQM principles on the social dimension (Hypothesis H_(1.2)

Table (10) The effect of TQM principles on the social dimension

The path			(β)	(C.R.)	(Sig.)	Note
Leadership	→	*social dimension*	**0.255**	**4.90**	**0.000**	Most influential
Strategic Planning	→		0.062	1.34	0.180	Not significant
Customer Focus	→		0.040	0.81	0.418	Not significant
Process Management	→		0.155	3.12	**0.002**	Significant
Resource Focus	→		0.198	3.85	**0.000**	Significant
Information and Analysis	→		0.103	2.05	**0.040**	Significant
Quality Results	→		0.035	0.70	0.484	Not significant

"The source was prepared by the researcher using the SPSS program."

The analysis results in Table 1 indicate a significant impact of all TQM dimensions on the social dimension of sustainable manufacturing. Specifically, the Leadership dimension recorded the highest impact value, 0.255, and strong significance. The social dimension, which encompasses employee health and safety, training, and fairness, is both value-based and culturally driven. Thus, commitment to it necessarily originates from the top of the organizational hierarchy. Top management allocates resources to the occupational safety programs, establishes training and empowerment policies, and encourages teamwork—all accepted methods for successful TQM. These factors are directly impacting the well-being of employees and the social responsibility of the plant. In addition to leadership, the human resources focus dimension also had a strong

impact, indicating that the social sustainability of the plant is closely related to how individuals are empowered and trained in quality and safety. Thus, any improvement in social performance should first begin with a visible management commitment and then with the empowerment of human resources.

Third: The impact of TQM principles on the environmental dimension (Hypothesis H_(1.3)

Table (11) The impact of TQM principles on the environmental dimension

The path			(β)	(C.R.)	(Sig.)	Note
Leadership	→	*environmental dimension*	*0.102*	*2.15*	*0.031*	*Significant*
Strategic Planning	→		0.091	1.95	0.051	Negative
Customer Focus	→		*0.065*	*1.30*	*0.194*	*Negative*
Process Management	→		0.188	3.51	0.000	Significant
Resource Focus	→		*0.070*	*1.40*	*0.161*	*Negative*
Information and Analysis	→		0.301	5.98	0.000	Most influential
Quality Results	→		*0.125*	*2.60*	*0.009*	*Significant*
البيئي ←نتائج الجودة	0.125		2.60	**0.009**	Dal	

"The source was prepared by the researcher using the SPSS program."

The findings confirmed that the total TQM dimensions have a positive impact on the observation of the environmental dimension. The most influential dimension was Information, Analysis, and Improvement, with a constant value of 0.301, which exceeded the significance level of 0.05. The relationship between data and the environment is one of causal determinism; a plant cannot reduce emissions or optimize energy consumption without a statistical system in place to measure, control, and analyze these variables. Therefore, TQM's Information, Analysis, and Improvement dimension provides the necessary statistical tools to accurately observe environment-related indicators, enabling proactive detection and elimination of waste causes. I would like to add that all these also clarify a preliminary warning process and a monitoring process for any pollution issues. Another strong and causal relationship was Process Management, as the vehicle of this improving strategy is actually the means to remove Pollutant A from product process B; in other words, the vehicle that gives a lift to removing pollutant A from product process B. From this result, we can argue that most environmental transformation is not about new equipment, but rather about analyzing relevant data and operating practices to a certain level, at best practice levels.

4- Discussion of the results

Structural analysis has confirmed the strong and statistically significant positive relationship between the overall dimensions of TQM and SM, accepting the engineering model of TQM as the strategic driver of sustainability transition. The overall fit of the model to the data was excellent, indicating its validity as a management model in the lab environment. The overall standardized score was 0.654, indicating that the improvement of each step in the TQM practices had a significant influence on achieving the goals of sustainable manufacturing. TQM explains approximately 60.8% of the variance in sustainable performance, making it the most influential element. The overall level of its implementation was acceptable; however, the more important issue was the variation in the degree of implementation across the dimensions.

The descriptive analysis revealed an imbalance in the application of both variables. In the TQM, the apparent strength of the customer focus corresponded to the external philosophy of the plant. However, process management, information, and analytics, which were core to data-driven continuous improvement, had the lowest implementation measure, and this was a crucial weakness in achieving SM. Regarding the SM dimension, note that while the implementation of

the environmental dimension had the highest level of expectation for the heavy industry, the economic dimension had the lowest level, followed by the social dimension practices. The findings demonstrate evidence that the factory made an environmental commitment but struggled to translate quality efforts into effective economic efficiency and social well-being.

The sub-hypothesis analysis explains the imbalance. Process management was the most influential factor in achieving the economic dimension, and the weak implementation meant that the dimension had the lowest level in history. Hence, it can be concluded that the improvement of sustainable economics was related to the elimination of waste from processes, and the plant's internal savings were also evident from the sub-hypothesis that the information and analytics dimension was the strongest factor in measuring the environmental dimension. The social dimension was influenced most by top management. The application-level findings lead to the overall conclusion that the factory was unable to activate the internal dimensions of TQM, including process and information management. The developed model operates as an integrated model, with seven dimensions of TQM serving as input variables, and the enablers are necessary for achieving and improving sustainable manufacturing performance in three dimensions.

Table (12) Enabling Factors (Inputs): Dimensions of Total Quality Management

TQM Dimensions	Description as an enabler of sustainability:	The direct impact on SM:
Quality Results	Achieving high product quality means minimizing defects and rework, which automatically leads to reduced resource consumption and waste.	Improving the economic dimension (profitability) and the environmental dimension (reducing resource consumption).
Information, Analysis, and Improvement	**Measuring and monitoring environmental and social performance indicators alongside traditional quality indicators using statistical tools.**	Making data-driven decisions to minimize environmental impact and waste.
Process Management	Applying TQM tools (such as Kaizen continuous improvement) to improve the efficiency of raw material, energy, and water use at every stage of production.	Achieving substantial improvement in both the environmental and economic dimensions (cost reduction).
Human Resource Focus	Training employees in waste reduction and quality improvement techniques, and empowering them to make decisions that promote sustainability.	Improving the social dimension (skills and participation) and the economic dimension (efficiency).
Customer Focus	Meeting customer demands for environmentally friendly (green) and sustainable products, while taking community perspectives into account.	Enhancing the economic dimension (customer satisfaction and loyalty) and the environmental dimension.
Strategic Planning	Integrating waste reduction, energy efficiency, and social responsibility objectives into the organization's operational plans.	Activating sustainability as a practical objective, not just an initiative.
Leadership (Top	Establishing a shared vision for quality and sustainability, resource	Directing the strategy towards long-term sustainability.

Management)	allocation, and ethical commitment across all dimensions (EES).	

The researcher prepared the table based on the results of the practical aspect.

System Outputs (Results): Dimensions of Sustainable Manufacturing

This section represents the achieved results that reflect the overall sustainable performance of the facility, driven by the application of TQM principles.

Table (13) System Outputs (Results): Dimensions of Sustainable Manufacturing

The dimension of sustainable manufacturing:	Key indicators of success
A. Economic dimension	** Higher profits and lower prices for quality. * More efficient use of resources (energy, raw materials). * Green products have a stronger competitive edge.*
B. Environmental dimension	* Cut down on pollutants and emissions. * Cut down on solid and liquid waste. * Boost recycling and make the best use of water.
C. Social dimension	** Happy employees and better working conditions. * High standards for health and safety at work. * Better corporate social responsibility and a good reputation for the factory.*

The researcher prepared the table based on the results of the practical aspect.

5- Conclusions

A. Results show that the overall level of application of Total Quality Management principles is high and that employees typically agree with the application of core quality principles. Nevertheless, this high level is not uniform, and departments exhibit a moderate level of variation in commitment. The main strength of the lies lies in its application to customer and quality outcomes, with the highest level of agreement observed in the faculties. I was struck by the fact that the category “strong” was connected only to leadership engagement within the company. It means that the majority of companies within the industry have a high level of awareness about the quality requirements and customer needs. However, the application appeared to be weak in terms of process management, information analysis, and further use of the transformation. These aspects are at the very core of continuous improvement, data-driven control, process assessment, and further utilization. However, the finding that the application is not fully utilized means that a company cannot reach the advanced and sustainable level of efficiency and quality, regardless of how committed senior management might be.

B. The results of statistical analysis indicate that the overall level of application of the sustainable manufacturing concept in the industry is high. Furthermore, it demonstrates that employees agree on the need to apply factors that promote sustainability. However, the moderate CV coefficient value suggests that the level of effort applied is not uniform, with some departments applying more effort in promoting sustainable growth than others. The main strength in terms of a dimension is the environmental dimension, which ranks first in terms of the degree of application. This refers to management’s attention to direct environmental improvement and the reduction of emissions, a critical element in the cement industry.

C. In contrast, the analysis shows that the economic dimension is the least applied in the field, followed by a dimension that corresponds to a social dimension, which is, on average. The gap suggests that the industry prioritises the establishment of a high level of environmental

commitment. The economic and social rights need to be reviewed, as they are currently insufficient to achieve a comprehensive sustainability balance at the required high level.

D. The results of the statistical testing supported the hypothesis, confirming that the implementation of Total Quality Management principles has a substantial impact on achieving the economic dimension of sustainable manufacturing. The process management dimension was the most influential of all. This means that the goal of making the factory economically sustainable is almost entirely tied to the ability to implement TQM methodologies to govern the factory's operations and reduce or eliminate the waste associated with production processes. The more successful the factory is at controlling variations in certain processes and reducing overproduction, rework, and scrap, the more efficiently it utilizes materials and energy. This results directly in lower operational expenses and higher overall productivity. This is the purpose of the economic dimension of sustainable manufacturing. The application of the principles of TQM has a substantial, positive impact on the social dimension of sustainable manufacturing. The leadership dimension proved to be the most influential in this regard. This means that it is impossible to attain the social goals that the sustainability idea poses in terms of employee safety, satisfaction, and a just working environment if the highest level of the management hierarchy is not clearly committed, both ethically and culturally, to this purpose. The leadership sets the example and establishes the budgets for safety and the required training hours, and delegates the necessary authority to ensure that employees are an integral and equipped part of the quality system. It is highly capable of directly improving the employees' well-being within the factory.

E. In my opinion, the ninth finding that the required numerical value was not found cannot be disregarded. The results demonstrated that TQM principles are effective and have a positive impact on the environmental dimension of sustainable manufacturing. In addition, information, analysis, and improvement were the most positively influential things. This means that to control the factory's impact on the environment, an accurate and unbiased system of measuring and monitoring the environmental impact of factories is necessary. Thus, TQM tools are used to analyze this data, revealing the primary causes of environmental problems. As a result, the factory's efforts to improve are focused on eliminating the sources of pollution from the processes, rather than treating the pollution afterward. In other words, TQM ensures that the environmental transformation is a step-by-step, continuous, and evidence-based process.

6- Recommendations

Some recommendations and suggestions that can be offered to the studied laboratory to promote sustainable manufacturing through quality principles:

To rebalance the sustainability efforts, the plant should consider reviewing the economic efficiency and social well-being strategies, which have the lowest implementation levels. The plant should consider unifying sustainability implementation efforts across the various Departments to minimize the observed discrepancies. However, it should maintain its clear excellence in the environmental dimension, which is a vital strength, particularly in the cement industry.

To enhance focus on social well-being and ensure effective performance, Senior Management, which has the strongest and most decisive influence on the social dimension, should focus on strengthening its commitment to the social dimension by directly connecting the principles of Total Quality Management to social programs for employees. The plant should focus on increasing investment in occupational health and safety programs to reduce job risks for employees and delegate broader authority to empower employees in their decision-making and create a fair organizational culture, allowing for growing satisfaction with work and life to

ensure that its leadership's commitment is directly translated into the improvement of well-being at work and the social goal achievement of sustainability. 10

To ensure effective control of environmental impact, the plant should focus on enhancing the application of information, analysis, and improvement dimensions, and developing its mechanisms to create a precise system and systematize structured, detailed monitoring of environmental performance. The laboratory should utilize TQM tools to develop and implement a system for analyzing emission, energy consumption, and water use data, and identify the root cause of environmental issues. This will ensure that improvements focus on eliminating pollution sources in production processes, rather than merely treating the effects.

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