

The Use of Flexible Manufacturing System and Its Role in Enhancing Sustainable Quality: A Field Study in the Electronic Industries Company – Baghdad

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Abstract

The research aimed to demonstrate the extent of the relationship and impact that **Flexible Manufacturing** contributes to enhancing **Sustainable Quality** at the Electronic Industries Company – Baghdad. The research population consisted of employees holding the positions of managers and experienced and specialized workers. They were targeted through a purposive sample that included (57) individuals out of a total research population of (65) individuals. In total, (56) questionnaires were actually retrieved by the researchers, of which (1) was excluded due to invalidity, resulting in (55) questionnaires ready for statistical analysis. The main tool for data collection was the questionnaire form. To process the data, several appropriate statistical methods were employed based on SPSS V.27, the statistics application. The study came to a number of results, the most significant of which was the existence of a statistically significant correlation and impact of **Flexible Manufacturing** in enhancing **Sustainable Quality** and its sub-dimensions. Based on these findings, A list of suggestions was made, with a focus on how flexible manufacturing must be included into the production process as a culture in order to achieve sustainable quality.

Keywords: *Flexible Manufacturing; Sustainable Quality.*

1. Introduction

The speed by which the market has been evolving and the growing demands both in terms of quality, variety and efficiency demands have made industrial firms to need to embrace manufacturing systems which are able to respond to these demands. Such a system is flexible manufacturing that is considered one of the innovative approaches that allow companies to react to changes in market needs quickly, provide tailored solutions to individual customer needs, and increase operational efficiency and flexibility with the help of modern technologies simplifying the changing of products without significantly affecting productivity. Such a system is based on sophisticated equipment and automated control processes that would increase the level of customization and minimize wastes in order to contribute to the further increase of the final product quality.

Sustainable quality is considered to be one of the main goals of the flexible manufacturing system; it is aimed to not only reach the highest, the best, standards of the quality of produced products, but also keep on improving the

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processes and production methods to minimize wastes, balance between the productivity and efficiency, and preserve the environment.

The flexible manufacturing system improves the sustainable quality by providing the necessary flexibility to observe quality at all the production steps and also to guarantee the actual execution of quality standards.

2. First Axis: Research Methodology

2.1. First: Research Problem

The research problem is on shortages of technological and informational capabilities in the production firms. These strategies allow companies to compete in the global market, improve their positions both in the domestic and foreign markets, enter new markets as well as improve the utilization of the heterogeneous resources. Many trends have surfaced since the turn of the 20th century with the goal of making manufacturing processes more flexible in order to meet all client demands and attain high operational efficiency. The concept of flexible manufacturing generally focuses on achieving high performance while minimizing the use of time, inventory, labor, worker effort, and capital, with the goal of increasing production, enhancing productivity, reducing all forms of waste, and achieving efficient use of production capacity. This, in turn, ensures the realization of product value at the lowest possible cost. Accordingly, the research raises a set of sub-questions that reflect the research problem in the company under study:

1. What are the definitions of flexible manufacturing and sustainable quality, and what is the nature of the relationship between them?
2. How well does the management of the organization being studied see and envision the two research variables, and how much of a flexible manufacturing strategy is being used in the company?
3. How much does implementing flexible manufacturing contribute to encouraging the use of sustainable quality standards??
4. What is the nature of the relationship and impact between the two research variables in the company under study?

2.2. Second: Research Importance

The study builds on previous research that has helped frame the cognitive contributions associated with the research variables in terms of a theoretical framework that offers theoretical insights into their notions and dimensions. The research's significance stems from its emphasis on a crucial industry, the industrial sector, which is regarded as one of the main cornerstones of any nation's infrastructure. The study was used at the Electronic Industries Company, which is one of the top manufacturers of electronic devices and is situated in a Baghdad suburb.

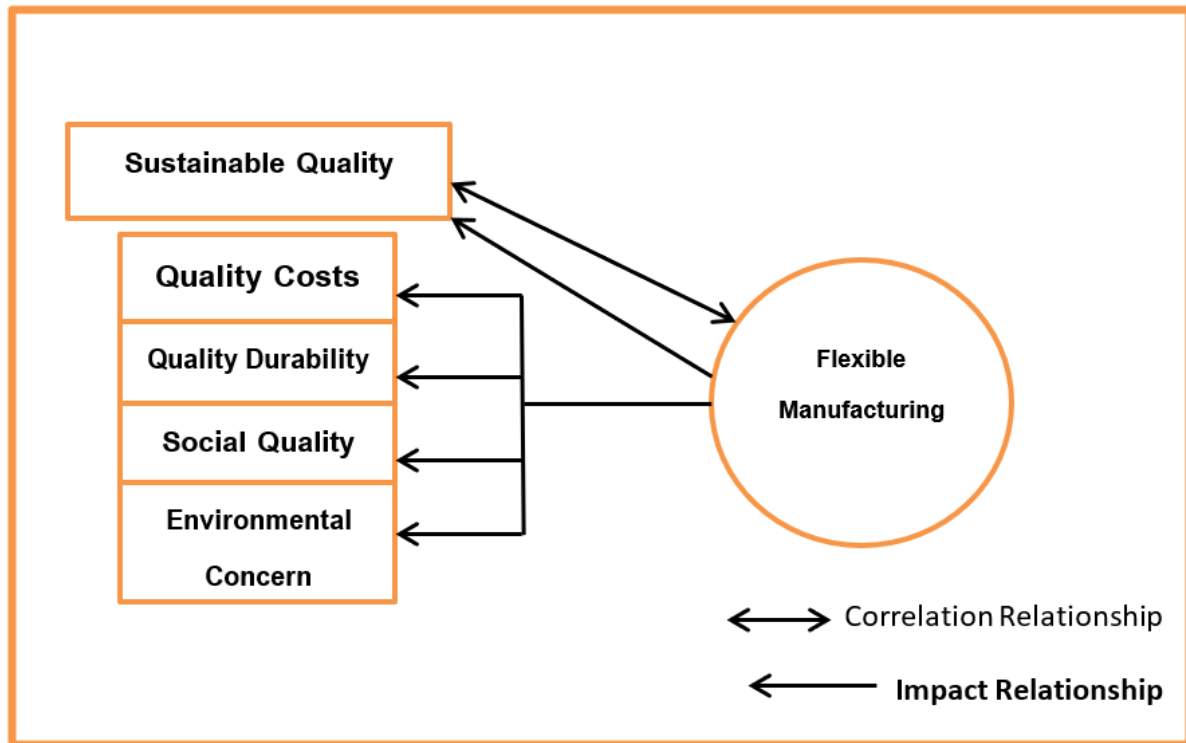
2.3. Third: Research Objectives.

Examining the connection between flexible manufacturing and sustainable quality is the primary goal of the study. This premise gives rise to a number of sub-objectives:

1. To identify the extent to which the company under study possesses the infrastructure for flexible manufacturing and the degree to which it invests in its operational activities.
2. To investigate how much the integrative relationship between flexible manufacturing and sustainable quality improves manufacturing flexibility.
3. In order to ascertain the degree to which the research organization possesses both the sustainable quality and flexible manufacturing dimensions.
4. To provide the management of the company being studied with a set of suggestions based on the findings of the field research in a way that improves the firm's performance and fosters its expansion and survival in the cutthroat market in which it works.

2.4. Fourth: Research Hypothetical Framework

The model was created to show the link between the independent and dependent variables in order to represent the research problem and the desired outcomes. The link between the two variables is depicted in Figure (1).



Source: The researcher's preparation

2.5. Fifth: Research Hypotheses

The research hypotheses can be framed as follows:

1. **First Main Hypothesis:** There is a significant, correlation. between flexible manufacturing and sustainable quality at the overall level, from which the following sub-hypothesis emerges:
 - There is a significant correlation between flexible manufacturing and each dimension of sustainable quality.
2. **Second Main Hypothesis:** There is a significant impact. relationship between flexible manufacturing, and sustainable quality at the overall level, from which the following sub-hypothesis emerges:
 - There is a significant, impact relationship, between flexible manufacturing and each dimension of sustainable quality.

2.6. Sixth: Research Population and Sample

The research population included the Electronic Industries Company – Baghdad. In light of the research problem and to test its hypotheses and achieve its objectives, a purposive sample was selected from the research population based on Morgan's Table shown in Appendix (1). The sample consisted of (55) individuals, including department heads, division heads, and specialized workers. The distribution results indicated that the response rate reached (96%) based on the percentage of questionnaires valid for analysis, which is considered a very high rate.

3. Second Axis: Theoretical Framework

3.1. First: Flexible Manufacturing

i. Concept of Flexible Manufacturing.

One of the techniques of comprehensive manufacturing, flexible manufacturing first appeared in the latter decade of the 20th century and was considered a crucial component of industrial enterprises' success. Innovation in industrial processes is the foundation of flexible production, which provides a large variety of products in various ways. (Al-Sabawi and Al-Azzawi, 2019, p. 215). Initiatives for flexible manufacturing have their roots in the Toyota Production System (TPS), which was first implemented under no in 1978 and expanded upon under Shingo in 1989. In order to increase manufacturing's added value, it emphasises the methodical and efficient use of resources through process scheduling, waste reduction, inventory minimisation, restricted human use, decreased material mobility, and close proximity to suppliers and consumers. (Kitan & Yasir, 2015, p. 84).

(Hamidi, 2018, p. 204) sees flexible manufacturing as the establishment of a collection of workstations with sophisticated machinery and equipment that are computer-programmed to handle, store, and produce a variety of goods under the same circumstances in order to gain a competitive edge.

(Jasim ,2008, p. 21) explains that it is a kind of computer-guided adaptive automation system for intermittent operations that can produce small and medium-sized parts in response to demand and keep production processes at the same degree of efficiency.

ii. Importance of Flexible Manufacturing

The importance of flexible manufacturing stems from the numerous advantages achieved through its application, including (Hamidi, 2018, p. 205; 415) Weckenborg et al., 2024):

- a) Conducting manufacturing operations for various products that share similarities in terms of components, such as the type of raw material, manufacturing method, and nature of operational processes.
- b) These factors do not change the unit cost of production of items that are produced on a single production line hence enabling the production capacity to be optimally utilized and the length of time taken by the processes of taking setup.
- c) Higher product quality levels due to the reduced human intervention in manufacturing processes.
- d) Flexibility in the variety of product paths during manufacturing operations, thereby minimizing constraints and limitations in the production stages.
- e) Minimising waste and getting rid of any processes that don't bring value to the product.
- f) The process of building long-term relationships with suppliers requires the existence of open communication lines and involving suppliers into information flow and risk management.

iii. Characteristics and Advantages of Flexible Manufacturing

The flexible manufacturing system has several characteristics which distinguish it compared to the traditional systems especially in respect of speed, flexibility, quality and efficiency. It is characterized by the following (Manu, 2018, p. 324; Al-Sabawi and Al-Azzawi, 2019, p. 216):

a. Process Flexibility: The ability to design various production activities in a highly flexible manner, hence making it possible to repeatedly re-arrange production.

b. Fashionability in Material Handling: There are several avenues through which production activities can transverse to handle products.

c. Machine Flexibility: A machine is used to perform multiple production functions.

d. Product Flexibility: The ability to manufacture a heterogeneous combination of products or production of new products and simultaneously staying cost effective and reducing time spent.

e. Flexibility in Routing: The use of multiple different routes to produce a given number of products.

f. Volume Flexibility: The ability to be able to deliver different amounts of products based on the demand or to change the production plan and easily adapt to this change.

iv. Pillars of Flexible Manufacturing

The system is supported by several underlying factors which ensure flexible production operations, which include:

a. Just-in-Time (JIT) Production System: The JIT system is an organizational doctrine, which is based on the accomplishment of requisite actions at the exact juncture of the time, consequently avoiding an anticipatory or delayed action. Moreover, it coincides with the pull-based production paradigm whereby products are only provided on the request of the customers. The general goal of the system is to reduce non-value-added processes and improve the quality standards thus handing over a relative decrease in the general level of costs (Weckenborg et al., 2024:418).

b. Cellular Manufacturing: Cellular manufacturing is a production strategy that enables efficient production of various sets of products and at the same time reducing wastage of materials. This method requires the organized lay-out of facilities and work areas in a manner that facilitates the smooth flow of material during the manufacturing process and also to reduce delays during the operations. The resultant production structure takes the shape of a cell, an assembly of workers, machinery, and a system of material conveyance, that is planned to minimize the amount of waste, reduce production lead times, improve quality measures, accurately estimate machine load, and line capacity, facilitate process redesign, allow management changes, and promote teamwork (Al-Tamimi & Saad, 2022, p. 175).

c. Kaizen: Kaizen: which is the most outstanding Japanese philosophy consists of two words, which are Kai which means change and Zen which means improvement. Kaizen, in turn, refers to the continuous improvement towards the perfect performance in the occupational setting, due to the continuous improvement and change of raw materials, working environment, machines, technologies, and process of promoting innovations throughout the entire production chain. The goal is to minimize waste and losses in resources, reduce costs, and direct human and cognitive efforts toward providing better services to customers to achieve the highest possible returns (Gupta et al., 2015, p. 174; Masouda, 2018, p. 6).

3.2. Second: Sustainable Quality

- i. **Concept of Sustainable Quality:** The concept of quality has recently expanded beyond the classical view of satisfying customer needs related to products, to include not only delivering excellence to a diverse group of stakeholders but also encompassing environmental safety and the social aspects of organizational performance. Accordingly, companies have moved toward adopting what is known as sustainable quality and its impact on company performance through its main determinants (Maletic & Gomiscek, 2011, p. 3). (Svenson ,2021, p. 79) states that sustainable quality is an effective control tool that works on detecting defects and errors in products and eliminating them to achieve the desired objectives of companies. (Sulaiman ,2022, p. 51) views sustainable quality as a strategic requirement and goal that companies strive to achieve, despite the obstacles that may arise and contribute, in one way or another, to limiting its

realization. This explains that sustainable quality is one of the future aspirations companies aim to achieve and the ultimate result they seek to reach.

- ii. **Importance of Sustainable Quality:** The concept of quality is closely linked to sustainability if a company aims to achieve its goals. Moreover, sustainable quality is connected to managerial activities related to planning, organizing, coordinating, and directing. Thus, a company's success depends on its ability to integrate these processes (Abbas, 2020, p. 83). (Henriques et al. ,2022, p. 21) stated that any errors in the processes affect the system's efficiency and effectiveness, highlighting the importance of sustainable quality in detecting defects and errors occurring during the process, working to repair and prevent them. Sustainable quality is therefore considered a vital tool for detecting, eliminating, and correcting errors during operations.
- iii. **Factors Influencing Sustainable Quality:**

There are many factors upon which sustainable quality depends and that significantly influence it. Prominent factors have a clear impact on the sustainability process of total quality, where sustainability here refers to the continuous improvement of products within the surrounding environment, management style, policies, and organizational structure, each having its own specific factors. These factors include (Blašková et al., 2022, p. 89):

a. **Technical Factors:** Modern technological and technical advancements help in developing new and advanced methods and tools to improve technology. Sustainable quality highly contributes to controlling technologies by improving production methods and control procedures.

b. **Economic Factors:** Companies bear high costs in repairing defects and errors resulting from inaccuracies in work methods, leading to waste of resources, money, energy, and time. Quality errors also result in higher operational costs, decreased profits and revenues, and withdrawal from global market competition, thus emphasizing the importance of promoting local production development.

c. **Environmental Factors:** Researchers and scholars have placed significant emphasis on the subject of quality because it represents a cornerstone of industry. The focus is on the quality of final products, but attention must also be given to the quality of performance in governmental activities by comparing actual production performance with pre-planned objectives. Moreover, it is essential to study the aspects that contribute to improving work and workers, and to compare the actual performance of various activities across all areas related to achieving goals and satisfying both management and customers.

- iv. **Dimensions of Sustainable Quality:** The dimensions of sustainable quality are considered an important element in determining the efficiency and effectiveness of company performance. Therefore, companies have moved toward clearly defining the goals and dimensions they pursue, and they have begun to promote a culture of quality among their employees as a work system. Over time, the use of quality as a sustainable advantage evolved, as it cannot possess sustainability unless companies fully adopt it. Thus, companies need to build a positive culture as a fundamental requirement for quality improvement (Maletič, 2018, p. 376). The researchers adopted the models of (Anitha Moosa & Feng He, 2021, p. 9) and (Sulaiman, 2022, p. 61), who indicated that there are four dimensions of quality that align with the current research orientations and can be summarized as follows:

a. **Quality Costs:** Quality costs serve as an indicator of all investments made to achieve quality or expenses incurred due to poor quality. The concept of quality costs was first introduced by quality experts (Juran, Feigenbaum, and Joseph) and is defined as the total cost incurred to prevent nonconformity.(Diele ,2021, p. 54) mentioned that there are several types of quality costs, including:

- **Prevention Costs:** These are the costs incurred to prevent the production of defective products. They include costs related to quality planning activities such as reviewing specifications and conducting tests, as well as training costs associated with training and supervising employees. Additionally, they cover process control

costs, which result from procedures that help diagnose process deviations, and improvement costs related to projects aimed at enhancing product quality.

- **Appraisal Costs:** These are costs related to evaluating the condition of products and materials based on requirements or specifications. They include costs of inspecting and testing raw materials, costs of inspection and testing equipment, and costs of materials and supplies used in inspection processes. (Al-Barqawi ,2023, p. 103) stated that quality costs represent the amount spent by the company to produce products that conform to specifications and meet the desired value for customers, thereby controlling the final product quality and the company's level of sustainability to meet customer needs.

b. **Quality Durability:** (Dehariya and Verma ,2015, p. 7) state that durability refers to the product's life cycle until its replacement and the extent of its benefit before deterioration, meaning the comprehensive and continuous utility derived from products. Durability expresses the strength and robustness of the product. It is a time-related concept, as customers' desire is evident in extending the lifespan of products to benefit from the services they provide. The longer the satisfaction benefits of products persist, the more important it becomes in saving customers' costs and effort (Amhashoul, 2023, p. 128). This implies that customers derive greater benefit from more durable products compared to those with lower durability. Rational customers tend to replace products only when they reach a point where they can no longer be repaired or reused, thus promoting resource economy, preserving resources, and using them wisely in consideration of future generations. It also enhances the environmental aspect by ensuring products do not turn into waste during the usage process (Putro, 2017, p. 33).

c. **Social Quality:** Companies clearly implement social responsibility activities to address social issues related to the environment, reduce poverty, and provide health and education services. (Holman and Waller ,2018, p. 247) defined social quality as the degree to which employees may engage in their communities' social, economic, and cultural life in ways that improve their own capacities and well-being. This participation is measured through factors such as leading social and economic security regarding material resources, social cohesion through the acceptance and sharing of values and norms, and the extent to which structures, relationships, and individuals enable participation and capacity development. Company activities can have both positive and negative impacts on workers within and beyond organizational boundaries, political discourse, and various aspects of society. Corporate social responsibility (CSR) is part of a broader field known in management literature as the company's social performance, which includes the total efforts a company makes to meet evolving societal conditions (Heizer & Render, 2017, p. 15).

(Sulaiman ,2022, p. 67) believes that social sustainability is achieved by adopting three key proposals that emphasize sustainable development, ethics, and responsibility: ensuring that management serves a higher socially significant purpose; integrating collective effort and organizational citizenship behavior into management systems; and rebuilding the philosophical foundations of management by redefining old business models not merely focused on efficiency but repositioning them within the context of the perception theory that as humans, we coexist and interact at the levels of body, mind, and spirit.

d. **Environmental Concern:** The interaction between companies and the environment has become a significant factor that has driven changes in production methods due to the growing global attention to climate change and sustainability issues. This phenomenon has brought about a qualitative change in the customer engagement practice by corporations, which have the twofold goal of increasing the level of stakeholder satisfaction and at the same time reducing environmental veils (Javaid et al., 2022, p. 38). (Krajewski et al. ,2021, p. 79) As noted, the issue of environmental quality has swept across consumers, and this has been explained by the increased awareness about the purchase of safe and benign products with respect to the environment. Consumers can even be willing to pay extra prices to acquire goods that do not have negative environmental impacts. The growing consumer awareness has compelled the manufacturing processes to be more environmentally conscious, and this has seen companies revise and perfect their production systems to fit the clean and environmentally friendly manufacturing practices.

Anitha (Moosa and Feng ,2021, p. 9) It has been established that products produced at high volumes and which meet design standards that are internationally accepted, are considered to have a higher quality of the environment as

compared to custom products. This is a strategy that is also known as productivity by low cost and environmentally sustainable strategy.

The eco-friendly approach to production helps decrease the amount of resources, reduce the use of energy, and save money with the help of standardization of not only manufacturing processes but also training of employees as well as ensuring the systematic control over the environment. The standardized production processes also help in minimizing the inventory levels in organizations thus limiting the need to have vast warehousing and cutting down on the spending on storage.

4. Third Axis: Field Study

4.1. First: Diagnosing Research Variables

i. Assessment of the Research Sample's Primary Research Variable (Flexible Manufacturing)

Table 1 gives the mean and standard deviation. The statistics show that there is a significant desire to build a ground on the flexible manufacturing with the mean value surpassing the theoretical mean by 3.51 units. The coefficient of variation was 0.29 and the standard deviation (SD) was 0.99, which showed a significant variation of the responses. Besides, a T-test of 26.369 supports this conclusion. Individual item mean values were greater than the theoretical mean ranging between 3.47 to 3.80. These findings indicate that there is increased worries among the senior management regarding this construct due to its central role in integrating the activities and increasing the efficiency in the operation.

The two items, i.e. eight and seven, portrayed the highest statistical significance whereby they had the lowest coefficients variation (0.23, 0.24, respectively) and the highest average (3.80 and 3.69, respectively). These items had standard deviations of 0.890 and 0.879 and t-test values of 31.655 and 31.132 respectively.

These results support the interest of the company to adopt modern production modalities that would produce a product that satisfies new requirements and to minimize the total cost spending that will give the company an edge upon its introduction into the market.

Table (1): Descriptive Statistical Analysis for the Research Variable (Flexible Manufacturing)

No.	Statements	Mean	ST.D	C.V	T-test
1	The company has production lines capable of manufacturing according to customer demand continuously.	3.71	1.012	0.27	27.171
2	The company strives to provide production capabilities that allow producing different products.	3.75	0.879	0.25	29.304
3	The company is capable of operating its production lines according to computer control systems.	3.49	0.928	0.28	26.447
4	The company has the ability to design new products flexibly.	3.50	0.918	0.26	22.898
5	The company handles continuous changes in technical and administrative environments.	3.47	1.034	0.30	24.913
6	The company is able to quickly address problems faced by employees.	3.07	1.026	0.33	20.351
7	The company seeks to quickly present its products in the markets.	3.69	0.879	0.24	31.132
8	The company seeks to reduce total costs through adopting flexible production methods that aim to introduce new products.	3.80	0.890	0.23	31.655
9	The company reorganizes its production lines in case of any problem.	3.47	1.025	0.30	24.338

No.	Statements	Mean	ST.D	C.V	T-test
10	The company designs its production lines to enable parts to be moved to another line if a failure occurs.	3.75	0.879	0.25	29.765
11	The company maintains distribution flexibility in its social responsibilities by maintaining its competitive opportunities.	3.78	1.066	0.28	26.306
12	The company focuses on maintaining economic flexibility at high levels in the field.	3.82	1.038	0.27	27.280
13	The company provides maintenance workers to handle production line breakdowns quickly.	3.81	1.086	0.31	22.587
14	The production lines are capable of increasing the quantity of products according to customer demand and at the appropriate timing.	3.47	0.879	0.25	29.304
15	A material handling and storage system enables the business to make ongoing enhancements..	3.71	0.975	0.26	28.209
16	The business is capable of producing a wide range of goods in significant volumes.	3.24	1.186	0.37	20.241

N = 55 | Significance Level = 0.00 | $P \leq 0.01$ |

- ii. **Reality of Sustainable Quality Diagnosis of Research Sample.** The statistics that indicates the mean and standard deviation of the sustainable quality variable are available in Table 2. The average figure of 3.55 shows that the top management pays significant attention to the promotion of sustainable quality. The overall coefficient of variation (C.V.) of 0.27 and the overall standard deviation of 0.99 could indicate that there is a lot of dispersion in the responses. This observation is supported by a T -test value of 27.64. The measures of sustainable quality will be used to measure the quality in its different dimensions, as follows:

a. Description and Diagnosis of Quality Costs in the Research Sample

The results of the Table 2 can be interpreted as the agreement of the surveyed people with the items concerned with the quality-cost aspect (items X17-X21). The total average of this dimension was 3.74 which implies that this firm being studied is focusing on this dimension as a methodological framework to examine the level of resource utilisation in operation related to poor quality. The standard deviation was 1.02 with a coefficient of variation of 0.27 and T-test of 27.537. The average scores of this dimension were higher than the hypothesized one on individual items, ranging between 3.36 and 3.91, which indicated that the company management is devoting more efforts to this dimension to produce the required production quality that is cost-effective and thus regulates the quality of final products and future sustainability of the firm. Items 17, 18, and 19 became the most salient items to this dimension; they had rather low coefficients of variation of 0.23, 0.24, and high mean values of 3.82 and 3.84 respectively, which was relatively low in their standard deviations of 0.898 and 0.905 respectively. The t -test statistics also support this interpretation and provided the following values of 31.69 and 31.305, respectively.

b. Description and Diagnosis of Quality Durability in the Company under Study

The quality durability dimension was measured by the use of five items (2226) of the scale items as indicated in Table (2). The quality durability is of importance in the investigated firm based on the composite mean of these items, which was 3.69. This method will make products work longer, thus softening the effect on the environment with products that will not degenerate into garbage too soon and will avoid depleting the natural resources. A coefficient of variation (C.V.) of 0.28 and a standard deviation of 1.02 are supported by the calculated T -test statistic of 26.96.

As per the individual items, the mean values were greater than the hypothetical mean, 3.53-3.85, indicating the high extent of attention paid to the quality durability dimension by senior management owing to the critical nature of the quality dimension in ensuring that the products of the company are at the required standard specifications. One of the most important items that was found to be critical was item 22 that had a low coefficient of variation of 0.24, a large mean value of 3.85 and a fairly low standard deviation of 0.931, which was further supported by a T-test value of 30.694.

c. Description and Diagnosis of Social Quality in the Company under Study

Table (2) illustrates the items (27–31), which represent the social quality dimension. The combined mean value for the items was (3.14), which is higher than (3), indicating that the average leans toward agreement rather than neutrality. This suggests that the company under study places importance on social quality (confirming its social and legal commitment and its adherence to work ethics that protect the natural environment and benefit the community of which it is a part, while achieving financial gains). The T-test value of (28.82) supported the standard deviation of (0.96) and the coefficient of variation (C.V.) of (0.26).

With low coefficients of variation (0.25) and high mean values (3.89), (3.67), and (3.85), respectively, along with low standard deviations (0.956), (0.924), and (0.951), the most significant items were (28, 29, 31). These findings were further supported by the T-test values, which were 30.186, 29.476, and 30.59, respectively.

d. An explanation and diagnosis of the company's environmental concerns

Five (32–36) elements from the scale provided in Table (2) were used to measure this variable in order to evaluate the environmental concern dimension. These components' combined mean value was 3.36, which is a positive indicator of the company's emphasis on environmental care (raising consumer knowledge of the need to purchase safe, eco-friendly, and useful products).

The value of T test of 27.77 was used to verify that the coefficient of variation (C.V.) was 0.28 and the standard deviation was 0.99. The average scores of the different items were between 3.20 and 4.09, which exceeded the predicted mean, thus indicating increased focus by the senior management of the firm on the environmental concern dimension as they have realised the importance of maximizing the available resources and taking responsibility in ensuring that they do not cause destruction of the environment. Items (32) and (35) were among the most important, recording low coefficients of variation (0.23) and (0.24), respectively, with high mean values of (4.09) and (3.71), and low standard deviations of (0.928) and (0.875), respectively, further supported by T-test values of (32.678) and (31.436), respectively.

Table (2): Descriptive Analysis Test for the Research Variable of Sustainable Quality

No.	Statements	Mean	ST.D	C.V	T-test
17	The management of the organisation is interested in conducting product development procedures uniformly across time and space.	3.82	.905	0.24	31.305
18	The company has technological capabilities that ensure process reliability.	3.75	1.092	0.29	25.428
19	Reliable production processes contribute to reducing overall costs and production time.	3.84	.898	0.23	31.690
20	The company works on reducing barriers among all departments.	3.36	1.078	0.32	23.145

21	Participatory cooperation amongst all manufacturing departments is a component of the product design process.	3.91	1.110	0.28	26.115
	Total quality costs	3.74	1.02	0.27	27.537
22	The company possesses specifications and characteristics that reduce product defects.	3.85	.931	0.24	30.694
23	The company owns specifications that align with industry and manufacturing standards.	3.53	1.136	0.32	23.024
24	The company reduces waste by minimizing raw material consumption.	3.78	1.031	0.27	27.208
25	The company achieves high compatibility with final product specifications through minimizing defects.	3.67	1.037	0.28	26.257
26	The company continuously improves its processes through corrective actions and work amendments.	3.62	.972	0.27	27.616
	Quality Durability	3.69	1.02	0.28	26.96
27	Integration contributes significantly to increasing the company's market opportunities.	3.58	1.031	0.29	25.769
28	Integration accelerates the follow-up of production operations.	3.89	.956	0.25	30.186
29	Integration provides a major opportunity for cost reduction.	3.67	.924	0.25	29.476
30	Integration could help the business and production processes meet all technical criteria.	3.55	.919	0.26	28.602
31	The achievement of closed-loop production is facilitated by the integration of departments and activities .	3.85	.951	0.25	30.059
	Social Quality	3.14	0.96	0.26	28.28
32	The company conducts an optimal comparison among available alternatives to achieve the best outcomes.	4.09	.928	0.23	32.678
33	The company achieves optimal efficiency in utilizing financial and human resources.	3.62	1.045	0.29	25.675
34	The company works on raising the value added to products.	3.51	.900	0.26	28.914
35	The company's management strives to maximize the utilization of facilities at optimal production capacity.	3.71	.875	0.24	31.436
36	The production system is designed in a way that prevents operational failures.	3.20	1.177	0.37	20.164
	Total for Environmental Concern	3.63	0.99	0.28	27.77

N = 55 | Significance Level = 0.00 | $P \leq 0.01$ |

4.2. Second: Correlation and Impact between Variables

To verify the validity of the first and second hypotheses, the following procedures were carried out:

i. **Correlation between Flexible Manufacturing and Sustainable Quality**

Based on Table (3), it is observed found, at the (0.01) level of significance, there was a statistically substantial correlation between sustainable quality and flexible manufacturing, with an overall correlation of 0.779. The first major hypothesis is accepted as a result of this finding. This research also shows that the more effectively a company uses flexible manufacturing, the more it contributes to improving sustainable quality inside the company. Achieving manufacturing processes that adjust to environmental changes, cutting down on the time needed for product design and development, expediting customer delivery, and preserving low cost levels are all made possible by flexible manufacturing. The computed probability value (P.Value), which was 0.000 a number below the significance level (0.01) further supports this. The researcher's field visits to the company's location, in-person interviews, and observations of the contemporary production lines acquired from foreign businesses via senior management's processes to acquire cutting-edge machinery and equipment, as well as raw materials going through quality control and standardisation, all of which lend credence to this conclusion. Additionally, the researcher found that senior management is actively working to improve flexible manufacturing going forward in order to create useful instruments for attaining long-term quality.

Table 3: Findings from the Association between Sustainable Quality and Flexible Manufacturing

Dependent Variable	Independent Variable
Sustainable Quality	Flexible Manufacturing
0.779	

N = 55 P ≤ 0.01

Table (4) shows the findings of the correlations between sustainable quality and flexible manufacturing at the sub-variable level in the company under study.

Dependent Variable Independent Variable	Dimensions of Sustainable Quality				
	Adaptability	Standardization	Integration	Optimization	Overall
Flexible Manufacturing	0.718**	0.663**	0.529**	0.796**	0.779**

N = 55 P ≤ 0.01

Source: Prepared .by the researcher based , on statistical results.

Based on Table (4), it is observed showed the characteristics of sustainable quality and flexible manufacturing have typically substantial correlations, with correlation values of 0.718, 0.663, 0.529, and 0.796, respectively. The computed probability value (P.Value) of 0.000, which is less than the significance level (0.01), further supports the finding that there is a strong and statistically significant link. This finding supports the first sub-hypothesis, which states that a company's ability to attain sustainable quality across all dimensions increases with its level of focus on flexible manufacturing.

ii. Impact Relationship between Flexible Manufacturing and Sustainable Quality

The statistical analysis results, clearly shown in Table (5), indicate a noteworthy influence of the variable of flexible manufacturing on the variable of sustainable quality. According to the ANOVA test's probability value (P-Value), which was 0.000, less than 0.01, this effect is statistically significant. A one-unit shift in flexible manufacturing results in a change of (0.779) in sustainable quality, according to the value of (B1), which was (0.779). The estimated T-value (9.058), which is more than its tabular value (1.96) at the (0.01) level of significance, further supports the existence of this impact in the results shown in Table (5). Flexible manufacturing can account for 60.8% of the variation in sustainable quality, according to the coefficient of determination (R^2) of 0.608. Random variables that are either uncontrollable or not included in the regression model account for the remaining variation. As a result, the main impact hypothesis is accepted.

Table (5): Regression Coefficients for the Impact of Flexible Manufacturing on Sustainable Quality Combined in the Surveyed Company

Model Summary			ANOVA Test		Regression Coefficient				
Dependent Variable	R^2	Adjusted R^2	F	P-value	Independent Variable	Beta	B_0	T	significance level
Sustainable Quality	0.608	0.600	82.045	0.000	Flexible Manufacturing	0.779	22.397	9.058	0.000

N = 55

P ≤ 0.01

Source: Prepared by the researcher based on the analysis results.

To provide a broader view and deeper understanding, of the impact relationship between the independent variable (Flexible Manufacturing) and the dimensions of the dependent variable (Quality Costs, Quality Durability, Social Quality, Environmental Concern), the multiple regression analysis (Multiple Regression Analysis) was used as follows:

- i. **The Impact of Flexible Manufacturing on the Dimension of Quality Costs:**
The findings presented in Table (6) demonstrate that flexible manufacturing has a positive and statistically significant effect on the quality costs dimension, as demonstrated by the regression coefficient (β_1) value of 0.718 and a probability value (P-value) of 0.000, both of which are less than (0.01). The quality cost dimension accounts for 51.6% of the explained variations in flexible manufacturing, with the remaining percentage coming from random variables that are either uncontrollable or not included in the regression model, according to the coefficient of determination (R^2) value of 0.516. The first sub-hypothesis is accepted because the computed T-value (7.513) is greater than its tabular value (1.96), at the (0.01) significance level, confirming a significant relationship between quality costs (the dependent variable) and flexible manufacturing (the independent variable).
- ii. **The Impact of Flexible Manufacturing on the Dimension of Quality Durability:**
It is clear from Table (6) that there is a statistically significant impact of the explanatory variable (Flexible Manufacturing) on the dimension of (Quality Durability) as the dependent variable, based on the probability value (P-value) from the ANOVA test, which is (0.000) at a significance level less than (0.01). The coefficient of determination (R^2) reached (0.44), indicating that (44%) of the explained variations in flexible manufacturing are attributed to the dimension of quality durability, while the rest is due to random variables beyond control or not included in the research model. By tracking the

calculated (B_1) and the (T) test, it is evident that there is a significant impact of the explanatory variable on the dimension of quality durability as a dependent variable, with a calculated (B_1) value of (0.663) and a (T) value of (6.455), which is greater than its tabular value (1.96) at the (0.01) level of significance. This leads to the acceptance of the second sub-hypothesis for the impact relationship.

- iii. **The Impact of Flexible Manufacturing on the Dimension of Social Quality:** In light of Table (6), it is evident that the calculated (F) values for (Agile Manufacturing and Effective Manufacturing), coded in the table as (X_2 , X_1), were (56.446, 41.670, 20.584, 91.956) respectively. These values are statistically significant at the (0.01) level, indicating the existence of an impact of flexible manufacturing on the dependent variable (Dimension of Social Quality). This suggests that the slope of the regression between the two research variables is good and can be used to describe the nature of their impact relationship. The value of ($B_1 = 0.529$) indicates that a one-unit change in flexible manufacturing would lead to a change of (0.529) in social quality.

Additionally, the coefficient of determination (R^2), considered a descriptive measure indicating how well the regression equation explains variance and reduces errors, was (0.280), meaning that (28%) of the variance in social quality is explained by flexible manufacturing after its inclusion in the model. The remaining percentage is attributed to undiscovered factors or variables not included in the research model.

The significance of this impact was also confirmed by the probability value (P-value) of (0.000) and a calculated T-value of (4.537), which is greater than its tabular value (1.96) at the (0.01) significance level. Thus, the validity of the third sub-hypothesis regarding the impact is confirmed.

- iv. **The Impact of Flexible Manufacturing on the Dimension of Environmental Concern:** From Table (6), the significance of the tested research model is evident through the calculated T-value of (9.589), which is greater than the tabular value (1.96) at the (0.01) significance level. This indicates the existence of an impact of flexible manufacturing on the dependent variable (Dimension of Environmental Concern). It suggests that the regression slope between the explanatory and dependent variables is good and can be used to describe their impact relationship. The value of ($\beta = 0.796$) indicates that a one-unit change in flexible manufacturing would lead to a change of (0.796) in environmental concern. Moreover, the coefficient of determination (R^2) was (0.634), meaning that (63.4%) of the variance in environmental concern is explained by flexible manufacturing after its incorporation into the model. The remaining percentage is attributed to undiscovered variables or factors not included in the regression model.

Therefore, the validity of the fourth sub-hypothesis regarding the impact relationship is confirmed.

Table (6): Results of Multiple Regression Analysis for the Impact of Flexible Manufacturing on the Dimensions of Sustainable Quality at the Overall Level in the Research Field

Model Summary			ANOVA Test		Regression Coefficient				
Dependent Variable	R^2	Adjusted R^2	F	P-value	Independent Variable	Beta	B_0	T	significance level
Parallelism	0.516	0.507	56.446	0.000	Flexible Manufacturing	0.718	5.893	7.513	0.000
Standardization	0.440	0.430	41.670	0.000		0.663	4.940	6.455	0.000
Integration	0.280	0.266	20.584	0.000		0.529	8.547	4.537	0.000

Optimization	0.634	0.627	91.956	0.000		0.796	3.018	9.589	0.000
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$N = 55$ $P \leq 0.01$

Source: Prepared by the researcher based on the statistical analysis results.

5. Fourth Axis: Conclusions and Recommendations

5.1. First: Conclusions

This section presents the conclusions drawn based on the theoretical and field results of the research, which form the foundation for formulating recommendations deemed necessary by the researcher for the surveyed company, as follows:

- It is anticipated that the use of flexible manufacturing mechanisms and processes in the operations of the surveyed firm will make the implementation of sustainable quality across all the dimensions of the same firm easier.
- Sustainable quality is a modern theme that should be given a lot of consideration since it is characterized as a sophisticated approach to continuous enhancement.
- The research variables description and diagnosis provided good employee response, there was a real interest shown by the company by adopting these research variables as this is reflected by high levels of agreement and responsiveness of the resultant data.
- The descriptive and diagnostic analysis indicated that quality-costs dimension is the most widely embraced sustainable quality aspect in the surveyed firm with the mean score of 3.74. This means that employee perception is generally positive, which supports the fact that the firm is determined to manufacture products that meet specifications without compromising on quality of the end product and attaining sustainability that meets customer demands.
- Statistical testing of the main hypothesis and the subsidiary propositions, had shown that there is an overall significant relationship between the flexible manufacturing and sustainable quality with a correlation coefficient of 0.779 that is highly significant. In addition, the findings revealed strong associations between flexible manufacturing and every one of the components of sustainable quality.
- The secondary hypothesis and the adjunct hypothesis were tested and proved that there is a general interrelationship between the variables. Flexible manufacturing had statistically significant effect on the dimensions of sustainable quality, which is mostly in the environmental concern domain, at a disaggregated level. This observation supports the fact that the firm employs activities aimed at reducing the usage of raw-materials in manufacturing activities and the development of the same in harmony with clean and environmentally friendly manufacturing.

5.2. Second: Recommendations

Following the conclusions made and in the perspective of strengthening the productive and environmental aspects of the surveyed company, the following recommendations are put forward to enable the application and improvement of each research variable:

- The company's management must adopt the necessary requirements for implementing flexible manufacturing and execute them according to a future strategic orientation to ensure survival in an intensely competitive environment.
- Rely on comprehensive maintenance programs to eliminate all types of waste in the production process and promote a philosophy of waste elimination among employees to achieve high-value outcomes.

3. Consider the company's social, economic, and environmental facets to lessen its adverse effects on the environment and attain sustainability in line with its size and situation by implementing modern manufacturing technology.
4. Instead of addressing the viability issue superficially or with a media-focused strategy, embrace the aspects of sustainable quality based on industrial dependability requirements as a basic function for continual improvement.
5. Encourage and attract employees with skills and expertise in environmental and technical specializations to activate the effective integration of flexible manufacturing and sustainable quality in a sustainable manner that enhances the company's reputation.
6. Redesign the current "cradle-to-grave" approach instead of the supply chain pathway using a "cradle-to-cradle" concept, acknowledging customers as suppliers to the business, and improve recycling procedures even more.

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Appendix No. (1)

Morgan Table

تحديد حجم العينة

(حجم المجتمع N ، حجم العينة S)

S	N	S	N	S	N
291	1200	140	220	10	10
297	1300	144	230	14	15
302	1400	148	240	19	20
306	1500	152	250	24	25
310	1600	155	260	28	30
313	1700	159	270	32	35
317	1800	162	280	36	40
320	1900	165	290	40	45
322	2000	169	300	44	50
327	2200	175	320	48	55
331	2400	181	340	52	60
335	2600	186	360	56	65
338	2800	191	380	56	70
341	3000	196	400	63	75
346	3500	201	420	66	80
351	4000	205	440	70	85
354	4500	210	460	73	90
357	5000	214	480	76	95
361	6000	217	500	80	100
364	7000	226	550	86	110
367	8000	234	600	92	120
368	9000	242	650	97	130
370	10000	248	700	103	140
375	15000	254	750	108	150
377	20000	260	800	113	160
379	30000	265	850	118	170
380	40000	269	900	123	180
381	50000	274	950	127	190
382	75000	278	1000	132	200
384	1000000	285	1100	136	210

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