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The Reality of Applying the Dimensions of Sustainable Manufacturing in the Pharmaceutical Industry: A Diagnostic Study at the Intravenous Solutions Factory in Mosul

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Abstract

Industrial organizations try to balance the economic, environmental, social and technological aspects of their operations to improve production processes efficiency, make them sustainable, sustainable manufacturing is regarded as one of the contemporary approaches that they try to adopt. This is especially critical in the pharmaceutical sector where it is a critical element in addressing societal healthcare needs and must be executed in accordance with environmental, quality and operational efficiency standards.

The present study was aimed at diagnosing the state of the application of the dimensions of sustainable manufacturing in the Intravenous Solutions Factory in Mosul, focusing on the four main dimensions, which are the environmental dimension, the economic dimension, the social dimension and the technological dimension. The study used descriptive diagnostic approach because of the nature and objectives of the study.

For data collection, the study relied on a checklist developed based on the relevant literature and previous studies on sustainable manufacturing. The checklist included a set of indicators for each of the dimensions adopted in the study. It also employed four assessment alternatives: (implemented and documented, implemented but not documented, not implemented but documented, and neither implemented nor documented), with the aim of diagnosing the level of application of the dimensions of sustainable manufacturing in the investigated factory.

The study seeks to provide a realistic picture of the level of implementation of the dimensions of sustainable manufacturing at the Intravenous Solutions Factory and to identify the strengths and shortcomings of its sustainable manufacturing practices. This is intended to support decision-makers and provide a set of recommendations that contribute to enhancing the adoption of sustainable practices and improving industrial performance in line with the requirements of sustainable development.

Keywords: *Sustainable manufacturing; dimensions of sustainable manufacturing; pharmaceutical industry; environmental dimension; economic dimension; social dimension; technological dimension.*

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Introduction

Over the past decades, the industrial environment has undergone rapid transformations driven by increasing environmental, economic, and social challenges. These developments have compelled industrial organizations to adopt modern managerial and production approaches that contribute to achieving a balance between the requirements of economic development, the conservation of natural resources, and the improvement of social well-being. Among these approaches, sustainable manufacturing has emerged as a contemporary concept aimed at developing production processes in a manner that achieves economic efficiency, protects the environment, and enhances the well-being of employees and society.

Sustainable manufacturing is a holistic approach that aims to maximize the efficiency of manufacturing processes, minimize waste and pollution, and optimize the use of resources. It also fosters social responsibility and the use of cutting-edge technologies to help realize sustainable development. In the pharmaceutical industry, where the quality of products affects human health, the operational efficiency and adherence to environmental and health regulations are paramount, this concept has garnered growing attention across many industrial fields.

Section One: Research Methodology

First: Research Problem

Considering the current shift in the focus towards sustainable practice in the industrial sector, sustainable manufacturing is one of the basic pillars that the industrial organizations are trying to implement in order to attain a balance between the environmental, economic, social and technological aspects. Although this is a crucial method, some industrial organizations are not clear about the level of implementation of the dimensions of sustainable manufacturing; thus it is necessary to assess the actual level of the dimensions and the extent to which they are implemented in these organizations. Thus, the problem of the research can be stated in the following form of the main question:

What is the current state of the implementation of the dimensions of sustainable manufacturing at the Intravenous Solutions Factory in Mosul?

The following sub-questions are derived from this main question:

1. What is the level of implementation of the environmental dimension in the factory?
2. What is the level of implementation of the economic dimension in the factory?
3. What is the level of implementation of the social dimension in the factory?
4. What is the level of implementation of the technological dimension in the factory?

Second: Research Importance

The significance of this research is related to the importance of sustainable manufacturing as one of the modern managerial and industrial concepts that plays an important role to enhance the industrial performance and sustainable development of environment, economy and society. The research also is significant because of the pharmaceutical industry's importance as a key sector, as well as the attempt to diagnose the state of the implementation of the dimensions of sustainable manufacturing at the IVS Factory, which provides scientific indicators to help decision-makers develop sustainable practices.

Third: Research Objectives

The purpose of this study is to accomplish the following:

1. Identify the idea of sustainable manufacturing and the primary dimensions of sustainable manufacturing.

2. To provide a diagnosis of the status of implementation of the dimensions of sustainable manufacturing in the Intravenous Solutions Factory.

3. To assess the implementation of the environmental, economic, social and technological aspects in the factory.

4. To suggest a set of recommendations that will help to improve the implementation of the dimensions of sustainable manufacturing.

Fourth: Research Methodology

The study used descriptive-analytical approach, because it is appropriate for the nature and goal of the study. This approach involves describing the phenomenon being studied, making a diagnosis of the status of the phenomenon, examining the data in relation to the phenomenon and making accurate scientific conclusions. It is associated with an extensive and detailed analysis of the phenomenon, as well as the capacity to incorporate more than one scientific method at the same time: observation, personal interviews, the use of checklists, comparisons, and direct presentation of observations and inquiries for the acquisition of the information and data needed to fulfill the research goals.

Statistical Analysis Methods and Score Limits

The researcher employed several statistical methods and tools to analyze the data related to the research variables, including frequency distribution, the hypothetical mean, and arithmetic means for the checklist items, in order to determine the level of responses for each item. The calculation procedures are presented as follows (Elias, 2015, p. 33):

1. **Result** = Weights × Frequencies.
2. **Mean** = Total Result ÷ Total Frequencies.
3. **Percentage of Conformity** = Mean ÷ 4 (Highest score on the measurement scale).
4. **Hypothetical Mean** = Percentage of Conformity × Mean ÷ Total Result.
5. **Gap Size** = 1 − Percentage of Conformity.

Source: Adapted from Elias, Saad Khudair. (2015). *The possibility of applying some principles of the Toyota Production System (TPS) to reduce waste in production processes: A case study of Al-Hukamaa Company for the Manufacture of Pharmaceuticals and Medical Supplies in Nineveh* (Published master's thesis). College of Administration and Economics, University of Mosul.

Fifth: Research Population and Sample

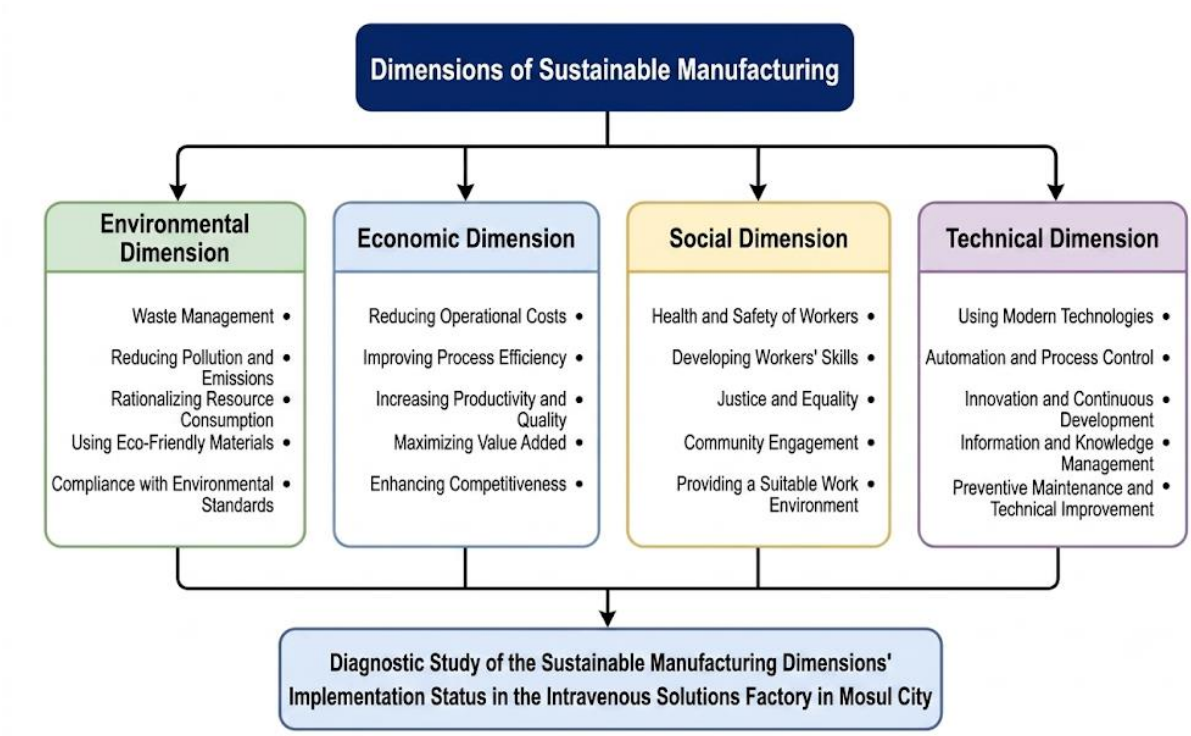
The research population consisted of administrative and technical personnel working at the Intravenous Solutions Factory in Mosul. These managerial and technical personnel were selected to respond to the questions included in the research checklist.

Sixth: Research Instruments

The study employed several quality assessment tools to determine the extent to which the dimensions of sustainable manufacturing are implemented. These included a checklist developed based on the relevant literature and previous studies on sustainable manufacturing, the **Ishikawa Cause-and-Effect Diagram**, and a **Histogram** for analyzing the main dimensions of sustainable manufacturing, namely the environmental, economic, social, and technological dimensions. These tools were used to diagnose the actual state of the implementation of these dimensions and to identify strengths as well as areas requiring development and improvement.

Seventh: Hypothetical Research Framework

The research is based on one principal variable represented by the dimensions of sustainable manufacturing, which consists of four sub-dimensions: the environmental dimension, the economic dimension, the social dimension, and the technological dimension. Collectively, these dimensions constitute the framework adopted to diagnose the current state of sustainable manufacturing in the investigated factory.



Eighth: Research Hypotheses

Consistent with the research objectives and its hypothetical framework, the following hypotheses were adopted:

The First Main Hypothesis: *The dimensions of sustainable manufacturing are not present at the Intravenous Solutions Factory.*

The following sub-hypotheses are derived from it:

- **The First Sub-Hypothesis:** The environmental dimension is not present at the Intravenous Solutions Factory.
- **The Second Sub-Hypothesis:** The economic dimension is not present at the Intravenous Solutions Factory.
- **The Third Sub-Hypothesis:** The social dimension is not present at the Intravenous Solutions Factory.
- **The Fourth Sub-Hypothesis:** The technological dimension is not present at the Intravenous Solutions Factory.

The Second Main Hypothesis: *There is no gap in the level of availability of the dimensions of sustainable manufacturing at the Intravenous Solutions Factory.*

The Third Main Hypothesis: *Some quality assessment tools cannot be used to diagnose the current state of the dimensions of sustainable manufacturing at the Intravenous Solutions Factory.*

Section Two: Theoretical Framework

First: The Concept of Sustainable Manufacturing

Thus, the idea of sustainable manufacturing emerged in light of the rapid transformation of the industrial environment and the problems associated with the use of scarce natural resources, high levels of environmental pollution and rising industrial economic and social strain. Thus, the necessity arose to find the ways of production, which would meet the requirements of economic growth, environment protection and satisfy social needs, which brought into existence the concept of the sustainable manufacturing as one of the modern ideas of modern industry thinking.

Sustainable manufacturing is based on the principle that production should not be defined by how much natural resources, the environment and society are impacted in order to achieve the production objectives. Instead, it needs to be achieved by managing industrial processes in a way that makes the best use of resources, energy and raw materials, and minimizes waste and harmful emissions. As a result, sustainable manufacturing has emerged as a strategy that is being embraced by industrial companies that are aiming to perform better and become more competitive in the ever-changing market.

Sustainable manufacturing is also considered as a managerial and production process that seeks to integrate economic, environmental, social and technological issues in all industrial processes and activities in order to increase the efficiency of the production, improve the quality of the product and minimize the negative impacts of industrial activities. This is the idea of going beyond the traditional concept of production which was only concerned with the output maximization to the concept of production where the production outcomes are achieved responsibly and sustainably.

In recent years, there has been a huge rise in interests in sustainable manufacturing because of the increasing demands of the environment, governmental regulations and consumers and stakeholders concern about sustainable manufacturing issues. Additionally, organizations have now realized that sustainable practices have played an even larger role in lowering expenses, boosting productivity, and enhancing competitive edge. Therefore, sustainable manufacturing is considered as one of the main pillars on which industrial organizations are based to follow sustainable development and sustainable continuity of their activities.

Second: Definition of Sustainable Manufacturing

Sustainable manufacturing is a process in Industrialistics that seeks to ensure the economic growth using efficiency in the use of resources and energy, reduce waste and emissions, and maximize the economic and social value of industrial activities (United Nations Industrial Development Organization (UNIDO), 2023).

Likewise, Kamble and Gunasekaran (2024) define Sustainable manufacturing as the integrated production system, which meets all operational aspects, technological innovation, and environmental and social responsibility to ensure the sustainable performance of industries in the long-term.

The researcher considers that sustainable manufacturing is a series of manufacturing practices and activities used by an organization to balance the three dimensions of sustainable development economic, environmental, social, and technological in the most effective way to maximize the use of available resources and to implement advanced technologies, all while improving manufacturing performance, reducing waste, and strengthening the sustainability of manufacturing processes.

Third: Importance of Sustainable Manufacturing

In recent years, sustainable manufacturing has been given more and more attention by researchers and industrial organizations because of its contribution to balance economic goals and environmental and social requirements. In today's context of scarcity of natural resources, environmental modification and fierce competition, the use of sustainable manufacturing methods is imperative.

In the context of sustainable manufacturing, Kamble and Gunasekaran (2024) showed that sustainable manufacturing can help to improve the operational efficiency of industrial organizations by optimizing the use of resources and minimizing waste in the manufacturing process. Similarly, Khan et al. (2023) claimed that the application of sustainable manufacturing principles helps organisations to reduce industrial emissions and waste, while minimising adverse environmental effects, thus improving their environmental performance.

In addition, Moktadir et al. (2024) pointed out that the sustainable manufacturing has been a significant competitive advantage and economic sustainability in enhancing productivity and reducing operating costs. In the same way, Chauhan et al. (2024) believed that the use of modern technologies and the innovations in the industry in the context of sustainable manufacturing help to increase industrial performance and improve product and service quality.

Based on the foregoing, the importance of sustainable manufacturing can be summarized as follows:

1. Enhancing the efficient utilization of natural resources and energy while reducing waste in production processes through the optimal use of raw materials and energy and improving resource utilization (UNIDO, 2023; Moktadir et al., 2024).
2. Reducing waste and harmful emissions and improving the organization's environmental performance through the adoption of cleaner production methods and environmentally friendly technologies (Khan et al., 2023; Yadav & Singh, 2024).
3. Strengthening competitiveness and achieving long-term economic sustainability by reducing operating costs, improving productivity, and maximizing value creation (Bag et al., 2023; Kamble & Gunasekaran, 2024).
4. Improving the quality of products and services through the development of production processes and the implementation of sustainable industrial practices that enhance efficiency and quality (Chauhan et al., 2024).

5. Promoting social responsibility and improving employees' working conditions by providing a safe working environment, supporting employees' rights, and developing their capabilities (Sharma et al., 2023; Ahmad & Wong, 2024).
6. Supporting innovation, technological development, and the adoption of advanced technologies in industry, thereby improving operational performance and achieving industrial sustainability (Nayal et al., 2023; Chauhan et al., 2024).

The researcher believes that the importance of sustainable manufacturing stems from its ability to achieve a balance between the requirements of economic efficiency, environmental protection, and social responsibility through the effective utilization of resources and modern technologies in a manner that enhances the sustainability of production processes and creates added value for both the organization and society.

Fourth: Objectives of Sustainable Manufacturing

Sustainable manufacturing seeks to achieve a set of objectives that ensure a balance between the requirements of economic growth, environmental protection, and social well-being. Interest in these objectives has increased with the expanding role of industrial organizations in achieving sustainable development, enhancing resource efficiency, and improving long-term organizational performance.

In this context, UNIDO (2023) states that sustainable manufacturing aims to promote industrial production in a manner that achieves economic growth while conserving natural resources and minimizing adverse environmental impacts. Similarly, Kamble and Gunasekaran (2024) argue that the primary objective of sustainable manufacturing is to establish a production system capable of achieving operational efficiency and competitive advantage while simultaneously fulfilling environmental and social responsibilities.

Furthermore, Moktadir et al. (2024) emphasize that sustainable manufacturing focuses on improving the efficiency of industrial processes by reducing waste and enhancing the utilization of resources and energy. Likewise, Chauhan et al. (2024) argue that the adoption of modern technologies and industrial innovation represents one of the fundamental objectives of sustainable manufacturing because of its role in improving performance and promoting long-term sustainability.

Based on the relevant literature and recent studies, the objectives of sustainable manufacturing can be summarized as follows:

1. Rationalizing the consumption of natural resources and energy by enhancing the efficient use of raw materials and energy and minimizing waste in production processes (UNIDO, 2023).
2. Reducing environmental pollution and industrial waste through the implementation of cleaner production methods and the reduction of emissions and pollutants generated by industrial processes (Khan et al., 2023).
3. Improving the efficiency of production processes by developing work procedures and utilizing available resources more effectively, thereby enhancing productivity and quality (Moktadir et al., 2024).
4. Promoting occupational health and safety by providing a safe working environment and minimizing occupational risks associated with industrial operations (Sharma et al., 2023).
5. Supporting innovation and the adoption of modern technologies through the implementation of advanced technologies and digital solutions that contribute to improved performance and industrial sustainability (Chauhan et al., 2024).
6. Achieving the organization's economic sustainability by reducing operating costs, improving resource utilization, and strengthening competitiveness in the marketplace (Bag et al., 2023).

7. Contributing to sustainable community development by promoting social responsibility and achieving a balance among economic, environmental, and social requirements (Ahmad & Wong, 2024).
8. Enhancing the integration of the environmental, economic, social, and technological dimensions to ensure the sustainability of industrial operations and create long-term added value for the organization and its stakeholders (Kamble & Gunasekaran, 2024).

The researcher believes that the importance of sustainable manufacturing stems from its ability to achieve a balance between the requirements of economic efficiency, environmental protection, and social responsibility through the effective utilization of resources and modern technologies in a manner that enhances the sustainability of production processes and creates added value for both the organization and society.

Fifth: Dimensions of Sustainable Manufacturing

Sustainable manufacturing is founded on an integrated set of dimensions which are linked together to enable achieving sustainable goals in industrial organizations. These dimensions form the basis of the framework that organizations use to balance the need to produce with economic efficiency with the need to protect the environment and to be responsible to society. The number of dimensions of sustainable manufacturing has been subject of debate, but the environmental, economic and social dimensions have been consistently highlighted in most studies, in more recent studies the technological dimension has been added because of its central role in facilitating the implementation of sustainable manufacturing practices and enhancing industrial performance. Based on these reasons, the present study uses four main dimensions of sustainable manufacturing, which are the most appropriate for the type of the organization studied and the research goals; the environmental dimension, the economic dimension, the social dimension and the technological dimension.

1. Environmental Dimension

The environmental dimension is regarded as one of the basic dimensions of sustainable manufacturing because it aims to reduce the negative environmental effects that are caused by industrial activities or processes while maintaining a balance between production requirements and environmental protection. This dimension seeks to encourage the efficient use of natural resources and energy and minimize waste and pollutant emissions by implementing environmentally friendly practices and technologies.

The environmental dimension is defined by Khan et al. (2023) as "a set of activities and practices that minimizes the environmental footprint of industrial activities by reducing emissions, waste, and the requirements for natural resources and energy.

Likewise, Yadav and Singh (2024) state that the environmental aspect emphasizes the implementation of eco-friendly technologies, sustainable manufacturing, and the supervision of industrial waste following contemporary environmental norms, improving the industry's environmental efficiency.

According to Zhang et al. (2024), the environmental dimension highlights the ability of the organization to optimize the use of resources and minimize environmental impacts arising from industrial operations in order to achieve the production goals while satisfying the environmental protection requirements.

Environmental dimension is considered as the most significant dimension of sustainable manufacturing as it is linked directly with the conservation of natural resources and the minimization of negative effects of industrial activities. In this regard, Khan et al. (2023) assert the significance of the environmental dimension in terms of minimizing the

emissions and waste generated in industry and increasing the efficiency of using resources and energy, thereby improving the environmental performance of industrial organizations.

Additionally, the environmental dimension allows organizations to implement eco-friendly production processes and meet current environmental norms, thereby benefiting the operational efficiency of production processes while minimizing environmental hazards, as suggested by Yadav and Singh (2024).

Similarly, Zhang et al. (2024) argue that environmental dimension is crucial for attaining sustainable development by ensuring sustainable use of natural resources and supporting organizations' adaptability to rising environmental demands.

Based on the foregoing, the importance of the environmental dimension is reflected in the conservation of natural resources, the reduction of industrial emissions and waste, the improvement of energy and raw material efficiency, as well as strengthening compliance with environmental requirements and enhancing the organization's image among society and stakeholders.

The researcher believes that the environmental dimension represents an organization's ability to manage its production processes and natural resources in a manner that reduces pollution and waste while improving the efficiency of energy and raw material utilization through adherence to sustainable environmental practices.

2. Economic Dimension

The economic dimension represents one of the fundamental dimensions of sustainable manufacturing, as it focuses on achieving efficiency in the utilization of available resources and enhancing the organization's ability to sustain and grow in a dynamic competitive environment. Bag et al. (2023) argue that the economic dimension aims to improve operational efficiency, reduce costs, and maximize added value through the optimal utilization of resources. Similarly, Moktadir et al. (2024) emphasize that economic sustainability is associated with achieving long-term profitability, improving productivity, and reducing waste in industrial processes. The importance of this dimension stems from its role in strengthening the organization's competitiveness, improving operational performance, and achieving financial sustainability through the efficient utilization of resources, minimizing losses, and enhancing the efficiency of production processes. To measure this dimension, the present study adopted a set of indicators, including reducing production and operating costs, improving the efficiency of available resource utilization, minimizing losses and waste in production processes, and achieving the optimal utilization of raw materials and energy.

The researcher believes that the economic dimension represents the organization's ability to create sustainable economic value by improving the efficiency of production processes and optimizing the utilization of available resources, thereby ensuring the continuity of industrial operations and strengthening its competitive position.

3. Social Dimension

The social dimension is one of the principal dimensions of sustainable manufacturing, as it focuses on the human aspects related to employees and the local community and seeks to achieve a balance between the organization's economic objectives and its social responsibilities. Sharma et al. (2023) state that the social dimension emphasizes providing a safe working environment, ensuring justice and equality, and promoting employees' well-being within the organization. Likewise, Ahmad and Wong (2024) indicate that this dimension reflects the organization's responsibility toward its employees and the local community through skills development, improved working conditions, and contributions to community development. The importance of the social dimension lies in its role in enhancing

employee satisfaction, increasing organizational commitment, improving relationships between the organization and the community, and contributing to the creation of a stable and safe working environment that supports the sustainability of organizational performance. To measure this dimension, the study adopted a set of indicators, including providing a safe and healthy working environment, supporting training and development programs, promoting justice and equality among employees, contributing to community service, and fulfilling the organization's social responsibility.

The researcher believes that the social dimension comprises the set of practices adopted by the organization to protect employees' rights and safety, develop their capabilities, and strengthen its role in serving the local community, thereby contributing to social sustainability and supporting the continuity of the organization.

4. Technological Dimension

The technological dimension represents one of the vital dimensions of sustainable manufacturing, as it contributes to the development and improvement of production processes through the application of modern technologies and intelligent systems across various industrial activities. The importance of this dimension has increased with the rapid advances in automation, digital transformation, and the applications of the Fourth Industrial Revolution, given their role in enhancing production efficiency and improving resource management. Chauhan et al. (2024) argue that the technological dimension involves the application of digital technologies, automation, and artificial intelligence to improve the efficiency of industrial processes and promote sustainability. Similarly, Nayal et al. (2023) emphasize that technology is a key driver of sustainable manufacturing by improving resource management, reducing waste and emissions, and enhancing production quality. The significance of this dimension stems from its role in promoting industrial innovation, improving the quality of products and services, enhancing the efficiency of resource and energy utilization, and strengthening the organization's ability to adapt to technological changes and achieve a sustainable competitive advantage. To measure this dimension, the study adopted a set of indicators, including the use of modern technologies in production processes, the application of information systems and intelligent systems in process management, the development of technological infrastructure supporting production, and the promotion of innovation and continuous improvement in work and production methods.

The researcher believes that the technological dimension refers to the application of modern technologies, intelligent systems, and industrial innovations to develop production processes and improve their efficiency in a manner that supports the achievement of sustainable manufacturing objectives and enhances the organization's ability to achieve superior performance and long-term sustainability.

Sixth: Previous Studies

Table (1)

Summary of Previous Studies and the Present Study

Researcher & Year	Study Title	Study Objective	Key Findings	Differences from the Current Study
Al-Samaan, 2022	The Role of Smart Manufacturing Technology in Sustainable Marketing	To demonstrate the role of smart manufacturing technologies in enhancing	A positive role exists for modern technologies in supporting sustainability and	It focused on smart manufacturing and sustainable marketing, whereas the current study focuses on diagnosing the

		sustainable marketing	improving performance	dimensions of sustainable manufacturing.
Hanna, 2022	Reflections of Sustainable Supply Chain Elements in Enhancing Customer Trust	To analyze the role of sustainable supply chain practices	Enhancing organizational performance and customer trust	It addressed sustainable supply chains and did not directly address the dimensions of sustainable manufacturing.
Saleh, 2023	The Role of Industry 4.0 Technology in Supporting Sustainable Consumption	To demonstrate the role of modern technology in supporting sustainability	Improving resource efficiency and reducing waste	It focused solely on the technical dimension, whereas the current study addresses all dimensions.
Khan et al., 2023	Sustainable Environmental Practices in Manufacturing Industries	To study the impact of environmental practices on environmental performance	Improving environmental performance and reducing emissions	It was limited only to the environmental dimension, excluding the rest of the dimensions.
Moktadir et al., 2024	Economic Sustainability and Manufacturing Performance	To analyze the impact of economic sustainability on industrial performance	Improving operational efficiency and long-term sustainability	It focused solely on the economic dimension and did not adopt a comprehensive diagnosis of all dimensions.

Third Section
Practical Aspect
(Presentation of the Results of Quality Measurement Tools and Testing the Research Hypotheses)

This section aims to present the results obtained through the checklist, the cause-and-effect diagram, and the histogram using statistical methods to determine the reality of applying the dimensions of sustainable manufacturing in the Intravenous Solutions Factory. In addition, the cause-and-effect diagram and the histogram are employed to support the analysis.

Based on the above, this section presents the mechanism for verifying the checklist items through the quality measurement tools adopted in this study as instruments for identifying the reality of applying the dimensions of sustainable manufacturing in the Intravenous Solutions Factory. These tools include the checklist, the cause-and-effect diagram, and the histogram. Furthermore, the most significant findings are presented in accordance with the achievement of the study objectives and the testing of its hypotheses through the following:

First: Checklist (Main Items of the Statistical Analysis)

The data collected through the checklist concerning the reality of applying the dimensions of sustainable manufacturing in the Intravenous Solutions Factory were analyzed according to the formulated research hypotheses, as follows:

• Testing the first main hypothesis and its derived sub-hypotheses:

1. Environmental Dimension

The results of the analysis conducted on the checklist of this dimension, as can be seen in Table (2) shows that the items (2, 3 and 4) have a higher score of (4) out of (16) namely (25%) is higher than the hypothetical mean of (20.3%). This means the Intravenous Solutions Factory is mindful of the environmental aspect and takes proper care of the emissions and waste generated during the production process, takes the environmental impact of the raw materials into account when choosing them, and uses environmentally friendly materials that help to reduce waste.

On the other hand, item (1) was scored (1) out of (16) which is (6.25%) lower than the hypothetical mean of (20.3%). This means that the Intravenous Solutions Factory is still using an environmentally damaging or polluting fuel.

The overall mean value was obtained as (3.25) out of (4); the conformity percentage was (81.2%) which is very good level of conformity. Therefore gap size was 18.8%).

From these results, the first sub-hypothesis of the first main hypothesis "The environmental dimension is not available in the Intravenous Solutions Factory" is rejected and the alternative hypothesis "The environmental dimension is available in the Intravenous Solutions Factory" is accepted.

Table (2). Analysis of the Checklist for the Environmental Dimension

No.	Items / Paragraphs	Not Implemented & Not Documented	Not Implemented & Documented	Implemented & Not Documented	Implemented & Documented
-	**Environmental Dimension**				
1	Our factory uses environmentally non-polluting fuel.	✓			
2	Our factory treats emissions and waste resulting from the production process.				✓
3	Our factory considers environmental impacts when selecting raw materials.				✓
4	Our factory uses clean materials to minimize waste.				✓
-	**Weights**	**1**	**2**	**3**	**4**
-	**Frequencies**	**1**	**0**	**0**	**3**
-	**Score / Result**	**1**	**0**	**0**	**12**
-	**Mean / Average**	**3.25**			
-	**Percentage of Compliance Extent**	**81.2%**			

-	**Hypothetical Mean Rate**	**20.3%**			
-	**Gap Size**	**18.2%**			

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

2. Economic Dimension

According to the analysis of the checklist results for this dimension based on points (4) out of (20) which is equal to (20%), the highest score was obtained by items (5, 6, 9, 8, 7) respectively at (20%), that is, the hypothetical mean of (20%). This means that the Intravenous Solutions Factory has sustainable standards, uses clean technologies to make cost savings, makes itself more competitive with sustainable technologies, implements strategies for increasing efficiency and productivity in a sustainable way and balances return of investment with investments in sustainable manufacturing.

The overall mean is (4) and the conformity percentage is (100) which indicates a very high level of conformity. Therefore, the gap size was (0%).

The second sub-hypothesis that has been generated from the first main hypothesis "The economic dimension is not available in the Intravenous Solutions Factory" is rejected; and the alternative hypothesis "The economic dimension is available in the Intravenous Solutions Factory" is accepted.

Table (3). Analysis of the Checklist for the Economic Dimension

No.	Items / Paragraphs	Not Implemented & Not Documented	Not Implemented & Documented	Implemented & Not Documented	Implemented & Documented
-	**Economic Dimension**				
5	Our factory adopts sustainable standards.				✓
6	Our factory uses clean technology and process improvements to achieve cost savings.				✓
7	Achieving competitiveness in our factory through the adoption of sustainable practices.				✓
8	Our factory uses strategies to increase efficiency and productivity in sustainable ways.				✓
9	Our factory balances financial returns with investments in sustainable manufacturing.				✓
-	**Weights**	**1**	**2**	**3**	**4**

-	**Frequencies**	**0**	**0**	**0**	**5**
-	**Score / Result**	**0**	**0**	**0**	**20**
-	**Mean / Average**	**4**			
-	**Percentage of Compliance Extent**	**100%**			
-	**Hypothetical Mean Rate**	**20%**			
-	**Gap Size**	**0%**			

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

3. Social Dimension

The highest score obtained by items (10, 11, 12, 13, 14) in this dimension is (4) out of (20) equating (20%), and this score corresponds to the hypothetical mean of (20%). This means that the Intravenous Solutions Factory works on the premise of safe and healthy working environments for its employees, encourages workers' rights and social justice as part of the sustainable manufacturing process, embraces gender equality, diversity and inclusion in the workplace, promotes sustainable employment opportunities as part of sustainable manufacturing and contributes to the promotion of local development, and promotes education and skills development as part of sustainable manufacturing.

The overall mean was obtained (4) of (4) and the conformity percentage was (100) which is very high level of conformity. Thus, the gap size was (0%).

Based on the above, the third sub-hypothesis arising from the first main hypothesis that is “The social dimension is not available in the Intravenous Solutions Factory” is rejected and the alternative hypothesis that is “The social dimension is available in the Intravenous Solutions Factory” is accepted.

Table (4). Analysis of the Checklist for the Social Dimension

No.	Items / Paragraphs	Not Implemented & Not Documented	Not Implemented & Documented	Implemented & Not Documented	Implemented & Documented
-	**Social Dimension**				
10	The factory provides safe and healthy working conditions for the workers in the factory.				✓
11	Our factory promotes workers' rights and social justice within the context of sustainable manufacturing.				✓
12	Our factory adopts the promotion of gender equality, diversity, and inclusion in the work environment.				✓
13	The factory contributes to providing sustainable job				✓

	opportunities and promoting local development.				
14	Our factory promotes education and skills development within the context of sustainable manufacturing.				✓
-	**Weights**	**1**	**2**	**3**	**4**
-	**Frequencies**	**0**	**0**	**0**	**5**
-	**Score / Result**	**0**	**0**	**0**	**20**
-	**Mean / Average**	**4**			
-	**Percentage of Compliance Extent**	**100%**			
-	**Hypothetical Mean Rate**	**20%**			
-	**Gap Size**	**0%**			

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

4. Technological Dimension

The highest score of (4) for (16) items, representing (25%) were obtained by items (16, 17 and 18), respectively, higher than the hypothetical mean of (20.3%) for this dimension as presented in Table (5). This shows that the Intravenous Solutions Factory considers the technological dimension, using technology to optimise the use of resources in manufacturing, utilising technology for control in monitoring, and introducing technology in the creation and application of sustainable materials in manufacturing.

However, item (15) earned a score of (1) out of (16) or (6.25%), lower than the hypothetical (20.3%). This means that the Intravenous Solutions Factory does not employ any energy saving processes in its manufacturing.

The overall mean was achieved (3.25) out of (4), with conformity percentage (81.2%) which is high level of conformity. As such, the gap size was (18.8%).

On the basis of the above, the fourth sub hypothesis which was 'The technological dimension is not available in the Intravenous Solutions Factory' is rejected and the alternative hypothesis 'The technological dimension is available in the Intravenous Solutions Factory' is accepted.

Table (5). Analysis of the Checklist for the Technological Dimension

No.	Items / Paragraphs	Not Implemented & Not Documented	Not Implemented & Documented	Implemented & Not Documented	Implemented & Documented
-	**Technical Dimension**				
15	Our factory uses energy-saving technologies in manufacturing processes.	✓			

16	Our factory utilizes technology to improve resource management in manufacturing processes.				✓
17	Automated control systems can be applied for monitoring in our factory.				✓
18	Technology can be used in our factory to develop and utilize sustainable materials in manufacturing processes.				✓
-	**Weights**	**1**	**2**	**3**	**4**
-	**Frequencies**	**1**	**0**	**0**	**3**
-	**Score / Result**	**1**	**0**	**0**	**12**
-	**Mean / Average**	**3.25**			
-	**Percentage of Compliance Extent**	**81.2%**			
-	**Hypothetical Mean Rate**	**20.3%**			
-	**Gap Size**	**18.2%**			

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

Based on the results presented in Tables (2), (3), (4), and (5), the following can be concluded:

The **first main hypothesis** is rejected, and the alternative hypothesis stating that *"The dimensions of sustainable manufacturing are available in the Intravenous Solutions Factory"* is accepted.

• **Testing the Second Main Hypothesis:** *"There is no gap in the level of availability of the dimensions of sustainable manufacturing in the Intravenous Solutions Factory."*

Table (6)
Final Summary of the Level of Availability of the Sustainable Manufacturing Dimensions in the Intravenous Solutions Factory

Gap Percentage (%)	Percentage of Implementation Extent (%)	Arithmetic Mean	Dimension	No.
18.8	81.2	3.25	Environmental Dimension	1
0	100	4	Economic Dimension	2
0	100	4	Social Dimension	3
18.8	81.2	3.25	Technical Dimension	4
9.4	**90.6**	**3.62**	**Summary of Specification Implementation**	**-**

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

Table (6) indicates that the highest level of implementation in the investigated factory is attained for the economic and social dimensions with 100% and 100% for both, respectively. The environmental and technological dimensions were

each at 81.2% implementation rate, followed by the health risk dimension at 72.5%.The health risk dimension was at 72.5% implementation rate, followed by the environmental and technological dimensions at 81.2% implementation rate. From these findings, it can be concluded that there is a strong focus in the investigated factory to embrace the dimensions of sustainable manufacturing.

The overall use of the dimensions shows that the average score of the dimensions is 3.62, which is above the hypothetical average of 2.5. The conformity percentage of the checklist items was 90.6% (9.4% gap), which is very high. This finding supports the second primary hypothesis - "There is no difference in the availability of the dimensions of sustainable manufacturing in the Intravenous Solutions Factory.

The overall gap percentage level was fairly low (9.4%), but nonetheless the presence of this gap suggests that the dimensions of sustainable manufacturing are not fully met. Hence, this gap is considered as limited or low, which means the sustainable manufacturing dimensions are well implemented within the factory investigated. The result confirms the second main hypothesis, "There is no gap in the level of availability of the dimensions of sustainable manufacturing in the Intravenous Solutions Factory" as the gap percentage is low, 9.4% and Conformity percentage is high, 90.6%.

• Testing the Third Main Hypothesis: "Some quality measurement tools are not suitable to evaluate the use of the dimensions of sustainable manufacturing in the Intravenous Solutions Factory.

Second: Cause-and-Effect Diagram (Ishikawa Diagram)

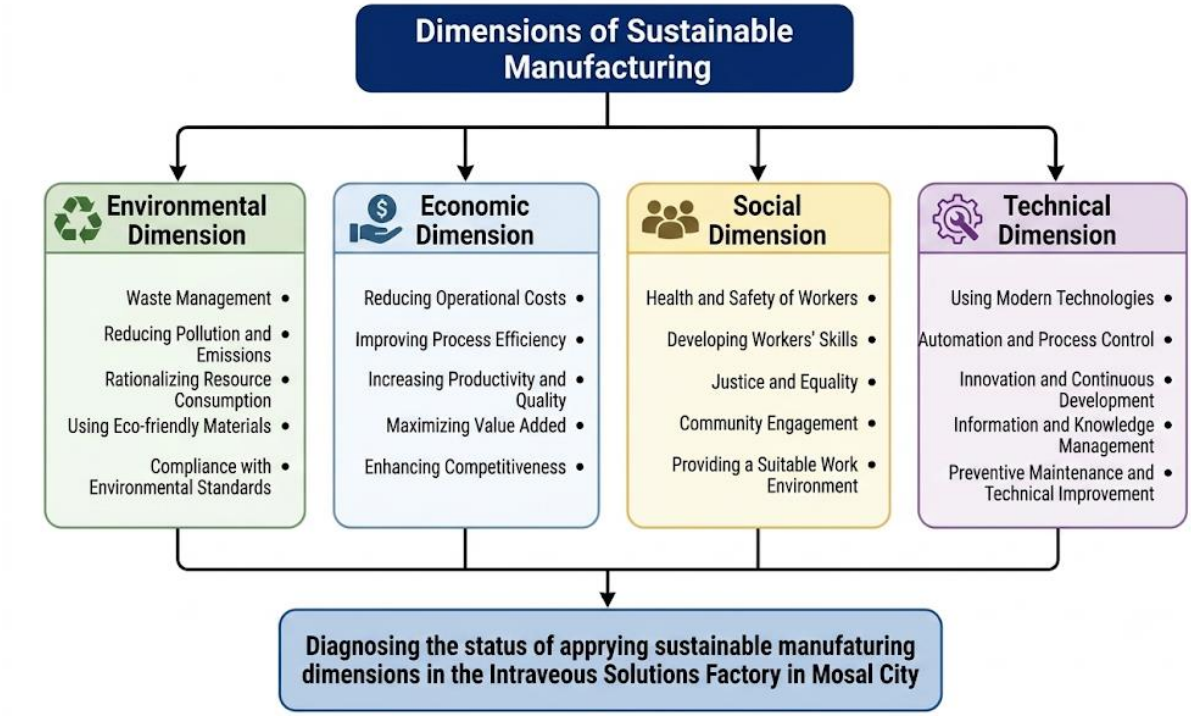
The cause and effect diagram, or fishbone diagram, is a tool to find the causes of a problem and to show the connections between the problem and the causes. The problem or effect is stated first and it is represented as the head of the fish. Then the main branches and a central spine are drawn, each branch being a leading cause of the problem. Secondary branches are then added on to each primary branch to depict the secondary causes for each primary cause.

The table below shows the main and secondary causes of the issues regarding the scarcity of the dimensions of sustainable manufacturing in the Intravenous Solutions Factory.

Table (7)
Primary and Secondary Causes of the Problems Related to the Dimensions of Sustainable Manufacturing

Main Causes	**Environmental Dimension**	**Economic Dimension**	**Social Dimension**	**Technical Dimension**
Sub-Causes	Our factory uses environmentally polluting fuel.	There are no problems due to the absence of a gap in this dimension.	There are no problems due to the absence of a gap in this dimension.	The Intravenous (IV) Fluids Factory does not use energy-saving technologies in manufacturing processes.

Source: Prepared by the researcher.



Here is the academic English translation without additions:

The results shown in **Figure (2)** indicate that the branches extending from the main line represent the **main causes**, whereas the boxes branching from the secondary lines represent the **sub-causes**. The Fishbone (Cause-and-Effect) Diagram illustrates the causes and effects associated with the Intravenous Solutions Factory.

The diagram reveals that the **environmental dimension** has secondary causes that somewhat hinder the full implementation of this dimension within the factory, despite a high application level. The primary cause is the failure to satisfy the requirement of using environmentally friendly, non-polluting fuel. Regarding the **technological dimension**, the results indicate a weakness in the use of modern energy-saving technologies within the factory.

2. Histogram

A histogram is an effective tool for organizing data and is used to measure characteristics or attributes represented by a set of criteria that summarize the main features of the data. It is also a method for displaying and comparing the distribution of data against predetermined specifications.

The histogram illustrates the set of measured values in the Intravenous Solutions Factory corresponding to each value. It also presents the conformity percentages of the sustainable manufacturing dimensions and the gaps identified for each dimension, which result from variations in measurement. **Figure (3)** presents the histogram illustrating the conformity percentages and gap values for the Intravenous Solutions Factory.

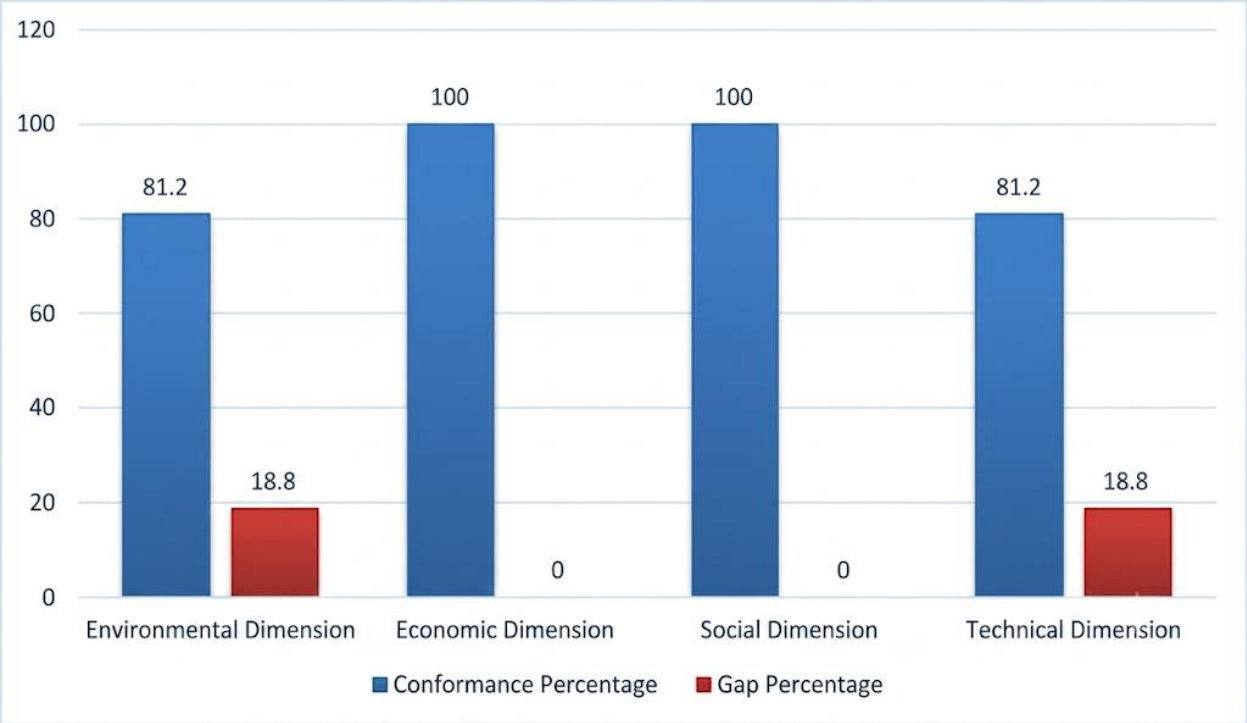


Figure (3)
Histogram Illustrating the Conformity Percentages and Gap Values for the Intravenous Solutions Factory

Source: Prepared by the researcher.

It is evident from **Figure (3)** that there is a relatively small gap in the **environmental dimension**, amounting to **18.8%**, indicating the need for the Intravenous Solutions Factory to adopt clean, environmentally friendly fuel. Regarding the **technological dimension**, a similarly limited gap of **18.8%** is observed, resulting from the factory's failure to utilize modern energy-saving technologies. These gaps are primarily attributed to the factory's failure to establish environmental objectives at the functional, operational, and process levels relevant to the environmental management system.

With respect to the **economic** and **social dimensions**, no gaps were identified. This is attributed to the fulfillment of all economic and social requirements within the Intravenous Solutions Factory. Therefore, the factory should address the identified gaps to improve its performance, achieve full compliance (100%) across all sustainable manufacturing dimensions, and subsequently apply for international certification related to the Environmental Management System. Based on these findings, the **third main hypothesis** is rejected, and the alternative hypothesis is accepted, which states:

"Some quality measurement tools can be used to assess the application of sustainable manufacturing dimensions in the Intravenous Solutions Factory."

The results reveal that some checklist requirements are linked to the environmental and technological gaps identified. Specifically, this is when these are based on environmentally polluting fuel in the environmental dimension and the lack of an energy-saving technology in the technological dimension. Thus, the conformity percentages of these two

dimensions were lower than those of the economic and social dimensions, where the conformity percentages were both 100%.

Chapter Four
Conclusions and Recommendations

After performing the theoretical and practical part of the research, and after having derived the results from the research related to the current state of the dimensions of sustainable manufacturing in the Intravenous Solutions Factory, using quality measurement tools, the main conclusions of the research are presented in this chapter in addition to a set of recommendations which could help to improve the implementation of some dimensions of sustainable manufacturing and overcome the identified gaps, and thus support continuous improvement and development inside the factory.

First: Conclusions

1. According to the results of the study, the ISF practices the dimensions of sustainable manufacturing at a high level with high conformity percentages for most of the dimensions studied.
2. The level of implementation for the economic and social dimensions had been the most complete with full conformity, indicating the factory management's dedication to the economic and social component of sustainability.
3. The results showed that the environmental and technological dimensions are applied at an acceptable level but limited gaps imply that there is a need to focus on some requirements pertaining to these dimensions.
4. The overall conformity percentage of the sustainable manufacturing dimensions shows a high percentage, which means that the factory has the proper capabilities to implement more sustainable manufacturing practices.
5. The environmental gap was mainly blamed on the lack of ‘environmentally friendly fuel' and their impact on compliance with the requirements of this dimension as compared to the other dimensions.
6. The main weakness that was found in the technological dimension was the lack of use of energy-saving technologies in manufacturing operations that was manifested in conformity percentage of this dimension.
7. The tools used to measure quality in the study were found to be effective in identifying the current state of the sustainable manufacturing dimensions and also in identifying the areas that needed to be improved in the factory.
8. The use of the Cause-and-Effect Diagram and the Histogram helped in identifying the causes of the existing gaps and priorities for future improvement activities.

Second: Recommendations

1. Implement the environmental dimension and minimise environmental impacts of production processes by using environmentally friendly fuels as alternatives.
2. Implement energy-saving modern technologies and methods of use in manufacturing processes to increase the efficiency of the use of resources and reinforce the implementation of the technological dimension.
3. Continue practices that enabled full conformity in the economic and social dimensions of school performance to maintain the current level of performance in these dimensions.
4. Use quality measurement instruments regularly to track the level of implementation of the sustainable manufacturing dimensions and pinpoint any future gaps.

5. Create a sustainable manufacturing dimension gap analysis plan with the aim of improving the level of conformity and increasing the sustainable performance of the factory by further addressing the remaining gaps in the dimensions of sustainable manufacturing.

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