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Statistical Analysis of Lean Supply Chain's Impact on Holonic Manufacturing

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Abstract: This study sought to examine the influence of a lean supply chain on the execution of a holonic production system, Kirkuk Soft Drinks, Juices, and Healthy Water Company Limited. This study employed a descriptive analytical methodology and utilized a questionnaire to gather data from a random sample of 60 employees within an organization. The data were analyzed using SPSS V25. The results indicated a significant interest in the lean supply chain and management's inclination towards implementing the holonic manufacturing system. The results indicated a statistically significant effect (at the 0.05 level) of the lean supply chain and its dimensions (industrial standards, process standards, waste reduction standards) on the implementation of the holonic manufacturing system. This research culminates in multiple recommendations

Keywords: Holonic manufacturing system, Lean Supply Chain

1 Introduction

The global landscape is becoming dynamic, unexpected, complex, and confusing [1]. Asim et al. [2] investigate supply chain vulnerabilities in Pakistan's industrial industry, emphasizing Resource Reformation (RR) as a pivotal element. Their findings highlight that efficient restructuring and resource optimization are crucial for public sector organizations to match operational plans with the magnitude of disruptions, thereby emphasizing the necessity for a thorough review of resource-use techniques. Ali Ala [3] examined IoT-enabled smart supply chains through the framework of ESG principles utilizing fuzzy nonlinear modeling. It addresses ambiguities and inaccuracies to enhance the evaluation of risks, responsibilities, and operational procedures. Iraq is a developing nation; its enterprises, especially in manufacturing, have difficulties in material processing and production owing to the intricacies of supply chains and contemporary manufacturing processes. Technological advancements, raw material sources, artificial intelligence, and various other elements hinder the implementation of supply chain operations and contemporary production systems in a manner that minimizes time and costs. Supply chain activities routinely neglect these changes, often leading to excessive stocks, wasted time, and heightened costs incurred by the organization. Consequently, it is imperative to explore alternative strategies to minimize waste and expenses. Consequently, the lean supply chain is regarded as a strategy that organizations utilize to mitigate losses and expenses, eradicate waste, and enhance value across the supply chain, exemplifying the implementation of contemporary manufacturing systems characterized by holonic production. Holonic manufacturing operates based on collaboration among holons, which encompasses order holons, product holons, material holons, scheduling holons, and computing holons. Dividing manufacturing systems into collaborative and participative groups diminishes costs, production duration, and waiting time, while enhancing operational flexibility. [4] indicated that the philosophy of the lean supply chain emphasizes the efficient implementation of the holonic manufacturing system within organizations by analyzing inputs to eliminate items that fail to satisfy the necessary criteria. The seamless movement of goods along with a reduction in the duration of production activities enhances the efficacy of the holonic manufacturing system. Armin et al. [5] affirmed that the re-engineering of material flows and lean techniques, facilitated by information technology, customer interactions, and strategic engagement with suppliers, are essential components in

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the implementation of the holonic manufacturing system. This study aims to address modern issues that are vital for maintaining a company's performance amid environmental degradation and technological obstacles. At Kirkuk Soft Drinks, Juices and Healthy Water Company Limited is experiencing a decrease in production levels and diminished competitiveness, particularly due to recent market liberalization towards regional markets. This necessitates the company's adoption of a lean supply chain and contemporary innovative production techniques to address these difficulties. This study focuses on determining the function of the lean supply chain in implementing a holonic production system. The global landscape is becoming dynamic, unexpected, complex, and confusing [1]. Asim et al. [2] investigate supply chain vulnerabilities in Pakistan's industrial industry, emphasizing Resource Reformation (RR) as a pivotal element. Their findings highlight that efficient restructuring and resource optimization are crucial for public sector organizations to match operational plans with the magnitude of disruptions, thereby emphasizing the necessity for a thorough review of resource-use techniques. Ali Ala [3] examined IoT-enabled smart supply chains through the framework of ESG principles utilizing fuzzy nonlinear modeling. It addresses ambiguities and inaccuracies to enhance the evaluation of risks, responsibilities, and operational procedures. Iraq is a developing nation; its enterprises, especially in manufacturing, have difficulties in material processing and production owing to the intricacies of supply chains and contemporary manufacturing processes. Technological advancements, raw material sources, artificial intelligence, and various other elements hinder the implementation of supply chain operations and contemporary production systems in a manner that minimizes time and costs. Supply chain activities routinely neglect these changes, often leading to excessive stocks, wasted time, and heightened costs incurred by the organization. Consequently, it is imperative to explore alternative strategies to minimize waste and expenses. Consequently, the lean supply chain is regarded as a strategy that organizations utilize to mitigate losses and expenses, eradicate waste, and enhance value across the supply chain, exemplifying the implementation of contemporary manufacturing systems characterized by holonic production. Holonic manufacturing operates based on collaboration among holons, which encompasses order holons, product holons, material holons, scheduling holons, and computing holons. Dividing manufacturing systems into collaborative and participative groups diminishes costs, production duration, and waiting time, while enhancing operational flexibility. [6] indicated that the philosophy of the lean supply chain emphasizes the efficient implementation of the holonic manufacturing system within organizations by analyzing inputs to eliminate items that fail to satisfy the necessary criteria. The seamless movement of goods along with a reduction in the duration of production activities enhances the efficacy of the holonic manufacturing system. Armin et al. [5] affirmed that the re-engineering of material flows and lean techniques, facilitated by information technology, customer interactions, and strategic engagement with suppliers, are essential components in the implementation of the holonic manufacturing system. This study aims to address modern issues that are vital for maintaining a company's performance amid environmental degradation and technological obstacles. At Kirkuk Soft Drinks, Juices and Healthy Water Company Limited is experiencing a decrease in production levels and diminished competitiveness, particularly due to recent market liberalization towards regional markets. This necessitates the company's adoption of a lean supply chain and contemporary innovative production techniques to address these difficulties. The study challenge centers on determining the function of the lean supply chain in implementing the holonic production system at Kirkuk Soft Drinks, Juices, and Healthy Water Company Limited.

1.1 Research Problem

A lean supply chain is regarded as a successful model designed to enhance operational efficiency and minimize waste in supply chains by streamlining processes, decreasing surplus inventory, and eradicating superfluous time. Conversely, the holonic manufacturing system exemplifies a sophisticated framework that depends on intelligent coordination among autonomous manufacturing units (holons), thereby offering significant flexibility in addressing evolving and varied production requirements. The research challenge involves assessing the degree to which the lean supply chain influences the implementation of the holonic manufacturing system within Kirkuk Soft Drinks, Juices, and Healthy Water Company Limited.

1.2 Importance of the Research

The significance of this research is categorized into two components: theoretical and practical, as outlined below.

Theoretical Significance

This study underscores the theoretical significance of the lean supply chain and the necessity of implementing a holonic manufacturing system. This research constitutes a significant addition to the Arabic scientific corpus, specifically enhancing the Iraqi library by offering substantial knowledge that advances future scientific inquiry and fosters the evolution of concepts and practices in modern management.

Pragmatic Significance

This research offers significant advantages to decision-makers and administrators at Kirkuk Soft Drinks, Juices, and Healthy Water Company Limited. This underscores the necessity of implementing contemporary techniques in administrative operations, including the lean supply chain, which may influence the deployment of a holonic manufacturing system within the organization.

1.3 Research Objectives

The primary aim of this study is to ascertain the influence of the lean supply chain on the implementation of the holonic manufacturing system inside Kirkuk Soft Drinks, Juices, and Healthy Water Company Limited. This study aims to accomplish the following sub-objectives:

1. Assess the degree of implementation of lean supply chain principles (industrial, process, and waste reduction standards) inside the studied organization.
2. Assess the efficacy of implementing the holonic manufacturing system in the studied company.
3. Assess the influence of the lean supply chain on the implementation of the holonic manufacturing system within the studied company.

2 Literature Review

2.1 Concept of Lean Supply Chain

The concept of a lean supply chain is one of the concepts that emerged at the beginning of the 21st century, which aims to reduce all types of waste throughout the chain through its activities, thereby enhancing its performance [6]. Companies focus on simplifying their processes by eliminating waste and non-value-added activities [7]. Applying agility in the supply chain is considered the most efficient strategic method to help companies make the supply chain more effective [8, 14]. According to [16], to apply agility in the supply chain, companies must commit to three management principles that will form the basis for transformation: lean is a strategy, promotion of the culture of lean, and individual redeployment, which can be explained in the following figure:

Altering individuals' mindsets facilitates the swift dissemination of agility within companies, especially in the supply chain, rendering agility a critical strategic concern essential for economic success [10]. In response to these intellectual advancements, various meanings and concepts have emerged to articulate the notion of a lean supply chain. According to [10], a lean supply chain is characterized by the utilization of the most efficient methods within the shortest timeframe, prompt responsiveness to customer demands, adaptability in material transfer, and the application of current data and information to enhance production efficiency. [2] defined it as standards that provide rapid responses and minimize timeframes, enabling enterprises to restock inventory more swiftly. According to [7], it is characterized by shared interests operating within a mindset of cooperation and agility for core activities, supported by a foundation that enhances chain performance to attain the company's objectives.

A lean supply chain comprises a series of interrelated operations that facilitate the flow of materials, goods, capital, and information, wherein the company endeavors to eradicate waste and non-value-added activities along the chain. [9] assert that the objective of a lean supply chain is to optimize value, defined as the disparity between the final product's worth to the customer and the costs incurred by the supply chain to fulfill the customer's demand. Lean supply chain at Kirkuk Soft Drinks, Juices, and Healthy Water Co. Ltd. represents an important methodology aimed at improving operational performance, reducing waste, and increasing production efficiency. In short, the company's lean supply chain is based on improving quality and efficiency, reducing waste, and accelerating production processes in line with market and customer requirements.

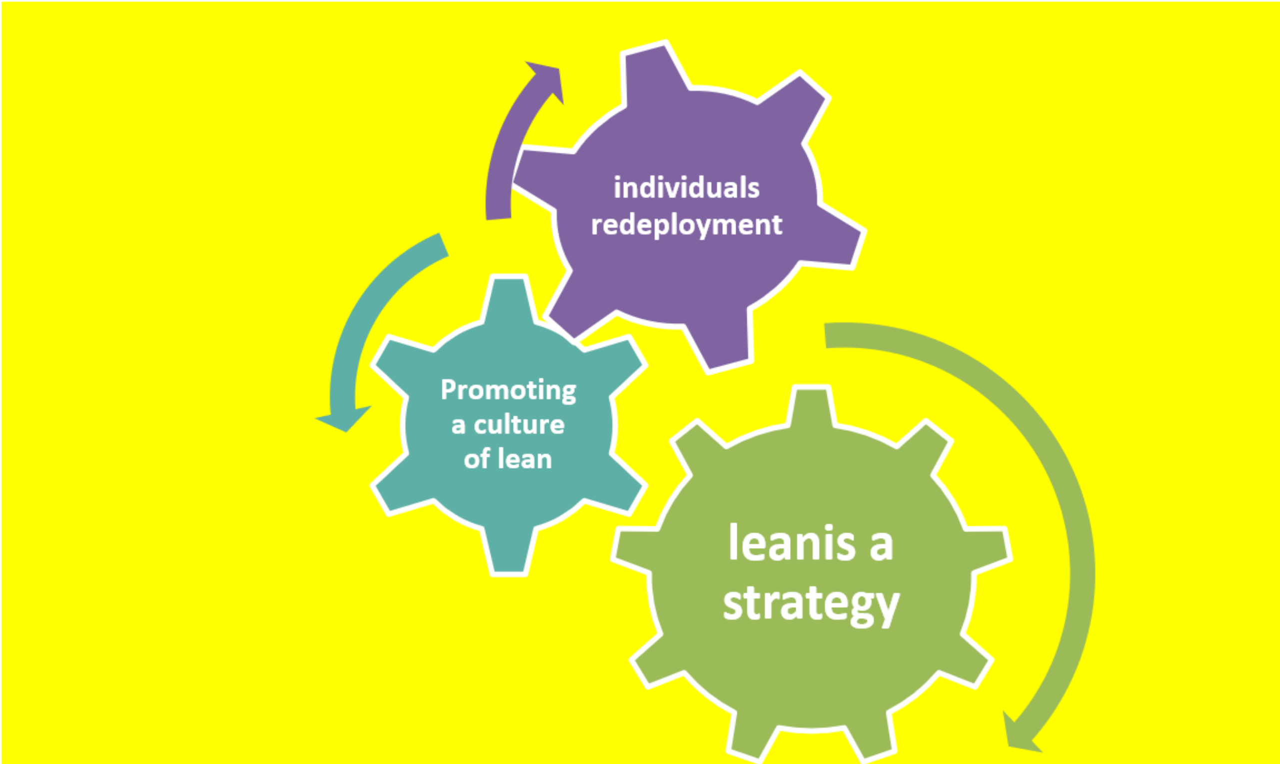

Fig. 1: Principles of transformation in the supply chain [**?**]

2.1 Dimensions of Lean Supply Chain

The lean supply chain represents a contemporary methodology in production and operations management, characterized by the eradication of waste across the chain and the removal of all non-value-added activities, serving as the initial step in establishing a lean supply chain. From this viewpoint, it sustains the progression of all materials that are converted through manufacturing processes into final goods that fulfill the needs and preferences of consumers. The lean supply chain emphasizes the dimensions that eradicate waste across the supply chain. [9] and [15] concur on these dimensions, encompassing industry standards, process standardization, and waste reduction standards, which will be incorporated in this study.

2.1.1 Industry Standards

Technological advancements in the 20th century facilitated production development across multiple sectors, prompting the establishment of standardized regulations that mandate compliance from partners (suppliers and producers) within the supply chain to ensure high quality and safeguard consumers and the environment [12]. From this viewpoint, firms must use contemporary management principles, such as a lean supply chain, which serves as a vital conduit for the company's dynamism and sustainability, linking it to suppliers, employees, and customers. This facilitates industrial progress [14]. Business standards are procedural and technical regulations that are typically adhered to by most business stakeholders.

2.1.2 Process Standardization

Process standardization facilitates an uninterrupted progression of activities throughout the supply chain, ensuring that work stages transition seamlessly from initiation to completion without delays, idle time, or waste, and that impediments to the flow process are eliminated [4]. Process standardization is essential for a lean supply chain and serves as a fundamental component of a quality system. This entails ensuring that supply chain activities are uniform and repeatable through a consistent methodology endorsed by all stakeholders in the chain [11].

2.1.3 Reducing Waste Standard

Eliminating or minimizing waste is a fundamental principle in managing the lean supply chain, which emphasizes the optimization of processes from the receipt of raw materials from suppliers through production to the delivery of finished products to customers [5]. Minimizing waste in both surface and subsurface natural resources, along with judicious utilization of economic resources, can facilitate sustainable development [8]. To establish a lean supply chain, firms must concentrate on eradicating waste in all its manifestations and minimizing it across the entire supply chain, rather than restricting efforts to a single partner, as the objective is collectively shared among all stakeholders [6]. Supply chain collaborators can jointly amend rules and processes to facilitate waste reduction and implement various strategies, such as resource recycling or resource reuse [13].

2.2 Holonic Manufacturing System

Since the inception of the Industrial Revolution, there has been a tendency to utilize machines instead of laborers to enhance the efficiency of production processes. This movement advocated an initial transition to mechanization, followed by a shift to automation. Automation facilitates enhanced production, superior quality, and decreased costs [9]. Considering the difficulties faced by contemporary manufacturing systems, holonic manufacturing systems have arisen as a subject that focuses on addressing specific obstacles within the existing industrial landscape. The concept of holonic manufacturing was introduced in 1990 by philosopher Koestler, who described holons as autonomous, self-organizing entities that may operate independently while depending on other units [8]. Koestler observed that complex systems may emerge only from stable and autonomous subsystems, wherein intelligence is disseminated among individual things. These creatures are collaborative, intelligent, and autonomous units referred to as holons [6]. Holonic manufacturing resembles a company composed of components, and in the absence of collaboration among these units, the company will be unable to function effectively within its environment. Holonic manufacturing systems exemplify unit collaboration to create a cohesive system, resulting in enhanced efficiency, predictability, resilience, and agility for heterogeneous control systems [5]. From this viewpoint, numerous ideas have arisen, and various conceptual meanings have been solidified to articulate the notion of a holonic manufacturing system. [6] characterized it as a system comprising a collection of holons at a subordinate level, while simultaneously being integrated into a larger company of holons at a superior level, which facilitates the connection of sub-entities or units with overarching units within a sequential framework. [9] identified it as an all-encompassing system that consolidates a complete array of manufacturing operations (holons), from order placement to design, production, and marketing, aimed at establishing a manufacturing enterprise distinguished by agility. [12] characterized it as a production system designed to integrate contemporary manufacturing processes to fulfill consumer demands and address the obstacles encountered by conventional systems. According to the aforementioned theoretical framework, researchers determined that the holonic manufacturing system comprises self-organizing units that collaborate to attain specified objectives, is distinguished by significant flexibility in delivering optimal products to customers, and possesses the ability to operate both autonomously and in conjunction with others simultaneously. The significance of a holonic manufacturing system is its capacity to operate autonomously from other holons while simultaneously collaborating with them. This attribute emphasizes the system's role in assisting the company in attaining its objectives through coordination with the external environment [13]. Researchers have exhibited diverse viewpoints on defining the parameters of holonic manufacturing systems. [12] delineated the dimensions of the holonic manufacturing system as resource, product, order, and staff holons. [10] identified the dimensions of holonic production as resource holon, product holon, and order holon. [15] delineated the dimensions of holonic production as resource holons, product holons, order holons, and computational holons. Holonic manufacturing systems function predominantly based on the availability of several dimensions on which they depend to execute their actions and attain their objectives accurately. The fundamental elements of the holonic manufacturing system were established and assessed through an examination of theoretical frameworks and empirical research.

3 Methodology

Given the nature and objectives of the study, a descriptive analytical technique was employed, concentrating on the examination of the phenomena that occur in reality. It also focuses on precisely characterizing and articulating it both qualitatively and statistically. The qualitative statement delineates the phenomenon and elucidates its attributes, whereas the quantitative expression offers a numerical description that conveys the quantity or scale of this occurrence and its degree of association with other phenomena.

Kirkuk Soft Drinks, Juices and Healthy Water Company Ltd. was considered as the spatial boundaries of the research, as the questionnaire form was distributed to a sample of (70) workers within the company under study, then this number was reduced to form the final number of this sample which is (60) valid questionnaires for analysis and the remaining (10) questionnaires were not returned. The questionnaire form was considered the main tool for collecting data. To identify the validity of the scale and the reliability of the questionnaire form, the (Crombach's alpha) scale was used, and it became clear that the alpha coefficient reached (0.902).

3.1 Research Hypothetical Model

In light of the research problem and its objectives, a comprehensive proposed model was designed to represent and diagnose the relationship between the lean supply chain on one hand and the holonic manufacturing system, as shown in the following figure, which was derived from the reality of research and academic literature related to the research variables.

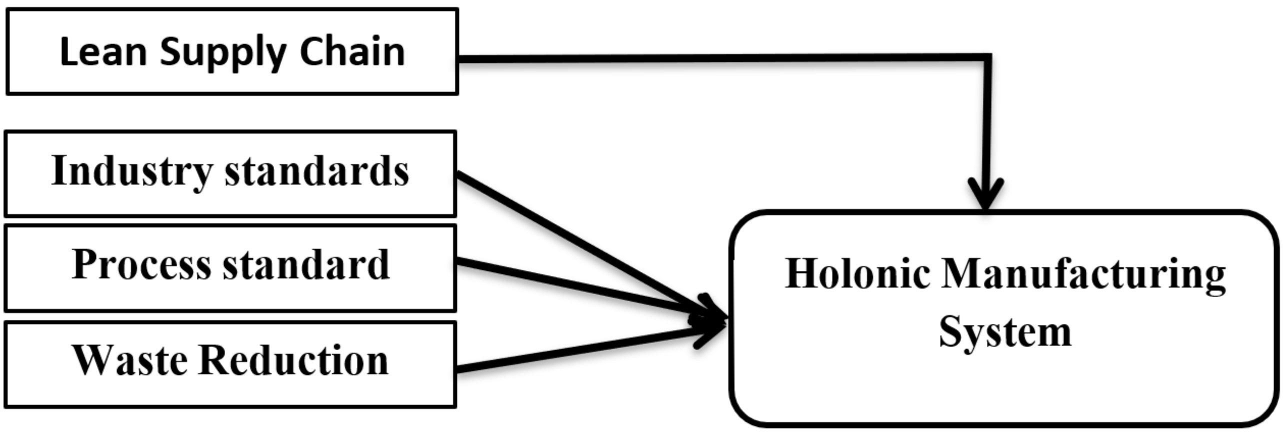

Fig. 2: Research Model

- –H_1: There is a statistically significant effect at the level of significance (0.05) of the lean supply chain with its dimensions (manufacturing standards, process standards, waste reduction standards) in applying the holonic manufacturing system in At Kirkuk Soft Drinks, Juices, and Healthy Water Company Limited.
  - –$H_{1\text{-}1}$: There exists a statistically significant effect at the 0.05 level of significance on manufacturing standards in the implementation of the holonic manufacturing system At Kirkuk Soft Drinks, Juices and Healthy Water Company Limited.
  - –$H_{1\text{-}2}$: A statistically significant effect exists at the 0.05 significance level regarding the process standard in the implementation of the holonic manufacturing system At Kirkuk Soft Drinks, Juices and Healthy Water Company Limited.
  - –$H_{1\text{-}3}$: A statistically significant effect exists at the 0.05 level of significance for the waste reduction criterion in the implementation of the holonic production system At Kirkuk Soft Drinks, Juices and Healthy Water Company Limited.
- –H_2: A statistically significant correlation exists at the 0.05 level of significance between the lean supply chain and its dimensions (manufacturing standards, process standards, and waste reduction standards) and the implementation of the holonic manufacturing system At Kirkuk Soft Drinks, Juices and Healthy Water Company Limited.
  - –$H_{2\text{-}1}$: A statistically significant association exists at the 0.05 level of significance between manufacturing standards and the implementation of the holonic production system At Kirkuk Soft Drinks, Juices and Healthy Water Company Limited.
  - –$H_{2\text{-}2}$: A statistically significant association exists at the 0.05 level of significance between the process standard and the implementation of the holonic production system At Kirkuk Soft Drinks, Juices and Healthy Water Company Limited.
  - –$H_{2\text{-}3}$: A statistically significant association exists at the 0.05 level of significance between the waste reduction standard and implementation of the holonic manufacturing system At Kirkuk Soft Drinks, Juices and Healthy Water Company Limited.

4 Empirical Results and Discussion

To analyze the data, extract conclusions, and test the validity of the study hypotheses, descriptive statistical methods will be used, utilizing the Statistical Package for Social Sciences (SPSS V.25), which includes the following:

1. Calculating means and standard deviations for the questionnaire items.
2. Correlation test.
3. Multiple regression test.

The arithmetic means and standard deviations for the sample's responses regarding the lean supply chain in applying the holonic manufacturing system in the researched company were calculated, and the results were as follows:

Independent variable: The independent variable includes three dimensions (industrial standards, process standards, and waste reduction).

Industrial standards: The results in Table (1) indicate the arithmetic means and standard deviations of the questionnaire results related to industrial standards:

Table 1: Arithmetic Means and Standard Deviations of Questionnaire Items Related to Industrial Standards

Number	Paragraph	Arithmetic Mean	Standard Deviation	Rank	Level
1	The company inspects the inputs to exclude those that do not conform to the required specifications.	2.550	0.746	3	High
2	The company's management relies on international principles in production processes.	2.383	0.804	4	High
3	The company's management is working to diagnose the reasons that limit product conformity to specifications.	2.600	0.693	2	High
4	The company's management seeks to maintain a continuous relationship with its suppliers.	0.733	0.578	1	High
Industrial standards		2.566	0.514	—	High

The results in Table (1) indicate the responses of the study sample members regarding the industrial standards items. The table shows that the arithmetic mean of the variable reached (2.566), indicating a high level of application of industrial standards in the researched company. The arithmetic means of the variable items ranged from (2.383) to (2.733). The item (4) which states "The company's management seeks to maintain a continuous relationship with its suppliers" ranked first in terms of relative importance, with an arithmetic mean of (2.733) at a high level. While item (2) which states "The company's management relies on global standards in production operations" ranked last with an arithmetic mean of (2.383) and at a high level.

Process Standard

The results in Table (2) indicate the arithmetic means and standard deviations of the questionnaire results related to the process standard:

The results in Table (2) indicate the responses of the study sample members regarding the process standard items. The table shows that the arithmetic mean of the variable reached (2.775), indicating a high level of application of process standard in the researched company. The arithmetic means of the variable items ranged from (2.700) to (2.900). The item (8) which states "The company's management seeks to ensure the achievement of product flow continuity to the consumer" ranked first in terms of relative importance, with an arithmetic mean of (2.900) at a high level. Item (7), which states, "The company's management places explanatory signs in process procedures," ranked last with an arithmetic mean of (2.700) and at a high level.

Table 2: Arithmetic Means and Standard Deviations of Questionnaire Items Related to Process Standard

Number	Paragraph	Arithmetic Mean	Standard Deviation	Rank	Level
5	The company's management establishes standard procedures for employees to follow to avoid confusion at work.	2.733	0.516	3	High
6	The company's management strives to achieve a balance between product demand and available capacity and capabilities.	2.766	0.499	2	High
7	The company's management places clear indications in the process procedures.	2.700	0.590	4	High
8	The company's management strives to ensure a smooth flow of products to the consumer.	2.900	0.302	1	High
Process Standards		2.775	0.346	—	High

Table 3: Arithmetic Means and Standard Deviations of Questionnaire Items Related to Waste Reduction Standard

Number	Paragraph	Arithmetic Mean	Standard Deviation	Rank	Level
9	The company's management works to reduce lead times between production activities.	2.600	0.643	4	High
10	The company inspects products between production stages to identify damaged and defective items.	2.883	0.323	1	High
11	The company's management collaborates with its suppliers to reduce errors that occur during the manufacturing process.	2.850	0.360	2	High
12	The company is committed to manufacturing products that meet customer needs and desires.	2.833	0.418	3	High
Reducing Waste Standard		2.791	0.291	—	High

Waste Reduction

The results in Table (3) indicate the arithmetic means and standard deviations of the questionnaire results related to waste reduction standards:

The results in Table (3) indicate the responses of the study sample members regarding the waste reduction standard items. The table shows that the arithmetic mean of the variable reached (2.791), indicating a high level of application of the waste reduction standard in the researched company. The arithmetic means of the variable items ranged from (2.600) to (2.883). Item (10), which states, "The company inspects products between production stages to identify damaged and defective ones," ranked first in terms of relative importance, with an arithmetic mean of (2.883) at a high level. While item (9) which states "The company's management works to reduce time lags between production operation activities" ranked last with an arithmetic mean of (2.600) and at a high level.

4.1 Independent Variable: Lean Supply Chain

Table 4 illustrates the lean supply chain variables. The arithmetic means for each dimension in the researched company were calculated in descending order of estimation, and the results were as follows:

Table (4) shows the arithmetic means, standard deviations, and scores for the lean supply chain dimensions. The table indicates a high level of lean supply chain in the researched company, with an arithmetic mean of (2.711). The table

Table 4: Arithmetic Means and Standard Deviations of Questionnaire Items Related to Lean Supply Chain Dimensions

Dimensions	Arithmetic Mean	Standard Deviation	Rank	Level
Waste Reduction	2.791	0.291	1	High
Process Standard	2.775	0.346	2	High
Industrial Standards	2.566	0.514	3	High
Total	2.711	0.325	—	High

also indicates that the waste reduction standard ranked first with an arithmetic mean of (2.791), followed by the process standard with an arithmetic mean of (2.775), and then the industrial standards ranked last with an arithmetic mean of (2.566), all of which were at a high estimation level.

4.2 Dependent Variable

It is measured comprehensively through 10 items, as shown in Table (5).

Table 5: Arithmetic Means and Standard Deviations of Questionnaire Items Related to the Dependent Variable

Number	Paragraph	Arithmetic Mean	Standard Deviation	Rank	Level
13	The company's management ensures that the required work is completed on time.	2.816	0.431	9	High
14	The company arranges production activities sequentially.	2.733	0.548	10	High
15	The company's management seeks to provide up-to-date information on the stages of the product life cycle.	2.900	0.354	7	High
16	The company's management takes customer feedback on its products to determine the required product specifications.	2.916	0.334	6	High
17	The company's management works to determine the required resource requirements for operations, both quantitatively and qualitatively.	2.850	0.404	8	High
18	The company's management seeks to allocate resources according to priorities.	2.950	0.286	4	High
19	The company's management schedules its operations effectively.	2.916	0.334	5	High
20	The company's management adheres to its customer appointments.	2.983	0.129	3	High
21	The company's management calculates the costs incurred as a result of implementing production operations.	2.983	0.129	2	High
22	The company's management uses devices to control production operations.	3.000	0.000	1	High
Holonic Manufacturing System		2.905	0.177	—	High

The results in Table (5) indicate the responses of the study sample members regarding the Holonic Manufacturing System items. The table shows that the arithmetic mean of this variable reached (2.905), indicating a high level of application of the system in the researched company. The arithmetic means of the variable items ranged from (2.733) to (3.000). The item (22) which states "The company's management uses devices to control production processes" ranked first in terms of relative importance, with an arithmetic mean of (3.000) at a high level. Item (14), which states that "the company arranges production activities in a sequential manner," ranked last with an arithmetic mean of (2.733) and at a high level.

4.3 Hypotheses Testing

H_1: There is a statistically significant effect at the level of significance (0.05) of the lean supply chain with its dimensions (industrial standards, process standards, waste reduction) on the application of the Holonic Manufacturing System in the researched company. To test the main hypothesis of the study, a regression test was conducted to determine the extent of the impact of the lean supply chain and its three dimensions on the application of the Holonic Manufacturing System in the researched company.

4.3.1 Strength of the Test Model

Table 6: Model Summary

Model	R	R2	Adjusted R2	Std. Error of the Estimate
1	0.592	0.351	0.339	0.143

Table (6) indicates that the value of the correlation coefficient between the independent variable and the dependent variable reached (0.592), and the value of the coefficient of determination (R^2) reached (0.351). Thus, it was possible to explain the independent variables by (35.1%) of the changes in the dependent variable. As for testing the general significance of the regression model, Table 7 represents the results of the ANOVA analysis to test the general significance of the regression model.

Table 7: Results of Analysis of Variance for Research Variables

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.648	1	0.648	31.326	0.000
Residual	1.200	58	0.021		
Total	1.848	59			

Table (7) illustrates the analysis of variance, which aims to identify the explanatory power of the model and the independent variable (lean supply chain) on the dependent variable. According to Table (7), there is a high significance for the F-test, estimated at (31.326), at a significance level of (Sig = 0.000), which is less than the level ($\alpha \leq 0.05$). Therefore, the regression model is suitable for measuring the causal relationship between the independent and dependent variables in the application of the Holonic Manufacturing System. In this context, the null hypothesis is rejected in favor of the alternative hypothesis, which states that "the regression model is significant (there is an effect of the independent variables on the dependent variable)." Therefore, there was an effect of the independent variable on the dependent variable, where the independent variables explained 64.8% of the dependent variable.

4.3.2 Multiple Regression

Table 8 shows the regression coefficient values for the ability and statistical tests as follows:

$H_{1\text{-}1}$: A statistically significant influence of significance on industrial standards in the implementation of the Holonic Manufacturing System inside Kirkuk Soft Drinks, Juices, and Healthy Water Company Limited.

Table 8 demonstrates the statistically significant impact of industrial standards on the implementation of the Holonic Manufacturing System within the studied company, as evidenced by a calculated (t) value of (3.837) and a statistical significance level of (0.040), which is below the threshold of (0.05). Consequently, the null hypothesis is rejected in favor of the alternative hypothesis.

$H_{1\text{-}2}$: A statistically significant influence of significance regarding the process standard in the implementation of the Holonic Manufacturing System at Kirkuk Soft Drinks, Juices, and Healthy Water Company Limited.

Table 8: Regression Coefficients between the Independent Variables and the Application of the Holonic Manufacturing System

Unstandardized Coefficients			Standardized Coefficients		
Model	**B**	**Std. error**	**Beta**	**T**	**Sig.**
Constant	1.811	0.199		9.123	0.000
Industrial Standard	0.041	0.049	0.120	3.837	0.040
Process Standard	0.077	0.056	0.150	4.177	0.024
Waste Reduction	0.278	0.082	0.458	3.393	0.001

Table 8 demonstrates the statistically significant impact of the process standard on the implementation of the Holonic Manufacturing System within the studied company, as evidenced by a calculated (t) value of (4.177) and a statistical significance level of (0.024), which is below the threshold of (0.05). Consequently, the null hypothesis is rejected in favor of the alternative hypothesis.

$H_{1\text{-}3}$: A statistically significant effect of significance for the waste reduction standard when implementing the Holonic Manufacturing System at Kirkuk Soft Drinks, Juices, and Healthy Water Company Limited.

Table 8 demonstrates the statistically significant impact of the waste reduction standard on the implementation of the Holonic Manufacturing System within the studied company, as evidenced by a calculated (t) value of (3.393) and a statistical significance level of (0.001), which is below the threshold of (0.05). Consequently, the null hypothesis is rejected in favor of the alternative hypothesis.

H_2: A statistically significant correlation of 0.05 between the lean supply chain and its dimensions (industry standards, process standards, and waste reduction standards) in the implementation of the holonic manufacturing system at Kirkuk Soft Drinks and Healthy Water Company.

Table 8 indicates that there is a statistically significant effect of the waste reduction standard in applying the Holonic Manufacturing System in the researched company, where the calculated (t) value reached (3.393) and the statistical significance level (0.001) was less than the specified value (0.05). Therefore, the null hypothesis is rejected in favor of the alternative hypothesis.

The results show that industry and process standards have a positive and statistically significant impact on holographic manufacturing systems. This means that improving and implementing these standards in industrial and administrative processes effectively contributes to reducing waste levels within the company. This indicates that improving the company's daily processes and procedures and following precise process standards have a greater impact on reducing waste. Therefore, from an administrative perspective, it is better to prioritize improving processes and procedures, training on the precise application of process standards, and paying attention to waste management (production waste, energy consumption), as it is closely linked to the efficiency of holographic manufacturing. In short, the results confirm that the success of holographic manufacturing depends on the integration of technical and administrative aspects, with a focus on standards, efficiency, and sustainability.

Table 9: Direct and significant correlation between (the lean supply chain)

The First Variable	Relationship Direction	The Second Variable	Correlation Coefficient Value	P-value
Lean Supply Chain	———	Holonic Manufacturing System	.592	.000
Industry Standards			.490	.000
Process Standard			.433	.001
Waste Reduction Standard			.603	.000

Source: Prepared by the researchers.

Referring to Table (9) and Figure (3), it is clear that there is a direct and significant correlation between (the lean supply chain) and (the holonic manufacturing system), as indicated by the value of the correlation coefficient, which appeared to be equal to (0.592). This relationship is significant based on the probability value (P-value), the highest value of which appeared equal to (0.000), which is less than (0.05). We also note the presence of a direct and significant correlation between (industry standards) and (the holonic manufacturing system), as indicated by the value of the correlation coefficient, which is equal to (0.490). This relationship is significant based on the probability value (P-value), the highest value of which appeared equal to (0.000). Based on this, we accept the first sub-hypothesis. In the same context, we note the presence of a direct and significant correlation between (the process standard) and (the holonic manufacturing system), as indicated by the value of the correlation coefficient, which is equal to (0.433).

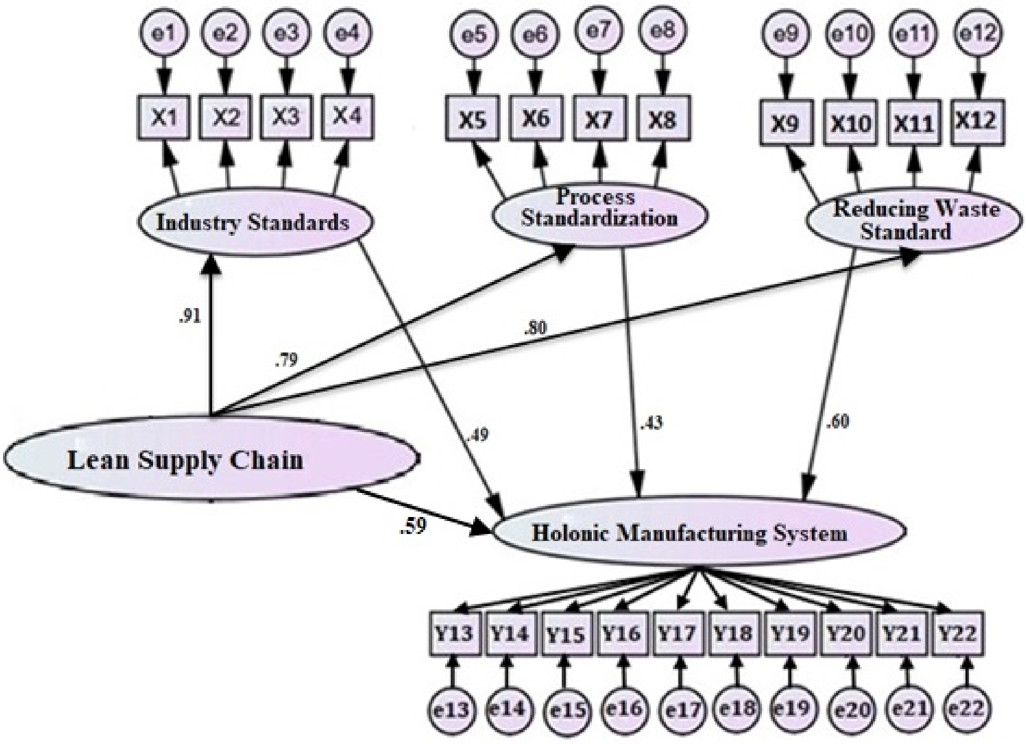

Fig. 3: Correlation coefficient values between the lean supply chain and its dimensions and holonic manufacturing system.

5 Presentation of Results

The results showed a high degree of estimation for the lean supply chain in the researched company from the perspective of the study sample. The results showed that waste reduction came in the first place, followed by the process standard, and finally, in the last place, the industrial operations standard. All these dimensions received a high estimation.

– Regarding waste reduction, the results showed a high degree of evaluation for this dimension. It was found that the company has an interest in reducing waste, as it continuously works to improve its production processes and develop manufacturing processes to increase efficiency and reduce waste in materials entering production processes.
– Regarding the process standard, the results showed the company's interest in this standard through a set of practices that ensure the quality and efficiency of production and administrative processes. This is achieved by performing several tasks that ultimately reduce the time, effort, and resources required to achieve desired results.
– Regarding industrial standards, the results showed a high evaluation of these standards in the researched company, as they significantly contribute to achieving sustainability and efficiency and ensure the delivery of high-quality products that meet the needs of the target market.

The results also showed a high degree of interest in the Holonic Manufacturing System in the researched company from the perspective of the study sample, which achieves high flexibility in adapting to environmental changes. This flexibility enables the system to achieve environmental sustainability by improving resource utilization, reducing waste, and enhancing production efficiency. The results also showed that the lean supply chain had an impact on the application of the Holonic Manufacturing System from the perspective of the study sample.

The results of the hypothesis testing indicated the following:

1. There is a statistically significant effect at the level of significance (0.05) for industrial standards on the application of the Holonic Manufacturing System in the researched company.
2. There is a statistically significant effect at the level of significance (0.05) for the process standard on the application of the Holonic Manufacturing System in the researched company.
3. There was a statistically significant effect at the level of significance (0.05) for the waste reduction standard on the application of the Holonic Manufacturing System in the researched company.

6 Conclusion

The lean supply chain significantly enhances the Holonic Manufacturing System by improving efficiency, lowering production costs, and fostering flexibility through strategies that minimize waste and enhance the quality of information and material flow. This results in increased productivity and responsiveness to evolving market demand.

The study demonstrated that the amalgamation of lean manufacturing principles with Holonic Manufacturing fosters a dynamic manufacturing ecosystem marked by innovation and ongoing interaction among diverse systems, thereby enhancing resilient infrastructure. Consequently, enhancing a company's capabilities, prioritizing training, and embracing contemporary technologies are essential for maximizing the advantages of this integration. This strategy is anticipated to propel companies toward operational excellence, allowing them to sustain competitiveness in swiftly evolving market landscapes.

Although the integration of the lean supply chain with the Holonic Manufacturing System has evident advantages, the application of these concepts necessitates an ongoing dedication to improvement and innovation, as well as proficient management of potential problems encountered during implementation.

7 Suggestions for Future Research

The relationship between waste management and holographic manufacturing and their impact on sustainable performance.

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