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THE ROLE OF HOLONIC INDUSTRIAL IN ENHANCING PRODUCT QUALITY: AN INVESTIGATIVE STUDY IN NORTH OIL COMPANY

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Abstract
The current study aims to determine the role of Holonic Manufacturing in enhancing product quality across its three dimensions (performance, reliability, durability). To achieve the research objective and answer the questions raised by its problem, the most prominent of which was: "What is the nature of the correlation and impact relationships between Holonic Manufacturing and product quality?" a random sample of 40 employees from North Oil Company was selected. A questionnaire was used as the primary tool for data collection from the surveyed company. For data analysis, the researcher relied on the (SPSS V25) program. The research concluded with several findings, the most significant of which was the existence of a meaningful correlation and impact relationship between Holonic Manufacturing and product quality. Based on this, a set of recommendations was presented to the management of the surveyed company, the most notable of which was the necessity of increasing attention to all means that could enhance product quality within the company.

Keywords: Holonic Manufacturing, Product Quality, Reliability.

Introduction

Manufacturing systems, in their various models and forms, are synergistic frameworks that combine ideas, procedures, and methods, with the primary objective of achieving results that meet the needs and desires of target groups. The manufacturing system evolves over time, starting from the Taylor system, with these systems striving to reduce employee holons, financial costs, and efforts, while adhering to the required class standards. Holonic manufacturing systems are considered the latest developments in this field, reflecting changes in consumer awareness levels due to technological advancements. Holonic manufacturing is a modern concept in the manufacturing domain that aims to enhance the efficiency and flexibility of production systems. The term "holonic" derives from the Greek word "holos," meaning "whole," indicating the idea that each unit within the system can operate independently while interacting and coordinating with other units as part of a larger system.

Given the limited studies linking Holonic manufacturing to product quality in North Oil Company, it is essential to adopt advanced manufacturing systems, making Holonic manufacturing the most suitable technology for this purpose. Hence, the research problem arises in clarifying the role of holonic industrial in improving product quality, which can be formulated through the following questions:

1. Does the organization of the surveyed company have a pure understanding of Holonic's manufacturing and product quality?
2. What is the nature of the association between holographic industrial and product quality?
3. Does Holonic manufacturing contribute to enhancing product quality?

Importance of the Research

The importance of the research is highlighted in the following aspects:

1. Knowledge Importance: This significance is reflected in its examination of one of the modern topics in the Iraqi industrial sector, specifically the use of Holonic manufacturing and its role in enhancing product quality in the field of petroleum products. The outcomes of this exploration may lead to important results. Moreover, addressing such topics will open avenues for other researchers to delve into additional variables not covered in this study, contributing to a cumulative body of knowledge regarding the studied variables.
2. Field Importance: This aspect is manifested in guiding the researched field to address and apply these topics with the aim of benefiting from them in enhancing the presentation of the surveyed company. It helps create consciousness and interest among administrators about adopting new management methods based on a sound understanding of the philosophy behind these methods and how to implement them. Additionally, it aims to achieve results that can specifically contribute to improving the presentation of the surveyed company.

Objectives of the Research

The research aims to:

1. Review Previous Research Studies: To survey relevant previous research studies and best practices in the field of Holonic manufacturing and product quality in oil production processes.
2. Explore Current Practices: To investigate current practices in the field of petroleum products concerning Holonic manufacturing and product quality and examine the possibility of improving them.
3. Clarify the Nature of the Relationship: To demonstrate the nature of the correlation and impact of Holonic manufacturing on product quality.

Research Methodology

Given the nature of the investigation and its objectives, a descriptive-analytical approach was adopted. This approach emphasizes studying the phenomenon as it exists in reality and aims to describe it accurately using both qualitative and quantitative methods. Qualitative analysis elucidates the phenomenon and highlights its characteristics, while quantitative analysis offers a numerical description that reflects the magnitude or extent of the phenomenon and its relationships with other phenomena.

Research Hypotheses

In light of the research problem and in line with its objectives, the following hypotheses are proposed:

1. There is no significant association between holonic manufacturing and product quality, which gives rise to the following sub-hypotheses:

- A. There is no significant correlation between the product holon and product quality.
- B. There is no significant correlation between the demand holon and product quality.
- C. There is no significant correlation between the resource holon and product quality.
- D. There is no significant correlation between the employee holon and product quality.

2. There is no significant impact of Holonic manufacturing on product quality, leading to the following sub-hypotheses:

- A. There is no significant impact of the product holon on product quality.
- B. There is no significant impact of the demand holon on product quality.
- C. There is no significant impact of the resource holon on product quality.
- D. There is no significant impact of the employee holon on product quality.

Hypothetical Model of the Research

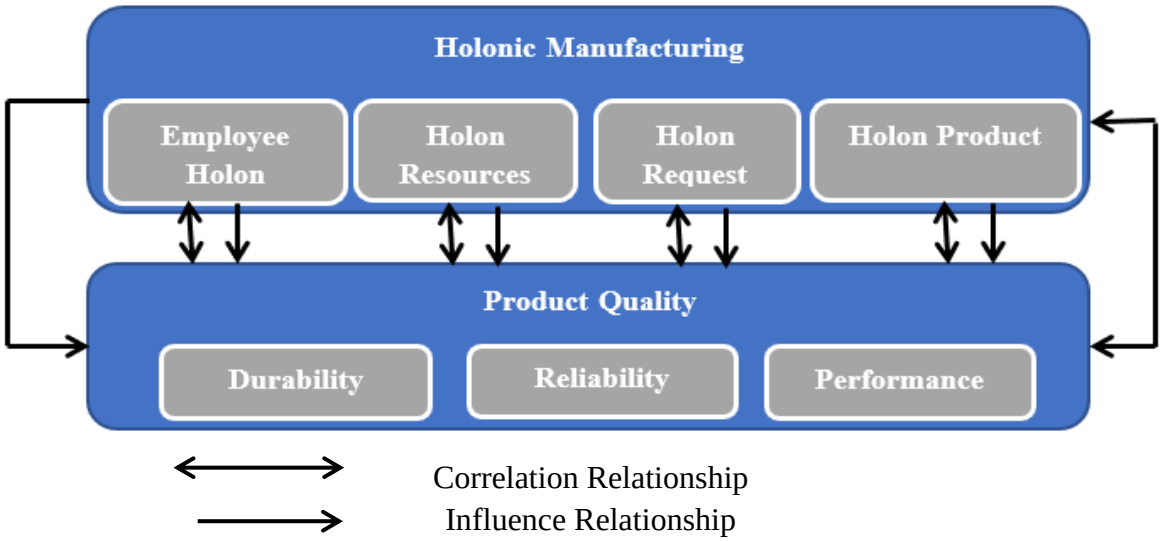

Figure (1): Hypothetical Model of the Research

Reference: Prepared by the researcher.

Chapter Two: Theoretical Framework of the Research

First: Concept of Holonic Manufacturing

1. Modern Definition Focusing on Technologies: Holonic manufacturing is an approach that combines autonomy and integration within a production system aimed at enhancing flexibility and sustainability using artificial intelligence and Internet of Things (IoT) technologies (Wang et al., 2020, p. 33).

2. Definition Related to Digital Transformations: Holonic manufacturing is a framework characterized by the ability to adapt to rapid changes in demand and production through holons that dynamically interact to form intelligent supply chains and digital production networks (Leitão et al., 2020, p. 34).

3. Holonic manufacturing is a modern production system that integrates the autonomy of production components with their integration to achieve common goals. This system relies on the concept of "holons," which are flexible and self-organizing production units that can interact and adapt to changes in the production environment. This system is characterized by high flexibility

and efficiency, making it ideal for addressing challenges related to changing demand and markets (Botti & Giret, 2021, p. 46).

Second: Importance of Holonic Manufacturing

Holonic manufacturing represents an important step towards improving the efficiency and flexibility of production systems in the modern era. This system is distinguished by its ability to break down the production process into independent units known as "holons," which can autonomously interact and adapt to variations in the manufacturing environment. These characteristics contribute to achieving several benefits, including:

1. Flexibility and Efficiency: Holonic manufacturing can easily adapt to changes in demand or production environments. It allows for rapid shifts between different production plans based on market needs (Botti & Giret, 2021, p. 47).
2. Cost Reduction and Increased Productivity: By allowing work distribution among independent holons, waste can be minimized, and the utilization of available resources can be improved, leading to reduced overall costs and increased productivity (Wang et al., 2022, p. 55).
3. Enhancing Sustainability: Holonic manufacturing contributes to improving the sustainability of operations by reducing waste and minimizing pollution resulting from production. Holons rely on optimizing material and resource flows in line with environmental sustainability strategies (Jain & Gupta, 2023).
4. Continuous Innovation: Due to its reliance on AI technology and intelligent control, the holonic system can achieve continuous improvements in productivity and quality, fostering innovation within factories (Birzeit University Libraries, 2023, p. 60).
5. Achieving Integration Among Different Systems: Holonic manufacturing allows for the integration and cooperation among multiple systems within the factory (Botti & Giret, 2021, p. 46).

Third: Requirements for Holonic Manufacturing

Holonic manufacturing (Holonic Manufacturing) is a production system that combines the flexibility of decentralized systems with the efficiency of centralized systems, allowing for rapid adaptation to market changes and improving operational efficiency. To successfully implement this system, the following requirements must be considered (Botti & Giret, 2021, p. 47-49):

1. Advanced Technological Infrastructure: Holonic manufacturing requires modern technologies such as distributed control systems, IoT, and AI to ensure effective communication and coordination among independent units.
2. Design of Independent Holonic Units: Production components should be designed as holonic units (Holons) that possess autonomy and decision-making capabilities, with the ability to collaborate and coordinate with other units to achieve common goals.
3. Effective Communication System: Holonic manufacturing requires a reliable and fast communication network to enable seamless and real-time information exchange among holonic units.
4. Unified Standards and Protocols: Standardized protocols must be adopted to ensure compatibility and integration among various units and systems within the holonic manufacturing environment.

5. Flexible Process Management: This system requires management mechanisms capable of adapting to rapid changes in the production environment and effectively distributing tasks among holonic units.
6. Training and Qualification of Human Resources: Training programs must be provided for employees to enhance their skills in dealing with modern technologies and understanding the principles of holonic manufacturing.

Fourth: Dimensions of Holonic Manufacturing

Many models illustrate the characteristics and dimensions of the holonic industrial system, which is a relatively new technology; as a result, these models are still subject to changes, updates, and expansions. In this context, the mental processing model was selected, consisting of four components, as outlined in various scientific publications (Ali et al., 2023, p. 76):

1. Product Holon: This holon includes the procedures and information associated with the product, ensuring the accuracy of production processes and compliance with relevant quality standards. It comprises comprehensive and up-to-date information about the product life cycle, addressing aspects related to customers, design, technical configuration, and quality assurance techniques.
2. Holon Request: This holon plays an important role in the production system because it is accountable for finishing the tasks assigned to it exactly within the specified time frame. In addition, it deals with the physical condition model of the product and processes the logistical information related to the work. Holon Request can represent customer requests, production orders for storage, work orders for prototypes, and maintenance and repair requests for materials.
3. Resource Holon: This component contains of the physical components that represent the productive resources within the manufacturing system, in addition to a data processing section related to resource control. Resource holons provide the productive capacity of other holons through scientific systems for allocating energy and providing information. They facilitate the understanding, use and organization of these resources.
4. Employee Holon: This holon is a crucial factor in achieving high performance in modern companies, as it embodies the ability to effectively apply human properties and accomplish the diverse mix of staffs in their various actions. Figure (2) illustrates the integration of the dimensions of holonic manufacturing.

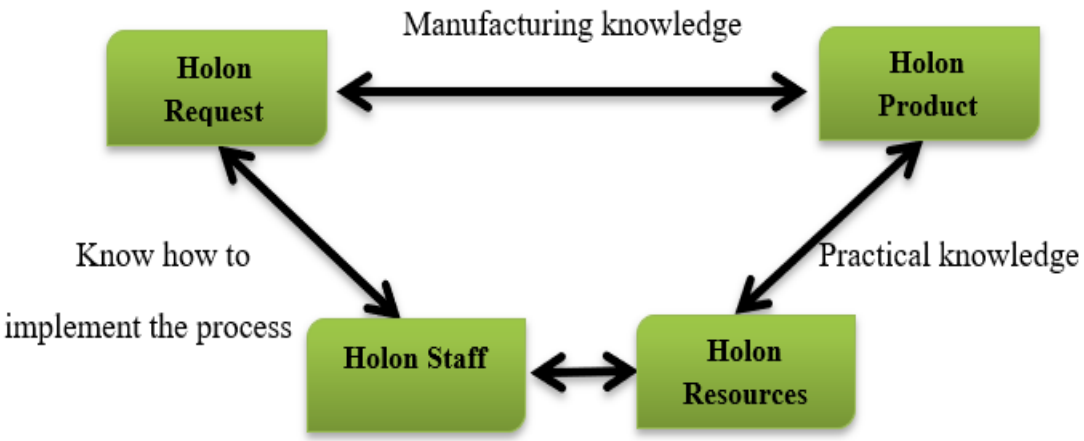

Figure (2): Prepared by the Student Based on Sources.

Fifth: Concept of Product Quality

Product quality is defined as "the capacity of a product or service to meet or surpass customer expectations" (Kotler & Keller, 2016, p. 143). It also refers to the inherent characteristics of the product that fulfill consumer needs and desires (Juran & De Feo, 2010, p. 5). Additionally, product quality is defined as "the capability of a product or service to meet or exceed customer expectations" (Evans & Lindsay, 2017, p. 23).

Sixth: Importance of Product Quality

Product quality is a critical factor in the success of companies, as it directly affects customer satisfaction and loyalty. According to Garvin (1984), product quality can be defined based on several dimensions, such as performance, reliability, durability, and conformity to specifications. Kotler & Keller (2016) indicate that improving product quality can lead to increased competitive advantage and enhanced brand image in the market. Furthermore, Zeithaml (1988) emphasizes that consumers' perceptions of quality are linked to their perceived value of the product, influencing their purchasing decisions. Thus, companies that focus on improving quality can achieve a long-term competitive advantage and increase their market share.

Seventh: Benefits of Product Quality

Product quality is a fundamental element for the success of organizations and increasing customer satisfaction. Here are the main benefits of product quality (Al-Barqi, A. M. S., & Abu Al-Sundus, I. A. 2020, p. 23-24):

1. Increased Customer Satisfaction: Improving product quality leads to meeting customer expectations and enhancing loyalty.
2. Enhanced Brand Reputation: High-quality products contribute to building a strong reputation and increasing trust in the market.
3. Cost Reduction: Reducing defects and rework helps lower operational costs.
4. Increased Sales and Revenue: Quality products lead to repeat purchases and attract new customers.
5. Improved Production Efficiency: Adopting quality standards reduces waste and increases operational efficiency.
6. Enhanced Competitive Capability: Companies that focus on quality enjoy strong competitive advantages in the market.
7. Reduction in Complaints and Returns: Good products minimize post-sale issues and improve customer relationships with the company.
8. Compliance with International Standards: High quality helps meet global market requirements and increases export opportunities.

Eighth: Dimensions of Product Quality

The following three dimensions are considered the most important due to their direct influence on customer approval and the success of the product in the market:

1. Performance: Performance is one of the most critical dimensions, reflecting the product's ability to execute the essential functions for which it was designed. The better the performance, the greater the chance of attracting and retaining customers (Kotler & Keller, 2016, p. 11).

2. Reliability: Reliability refers to the product's ability to function without failure over a prolonged period. Reliable products enhance customer loyalty and reduce maintenance and repair costs (Zeithaml, 1988, p. 32).
3. Durability: Durability represents the product's lifespan before it needs replacement. Products with high durability reduce replacement costs, making them more attractive to customers (Garvin, 1987, p. 15).

Chapter Three: Field Framework of the Research

This chapter provides a statistical description of the research variables based on their hypotheses and the proposed model, with the goal of clarifying the nature of the correlation and causal relationships between the dimensions of holonic manufacturing and product quality. The analysis utilizes various statistical tools, including means, standard deviations, coefficients of variation, and response rates for each dimension, along with simple correlation coefficients and regression coefficients to assess the correlation and impact relationships among the research variables.

First: Overview of North Oil Company

The company's origins go back to the Iraq Petroleum Company, which was established in 1929 in Kirkuk. The geographical area of this company spans from the Turkish border in the north to latitude 32.5° south, and from the Iranian border in the east to the borders with Syria and Jordan in the west. It encompasses the northern and central Iraqi governorates of Kirkuk, Nineveh, Salah al-Din, Baghdad, and Diyala, along with parts of Babil and Qadisiyah governorates. The company is tasked with the production of crude oil and natural gas from the oil and gas fields within its operational area, which consists of over fifty facilities, including pumping stations, concentration complexes, reservoir fields, gas separation and compression stations, and a large number of oil wells, all linked by multiple networks of flow pipelines and main pipelines distributed across the company's area. Through these facilities, the company supplies various types of crude oil to Iraqi refineries in the north and center, as well as associated gas to the North Gas Complex and power generation stations. It also exports quantities of crude oil abroad via export lines to the north through the Iraqi-Turkish pipeline, to the south through the strategic pipeline, and to the west through the western system to Syria.

Second: Description and Diagnosis of the Sample Responses

The results of the statistical analysis presented in Table (1) indicate a strong consensus among the sample members regarding management's interest in holographic manufacturing. The average values for all dimensions surpassed the hypothesized mean of 2 on the three-point Likert scale, with an overall mean of 2.5676, a standard deviation of 0.1811, and a coefficient of variation of 7.0567. This suggests a high degree of homogeneity within the studied sample, which had a response rate of 86.397%. The dimension that contributed most significantly to enriching this system was employee identity, which had a mean value of 2.7250, a standard deviation of 0.3884, a coefficient of variation of 2.8220, and a response rate of 89.112%. In contrast, the dimension that contributed the least was the holon product, which recorded a mean value of 2.3666, a standard deviation of 0.3884, a coefficient of variation of 16.411, and a response rate of 84.001%. The other dimensions produced mean agreement values that fell between these two extremes.

Table (1): Values of the Research Variables.

Variables	Dimensions	Means	St. Deviations	C. V.	Response Rates (%)
Holographic manufacturing	Product Holon	2.3666	0.3884	16.411	84.001
	Request Holon	2.6666	0.2649	9.9339	85.143
	Resources Holon	2.5125	0.3486	13.874	87.330
	Employee Holon	2.7250	0.0769	2.8220	89.112
Overall average		2.5676	0.1811	7.0567	86.397
Product quality	Performance	2.6375	0.1897	7.1924	83.932
	Reliability	2.3375	0.3467	14.832	87.141
	Durability	2.2875	0.5018	21.936	82.761
Overall average		2.4207	0.2498	10.322	84.612

Reference: Prepared by the researchers based on the results of SPSS V.25.

The outcomes also indicated a strong consensus among the sample members regarding management's interest in product quality, as the average values for all dimensions surpassed the assumed average of 2 on the three-point Likert scale. The overall average value was 2.4207, with a standard deviation of 0.2498 and a coefficient of variation of 10.322, reflecting the homogeneity of the surveyed sample, which had a response rate of 84.612%. The dimension that contributed most significantly to enhancing product quality was durability, which recorded an average value of 2.6375, a standard deviation of 0.1897, and a coefficient of variation of 7.1924, with a response rate of 83.932%. In contrast, the dimension with the least contribution was reliability, with an average value of 2.2875, a standard deviation of 0.5018, and a coefficient of variation of 21.936, along with a response rate of 82.761%. The performance dimension achieved an average agreement value that fell between these two averages.

Third: Testing the Research Hypotheses

1. Testing the Correlation between Holographic Manufacturing and Product Quality: The results presented in Table (2) indicate the correlation coefficients (R) between the independent variable (holographic manufacturing) at the aggregate level and the dependent variable (product quality). The correlation coefficient was determined to be 0.83 at a significance level of 0.05. Furthermore, the results displayed the R of the dimensions of the independent variable in relation to the dependent variable. The product holon ranked first with a correlation coefficient of 0.71, followed by the resource holon with a correlation coefficient of 0.66. The demand holon ranked third with a correlation coefficient of 0.57, while the employee holon also recorded a correlation coefficient of 0.57, placing it last.

Based on these findings, the first main hypothesis and the sub-hypotheses are rejected, while the alternative hypotheses, which propose that a relationship exists between holographic manufacturing and product quality at both the aggregate and dimensional levels, are accepted.

Table (2): Correlation coefficients (R) between holographic manufacturing and product quality.

Independent Variable / Dependent Variable	Holographic Manufacturing				
	Product Holon	Request Holon	Resources Holon	Employee Holon	Total Index
Product Quality	0.71	0.57	0.66	0.57	0.83*

Reference: Prepared by the researcher based on the results of SPSS V.25 program.

2. Testing the impact relationships between the research variables

A. Testing the Impact of Holonic Manufacturing on Overall Product Quality: The results shown in Table (3) indicate a significant impact of holonic manufacturing on product quality, as demonstrated by the coefficient of determination (R^2) value of 0.86. This suggests that 87% of the variations in product quality can be attributed to holonic manufacturing, while the residual percentage is due to additional factors not involved in the model. This conclusion is further reinforced by a P value of 0.01%, which is lower than the significance level of 0.05.

Additionally, the calculated F value is 63.08, exceeding the critical value of 4.08 at a significance level of 5%. The beta value of 0.89 suggests that a one-unit change in holonic manufacturing results in an 89% change in product quality. Based on these results, the null hypothesis is rejected, and the alternative hypothesis is accepted, which asserts that there is a statistically significant effect of holonic manufacturing on product quality.

Table (3): The effect of holographic manufacturing on product quality.

Independent Variable / Dependent Variable	Holographic Manufacturing					
	R^2	F		B_0	B	Sig.
		Cal.	Tab.			
Product Quality	0.86	63.08	4.08	0.86	0.89	0.001

Reference: Own elaboration based on the results of SPSS V.25

para. Test of the effect of holographic manufacturing dimensions on product quality

This trial assesses the sub-hypotheses derived from the second hypothesis, which statuses that there is no statistically significant effect of the dimensions of holographic manufacturing on product quality. Based on the results presented in Table (4), the following observations can be made:

1. Significant Impact of Holographic Manufacturing Dimensions on Product Quality: The R^2 is 0.78, indicating that 79% of the variations in product quality can be attributed to the dimensions of holographic manufacturing, while the residual percentage is due to other uncontrolled variables not included in the model. This finding is further supported by a calculated F value of 14.08, which exceeds the tabular value of 2.74 at degrees of freedom (5, 19) and a significance level of 5%. Additionally, the P value is 0.00, which is less than 5%. The beta regression coefficient is 0.89, suggesting that a one-unit change in the product holon will lead to an 89% change in product quality. This highlights the influence of the product holon on product quality within the investigated company; therefore, greater adoption of the holographic product will enhance product quality. Consequently, we reject the first sub-hypothesis and accept the alternative hypothesis, which asserts that there is a statistically significant effect of the product holon on product quality.

2. Significant Effect of the Demand Holon on Product Quality: The R^2 is 0.83, indicating that 84% of the variations in product quality can be attributed to the demand holon, while the residual percentage is due to other uncontrolled variables. This result is supported by a calculated F value of 22.62, which exceeds the tabular value of 2.74 at degrees of freedom (5, 19) and a significance level of 5%. The P value is 0.00, which is also less than 5%. The beta value is 0.85, suggesting that a one-unit change in the demand holon will lead to an 85% change in product quality. This finding highlights the significant impact of the demand holon on product quality within the studied firm; therefore, increased attention to the demand for components involved in product manufacturing will enhance product quality. Consequently, we reject the second sub-hypothesis and accept the alternative hypothesis, which asserts that there is a statistically significant effect of demand holon on product quality.

3. Significant Impact of Holon Resources on Product Quality: The R^2 is 0.61, indicating that 62% of the variations in product quality can be attributed to holon resources, while the residual percentage is due to other uncontrolled variables. This finding is supported by a calculated F value of 12.14, which exceeds the tabular value of 2.74 at degrees of freedom (5, 19) and a significance level of 5%. Additionally, the P value is 0.00, which is less than 5%. The beta regression coefficient is 0.77, suggesting that a one-unit change in the supplier holon will result in a 77% change in product quality. This underscores the impact of holon resources on product quality within the surveyed company; therefore, the more accurate the inventory database of the surveyed company, the greater the effect on product quality. As a result, we reject the third sub-hypothesis and accept the alternative hypothesis, which posits that there is a statistically significant effect of holon resources on product quality.

4. Significant Effect of Employee Holon on Product Quality: The R^2 is 0.55, indicating that 56% of the variations in product quality are attributable to employee holon, while the residual percentage is due to other uncontrolled variables. This finding is reinforced by the calculated F value of 10.71, which exceeds the tabular value of 2.74 at degrees of freedom (5, 19) and a significance level of 5%. Furthermore, the P value is 0.00, which is also less than 5%. The beta regression coefficient is 0.64, suggesting that a one-unit change in employee holon will result in a 64% change in product quality. This demonstrates the effect of employee holon on product quality in the surveyed company; therefore, more precise definition and management of the employee holon for production processes will enhance product quality. Accordingly, we reject the fourth sub-hypothesis and accept the alternative hypothesis, which states that there is a statistically significant impact of the dimensions of holographic manufacturing on product quality.

Table (4): The influence of the dimensions of holon manufacturing on product quality.

Dependent Variable / Dimensions of Independent Variable	Product Quality					
	R^2	F		B_0	B_1	Sig.
		Cal.	Tab.			
Product Holon	0.78	14.08	2.74	0.86	0.89	0.000
Demand Holon	0.83	22.62	2.74	1.23	0.85	0.000
Resource Holon	0.61	12.14	2.74	0.93	0.77	0.000
Employee Holon	0.55	10.71	2.74	0.76	0.64	0.000

Reference: Prepared by the researcher based on the outputs of SPSS V.25.

Chapter Four: Conclusions and Recommendations

In order to achieve the objectives, set, it is necessary to obtain logical and interpretable results that allow proposing solutions to the research problem. In this context, the researcher presented the results obtained from the analysis of the field data collected at the North Oil Company, which allowed him to reach the following conclusions:

First: Conclusions

The research reached several conclusions, the most important of which are:

1. The results revealed that the management of the surveyed company is concerned with both Holonic manufacturing and product quality equally.
2. The correlation coefficients (R) between each dimension of Holonic manufacturing and product quality vary, with the product holon showing the strongest correlation, while the employee holon exhibited the weakest correlation.
3. The results indicate that Holonic manufacturing has a significant impact on product quality; the more the surveyed company adopts this system, the more it contributes to enhancing product quality.
4. The dimensions of Holonic manufacturing differ in their impact on product quality, with the product holon being the most influential dimension, while the employee holon had the least impact.

Second: Recommendations

In light of the conclusions drawn from the research, the following recommendations can be proposed to enrich the surveyed field:

1. There should be a focus on systems that contribute to enhancing product quality for companies in general and North Oil Company in particular by adopting the dimensions that reflect it (performance, reliability, and durability).
2. The company should pay attention to Holonic manufacturing as one of the most important means of enhancing product quality.
3. Improving the infrastructure for Holonic manufacturing and providing the necessary resources for proper implementation to ensure the enhancement of product quality.

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