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Research Article

The Impact of Intelligence Quality Management system on Sustainable Manufacturing

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Abstract

Industrial organizations face many challenges such as resource depletion, energy consumption, increasing emissions and waste, and seeking to a higher quality of life. Therefore, it has become necessary to implement sustainable manufacturing. This study aims to examine the effect of the Intelligent quality management system on sustainable manufacturing in the Kufa Cement Plant- Iraq. The main problem is the low level of sustainable manufacturing application in the Plant, due to a defect in the application of the Intelligent quality management system. A questionnaire was designed and distributed to target community represented by (168) managers and engineers working in the Plant, the number of valid questionnaires for statistical analysis were (157). A model was developed and tested according to structural equation modelling by using SmartPLS v.3.3.2 program. The findings indicated that there is a direct positive and significant impact of the Intelligent quality management system on sustainable manufacturing. Forward quality module helps the designing according to market requirements, to make an adjustment to the standards from one time to another, which is reflected positively on customer and community satisfaction and enhances the social and technology aspect of sustainability.

Keywords

Intelligent Quality Management System, Sustainable Manufacturing, Kufa Cement Plant, Iraq

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Introduction

Global warming is a major global environmental challenge and the emissions of the cement industry are a major cause of it, the cement industry uses a lot of energy, especially during the clinker and calcination process that produces emissions such as nitrogen oxides, sulfur oxides, carbon dioxide and particulate matter that can be a local nuisance and health hazard. The greenhouse gases from the cement industry will continue to increase due to the increased demand for homes (Eshikumo& Odock, 2017:109). As a result of the impact caused by the production process of cement resistant to sulfur salts in the Kufa Cement Plant on environmental sustainability by affecting human health, climate change, land use and quality of the ecosystem, being an industry that consumes a lot of natural resources, thermal energy, fuel and water, which leads to a lot of emissions to water, air and soil, as it is an industry that continues to grow to meet the increasing demand for outputs
(Al-Mosawy, 2020: 21). Although the plant seeks to gradually replace the used fuel from black oil to gas, However, the environmental impact of the plant is still clear due to the emission of gases resulting from the burning processes and the dust generated by this industry1*.
The evolution of different manufacturing concepts has contributed to stakeholder value, and the proposed closed-loop system to include its use of an innovation-based 6R methodology not only to reduce, reuse and recycle but also to recover, redesign and remanufacture products over multiple life cycles (Jayal et al., 2010:145). The importance of sustainable manufacturing is to reduce cost through resource efficiency, improve regulatory compliance, brand reputation and reach new markets (Machado et al.;2020:1464). According to the OECD, the general principle of sustainable manufacturing is to reduce material intensity, energy consumption and emissions and create unwanted by-products while maintaining or improving the value of products to society, due to diminishing non-renewable resources, stricter environmental regulations, and Consumer preference of environmentally friendly products (Amrina & Yusof, 2011:1094).
With the continuous advancement of information technology, intelligent quality management (IQM) has gradually become a trend in quality management. The process of intelligent quality management (IQM) focuses on introducing data mining techniques to extract knowledge by identifying previously unknown cause-and-effect relationships (Xu, 2018: 441). Thus, IQMS gives the quality team the opportunity to come back to determine the reasons key leading to superior quality, in order to take proactive action to prevent any process failures (Lau et al., 2009:1814).
Intelligent Quality Management System (IQMS) is importance for many organizations to achieve competitive advantages in their respective industries, as it facilitates efficient and effective internal processes that lead to increased customer satisfaction and profitability (Abraham & Suganthi, 2013:307).
(Lau et al., 2009) presented the development of a prototype called the Intelligent Quality Management System (IQMS), to support knowledge within a work flow in a Chinese factory, it has proposed an algorithm for data exchange, process knowledge and improvement. (Gerlish & Gottschalk, 2019) explored the concept of intelligent quality management in relation to control methods and reducing deviations within the production processes of an office furniture manufacturer in Sweden, it showed that the deviations in the production processes are due to human and technological deficiencies.
(Ceptureanu et al., 2018) examined the impact of competitiveness on sustainable manufacturing practices in Romanian small and medium textile companies, and concluded that environmental pressures, management support, and employee participation did not significantly affect sustainable manufacturing practices. Also (Alnoor et al., 2018) studied the impact of reverse logistics on sustainable manufacturing and concluded that there is a direct positive impact of reverse logistics services on sustainable manufacturing.

The study contributes to employing a scientific methodology by diagnosing a real problem suffered by industrial organizations in general and the Kufa cement plant in particular, and working to adapt several scales from foreign studies to measure the study variables, as the scale of intelligent quality management system which has been adapted to suit Iraqi manufacturing environment, and focus on the study of sustainable industrialization as a comprehensive approach that includes the traditional areas of sustainability (environmental, social, economic) in addition to the fields of (manufacturing and technology).

1 * According to the interview conducted with the Director of the Mechanical Maintenance Department, on 1/9/2021

As a result, this study aims to answer the following questions:

1. What is the level of application of the Intelligent quality management system in Kufa Cement Plant?
2. What is the level of application of sustainable manufacturing in the Plant?
3. What is the impact of the Intelligent quality management system in achieving sustainable manufacturing in the Plant?

This study aims to diagnose the impact of Intelligent quality management system in sustainable manufacturing in the Kufa Cement Plant. To achieve the goal of the study, hypotheses will be built and examine using structural equation modeling to reach the results, finally the discussions and conclusions of this study.

Theoretical Background and Hypotheses

Intelligent Quality Management System (IQMS)

(Wang et al., 2009:1) introduced a Intelligence expert system for total quality management with knowledge discovery in databases, where the Intelligent quality management system is equipped with the feature of "data mining" to provide good knowledge with the ability to understand the relationships between the organization's management processes, solve the "knowledge bottleneck" problem in the traditional quality system, improve the ability for self-learning and collaboration to control the process efficiently and effectively. (Ansari-CH et al., 2011:152) defines it as a closed iterative quality management process consisting of knowledge-intensive activities for continuous improvement and enhancement of business process performance within the organization.
Intelligence Quality Management System is an approach to adopting data mining technology and knowledge discovery in databases, thus integrating information collected from quality control and quality management practices in a primary database and implementing an intelligent IQM quality management system, including assistive decision-making based on data mining (Gerlich & Gottschalk, 2019:21).
Based on the above, it can be said that the Intelligent quality management system is an integrative system that integrates total quality management and information technology within an intelligent system that uses algorithms to mine for quality control data to discover the knowledge needed to support decision making, conducting continuous improvement on processes and products.
IQMS gives the quality team the opportunity to identify the main causes that lead to superior quality, in order to take proactive actions to prevent any process failures. This decision support function can also significantly reduce workload and processing time.
Due to the scarcity of studies that dealt with a measure of the Intelligent quality management system, but it was relied on the study of both (Lau et al., 2009) and (Ho, 2007), which provided the components of this system. So the dimensions of Intelligent Quality Management System are:
* Process Data Exchange Module (PDEM): connects different member systems of the organization to share the same process information, this data is collected through several media, then the process data is divided into subgroups, classified and stored in the central data warehouse (Lau et al.,2009:1803).
*Backward Quality Tracking Module (BQTM): According to (Ishikawa, 1985; Kondo, 1993) the development of quality management to create value for the customer must take into account the bipolar definitions of quality, namely, reverse quality means the quality related to both (deviations, defects or deficiencies) and forward quality, means quality that relates to both (positive features or superior characteristics) (Setijono, 2008:4). BQTM is used to analyze the interrelationships between the process input group and the final quality with support of the algorithm, in order to identify deviations or defects (Ho ,2007: 54(.
*Forward Quality Optimization Module (FQOM): It is designed to improve the set of process operating parameters settings along the workflow in order to meet the requirements of customers, any unsuitable set of process parameters settings within the workflow will affect the quality of the final product, so the manufacturing strategy must be adjusted from time to time according to the

market situation and the requirements of the customers (Ho ,2007: 92).
*Algorithm of iterative process mining algorithm: by Using this algorithm, BQTM will discover hidden relationships between process data, and (FQOM) determine the optimal configuration of process parameters within the integrated workflow thus continually improving processes within the organization (Ho, 2007: 54).

Sustainable Manufacturing (SM)

Sustainable manufacturing has developed through several generations: traditional manufacturing; lean manufacturing; green manufacturing; and sustainable manufacturing at its most advanced stage (Kishawy et al.; 2018:3). It focuses on the 6Rs approach which is an extension of the previous use of 3Rs (reduce, reuse, recycle) that spread in the 1990s, and emphasizes recovering greater value from the end of the life cycle of products, and redirecting to the later life cycles of semi-permanent material flow, and the role of innovation in promoting Sustainability through these practices (Faulkner & Badurdeen, 2014:1).
Sustainable manufacturing evolved from the concept of sustainable development, which was formulated in the 1980s to address concerns about environmental impact, and economic development, Sustainable production was presented at the 1992 UNCED conference in Rio de Janeiro as a guide to help companies and governments to move towards sustainable development (Rosen & Kishawy, 2012: 159).
Sustainable industrialization is defined as the ability to use natural resources in a way that achieves economic, environmental and social aspects, and reduces the negative effects of industrial processes on the environment (Lucato et al.; 2018:2).
It is defined by the US Department of Commerce as "the creation of manufactured products that use processes to reduce negative environmental impacts, conserve energy and natural resources, are safe for employees, communities and consumers, and are economically sound" (Valase et al., 2018: 174).
Sustainable manufacturing is one of the topics that have gained great importance in the past few years, among researchers and industrialists (Dubey et al.; 2015:1).
It includes the production of sustainable products and paves the way for employment, product safety and community security, ensuring a sustainable environment (Moktadir et al.; 2018:4). Most of the researchers addressed the three areas of sustainable manufacturing (environmental, economic, social) such as (Kibira et al., 2009; Eslami et al., 2019) technological aspect has been added, such as (Garetti & Taisch, 2012; Sartal et al., 2020) and (Valase & Raut, 2018) added the manufacturing aspect. The Dimensions of sustainable manufacturing are:

* Environmental Domain: It refers to the impacts of companies on natural resources (Raj et al.; 2017:3), It classified emissions, resource consumption, pollution and the preservation of natural habitats (Joung, et al.; 2013: 152).
* Economical Domain: It refers to the economic aspect of sustainability performance in manufacturing and products, can be divided into three main groups: 'profit', 'manufacturing costs' and 'investment' (Eslami et al., 2019:7)
* Technology Domain: Technological progress indicators for manufacturing companies are designed to measure the new technology applied, the research and development capacity in manufacturing enterprises, and scientific papers published by the organization (Joung, et al.; 2013:155).
* Social Domain. It is designed to measure the well-being of employees, customers, and the community which affected by manufacturing activities and their products (Eslami et al.,2019:7).
* Manufacturing Domain: A manufacturing system produces final products that are stored as serviceable stock and include all the elements needed for manufacturing to occur, such as installed machine capacity, number of workers, productivity and manufacturing technology (Kibira et al.; 2009:9)

Intelligence Quality Management System and Sustainable Manufacturing

Despite the scarcity of studies that combine these two variables, (Gerlich & Gottschalk, 2019: 17) explained deviations in production processes often lead to quality problems referred to scrap and rework activities, these activities affect the Environmental and economic aspects of sustainability,

where scrap and rework activities lead to additional costs (economic factor) as well as additional use of energy and materials (environmental factor). In the context of sustainability, the objective of companies must be to ensure a level of quality in production processes that meet the needs of the present without compromising the ability of future generations through the optimization use of resources.
As (Siva, 2016: 37) mentioned to the basic principles of quality management such as customer focus, continuous improvement and employee participation contribute to environmental sustainability in terms of product development, and that there are a number of quality management practices such as the use of quality function deployment, failure mode and impact analysis; are included in the Design for Environmental Tools and Practices group. (Abbas, 2020:3)pointed out that total quality management aims to efficient use of resources, and it has a long-term orientation by looking at the impact of organizational activities on environmental and organizational performance over a longer period of time. The organizations should link their sustainable development goals with Quality management as it has great potential to improve organizational performance in all aspects of sustainability.
Finally, (Goyal et al., 2019) concluded in his study that the implementation of improved quality management systems supports sustainable manufacturing without compromising product quality. Based on the above, the **main hypothesis** can be formulated:

H: There is an effect relationship of the Intelligent quality management system in sustainable manufacturing.

Four sub-hypotheses emerge from this hypothesis:

Ha: There is an effect relationship of process data exchange module in sustainable manufacturing**.**
Hb: There is an effect relationship of algorithm of interactive process mining algorithm in sustainable manufacturing.
Hc: There is an effect relationship of backward quality tracking module in sustainable manufacturing
Hd: There is an effect relationship of forward quality optimization module in sustainable manufacturing.

Methodology of Research

The Sample and Data Collection

The study population is represented by all the workers in the Kufa Cement Plant, who number (1430) individuals, but not all the workers are directly related to the nature of the study variables and its objectives. Accordingly, the researcher can resort to choosing a subgroup of the community called the "target community", according to (Saunders et al, 2019: 194). The researchers identified the target community of managers (General Manager, Department Manager, Division and Unit Officer) and engineers which working at Plant, who numbered (168) individuals. The data was collected using the questionnaire method from the target community, and 157 responses were obtained.

Measures

The measure of Intelligent quality management system was developed based of the theoretical framework and the architectural structure of the system, according to the study of (Lau et al., 2009; Ho, 2007), which including four dimensions (Process Data Exchange Module; Algorithm of interactive Process Mining; Backward Quality Tracking Mining; Forward Quality Optimization Module). The sustainable manufacturing scale was also developed based on a study of (Valase & Raut, 2018; Valase & Raut, 2019), which including five dimensions (Environmental Domain; Economic Domain; Social Domain; Technical domain; Manufacturing Domain).

Data Analysis

SPSS v.26 program was used to do the descriptive statistics and calculate (arithmetic mean and standard deviation). Advanced statistical program SmartPLS v.3.3.2 was used to assessment the study scale; By building measurement models for the study variables, and testing hypotheses by building Structural Models based on Partial Least Squares (PLS- SEM).

Results

Descriptive Statistical Analysis

Table (1) shows the means and standard deviations of the Intelligent quality management system dimensions. The mean of intelligent quality management system variable reached (2.9042), which is less than the assumed mean (3). This indicates that the variable does not exist as required in the plant, and the dimensions of this variable need It be applied more. The algorithm of inter active mining had the least value, which indicates the weakness of this dimension. Table (1) also shows the means of sustainable manufacturing dimensions are higher than the assumed mean (3), and mean of the sustainable manufacturing variable is (3.5321) at high level, this indicates that the sustainable manufacturing variable is widespread in the Plant.

Table 1
Descriptive Statistical Analysis

Intelligent quality management system				
Dimensions	Item Code	Mean	S.t Deviation	Order
Process Data Exchange Module	PDE	3.0268	0.59704	2
Algorithm of interactive Process Mining	AIP	2.3643	0.61997	4
Backward Quality Tracking Mining	BQT	3.2115	0.66226	1
Forward Quality Optimization Module	FQO	3.0143	0.69236	3
Intelligent quality management system	IQMS	2.9042	2.9042	
Sustainable Manufacturing Dimensions	Item Code	Mean	S.t Deviation	Order
Social Domain	SocD	3.6994	0.69748	1
Manufacturing Domain	ManD	3.5134	0.65994	3
Environmental Domain	EnvD	3.4242	0.69517	5
Economic Domain	EcoD	3.4739	0.72829	4
Technical domain	TecD	3.5499	0.58576	2
Sustainable Manufacturing	SusM	3.5321	0.55112	

The Criteria of PLS-SEM

PLS-SEM Partial Least Squares structural modeling includes two basic steps.
First; assessment of the measurement model, which include building measurement models for the study variables, examining the quality of measurement tool in terms of Validity, reliability, and outer loading of items of the scale.
Second; assessment of structural model, which include examining the hypotheses of the study, measuring the explanatory power of the variables by (R^2). The criteria of two steps according to (Hair et al., 2017) is shown in table (3)

Measurement Model Assessment of Intelligent Quality Management System

The modified measurement model of (Intelligent quality management system) consists of (19) items within four dimensions (PDES-BQT-FQO-AIP). All items met the required criterion of loading

except 7 items (PDE3-PDE5-BQT2-BQT3-FQO3- FQO4-FQO4-AIP5). These items with outer loading less than 0.4, and outer loading between 0.4- 0.7 were deleted due to their impact on improving the rest of the criteria, Figure (1)
Table (4) shows all dimensions have met the acceptable limits of the of the measurement model criteria, such as Discriminatory validity, convergent validity (AVE) and Internal Consistency Reliability.

Table 3
The Criteria of measurement model and structure model Assessment

The Criteria	Acceptable limit
Assessment of Measurement Model	
Internal Consistency Reliability	Composite Reliability ≥ 0.60; Cronbach's Alpha ≥ 0.70
Indicator Reliability	indicator's outer loading ≥ 0.70
Convergent Validity	Average Variance Extracted (AVE) ≥ 0.50
Discriminant Validity	Heterotrait- Monotrait (HTMT) Ratio < 0.90
Assessment of Structure Model	
Collinearity Assessment	Variance Inflation Factor (VIF) < 5
Significance of path coefficients	t value > 1.96; p value < 0.05
Coefficients of Determination (R^2)	0.25, 0.50, 0.75 indicate small, medium, large effect
Effect sizes f^2	0.02, 0.15, 0.35 refer to small, medium, large effect

Source: Hair Jr, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2017). *A primer on partial least squares structural equation modeling (PLS-SEM)*. 2 ed. Los Angeles: Sage

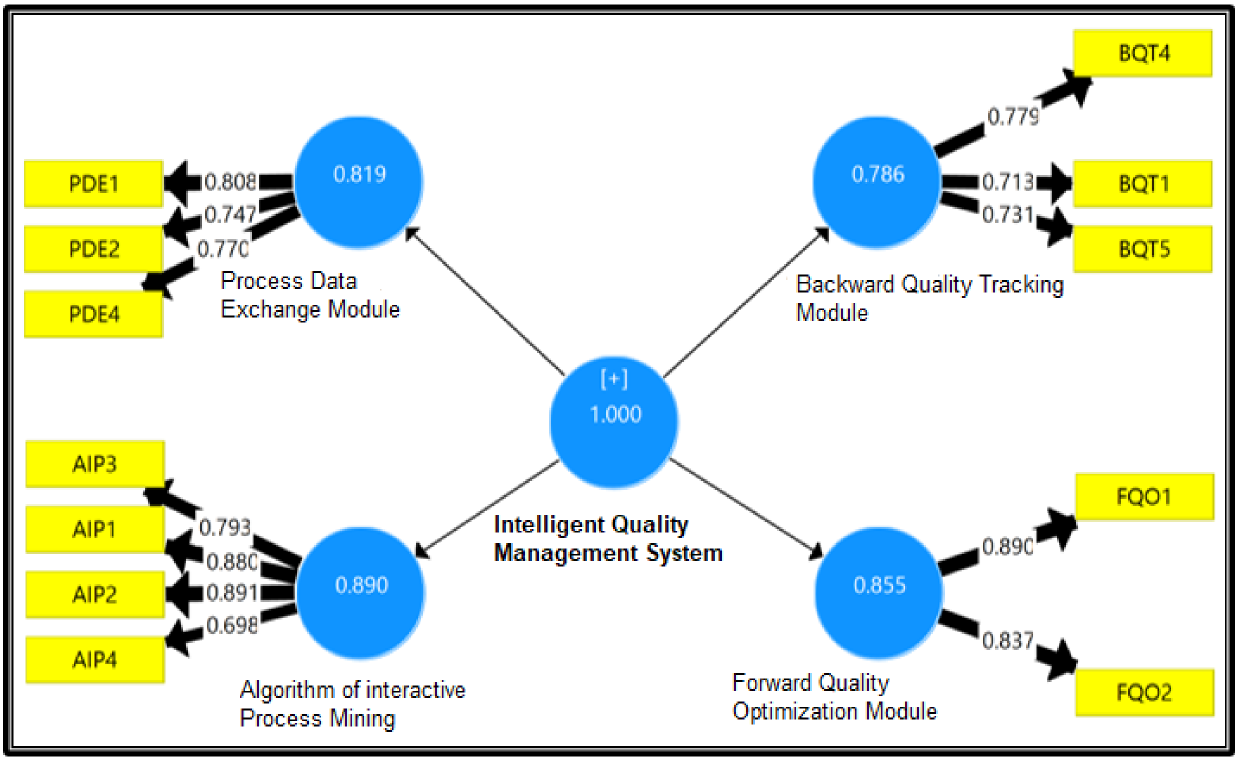

Figure 1. The measurement model of Intelligent Quality Management System After Modification

Table 4
Measurement Model Assessment for Intelligent Quality Management System

Dimensions	Discriminant Validity			Cronbach's Alpha	Composite Reliability	AVE
	AIP	BQT	FQO			
AIP				**0.841**	**0.89**	**0.671**
BQT	0.505			0.791	0.786	0.55
FQO	0.443	0.860		0.763	0.855	0.746
PDE	0.711	0.711	0.573	0.768	0.819	0.602

The Measurement Model Assessment of Sustainable Manufacturing

The modified measurement model of (Sustainable Manufacturing) consists of (26) items within five dimensions (EnvD-SocD-EcoD-TecD-ManD). All items met the required criterion of outer loading except 7 items (EnvD4-EcoD3-TecD4-TecD5-TecD6-Man1-Man4). These items with outer loading less than 0.4, and outer loading between 0.4- 0.7 were deleted due to their impact on improving the rest of the criteria, Figure (2)

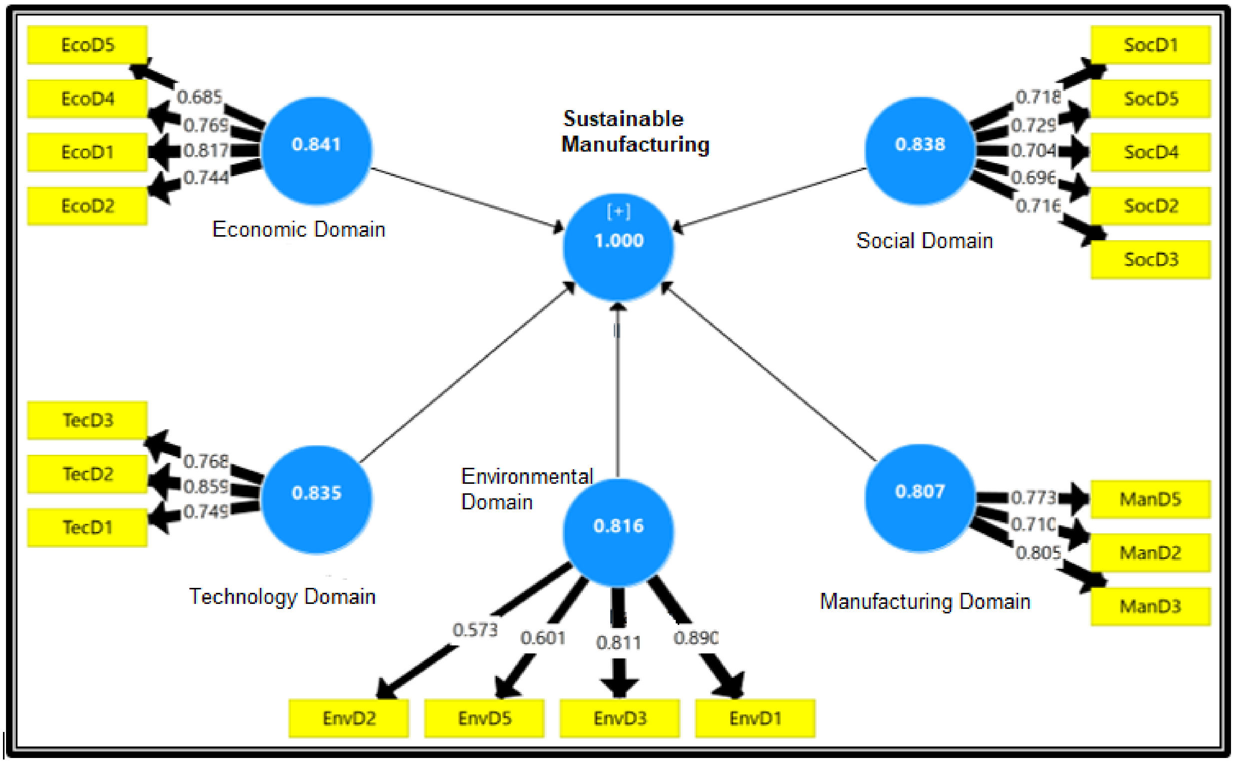

Figure 2. Modified measurement model of Sustainable Manufacturing variable

Table (5) shows that all dimensions have met the acceptable limits of the measurement model criteria, such as Discriminatory validity, convergent validity (AVE) and Internal Consistency Reliability.

Table 5
Measurement Model Assessment for Sustainable Manufacturing

Dimensions	Discriminant Validity				Cronbach's Alpha	Composite Reliability	AVE
	EcoD	EnvD	ManD	SocD			
EcoD					0.751	0.841	0.57
EnvD	0.792				0.714	0.816	0.535
ManD	0.741	0.651			0.743	0.807	0.584
SocD	0.886	0.86	0.81		0.762	0.838	0.508
TecD	0.681	0.805	0.68	0.879	0.704	0.835	0.629

Structural Models Assessment

To exam the hypothesis, the structural model was built in Figure (4).

Table 6
The structural model assessment for the hypothesis

Hypo-thesis	Path	VIF	Path Coeffic-ient	t Value	P value	Result	Effect size f^2	R^2	R^2 adj.
H	IQMS→SusM	1	0.677	18.019	0	accept	0.844	0.458	0.454
Ha	PDE→SusM	2.034	0.207	2.637	0.009	accept	0.053	0.522	0.509

Hb	AIP→SusM	1.177	-0.026	0.421	0.674	reject	0.001
Hc	BQT→SusM	2.062	0.432	5.784	0	accept	0.233
Hd	FQO→SusM	2.062	0.25	3.155	0.002	accept	0.087

IQMS=Intelligent Quality Management System, SusM= Sustainable Manufacturing.

Table (6) shows the results of structural model assessment of the hypotheses. which showed that all the path coefficients for the hypotheses (H, Ha, Hc, Hd) meet the required limits of the values of both ($t > 1.96$) and ($p < 0.05$). Except the hypothesis (Hb) which did not meet the required criteria. For the purpose of clarifying the explanatory power, the adjusted coefficient of determination R^2 is (0.454), this means that that the Intelligent quality management system explains the sustainable manufacturing variable by (45.4%) and the rest of the percentage are other factors that this study did not address.
This achieves the objective of the study:

There is an effect relationship of the Intelligent quality management system in sustainable manufacturing.

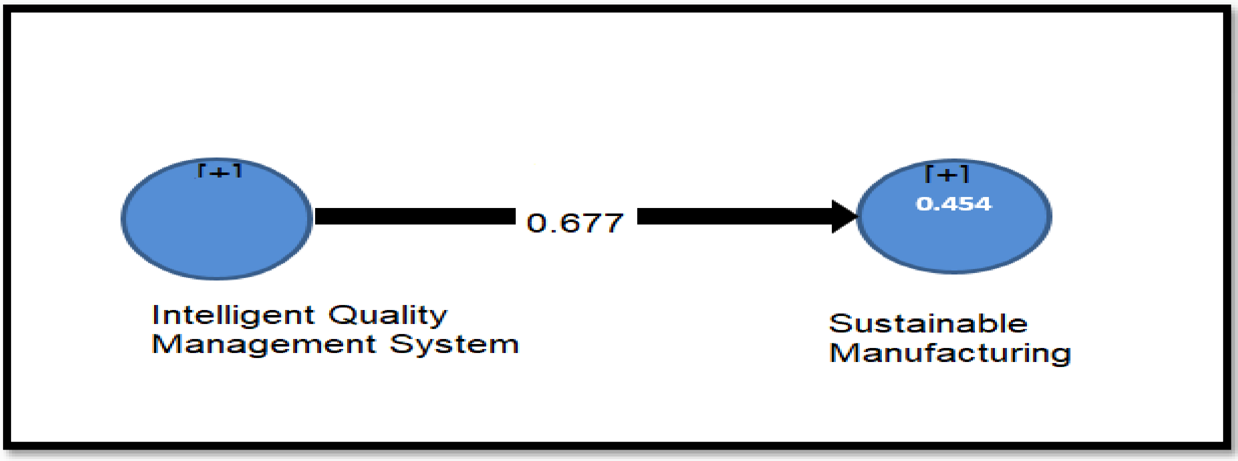

Figure 4. The Structural model of main Hypothesis

Discussion and Conclusion

This research has proposed a SEM to examine the effect of Intelligent Quality management system in sustainable manufacturing within the Iraq's manufacturing sector. The SEM supports the hypothesized relations.
Hypotheses have been tested to ensure the effect relationship between Intelligent quality management system and sustainable manufacturing (Siva, 2016:37; Gerlich & Gottschalk, 2019; Goyal et al., 2019). The results show:
First, there is direct significant effect of intelligent quality management in sustainable manufacturing, which indicates that the application of these dimensions in the plant help to achieve sustainable manufacturing, with the exception of the interactive process mining algorithm, which did not achieve the desired significant effect. Second, there is significant effect of **process data exchange module in sustainable manufacturing,** which indicates the collection of data and information on process quality requirements, categorizing and storing them in a central database so that they are available to all levels at appropriate time, lead to reducing defects, losses and the chance of process failure. Which reduces costs and enhances the economic and environmental aspect of sustainable manufacturing.
The **algorithm of interactive process mining did not achieve the required significant effect, So the third hypothesis was rejected.**
Fourth, there is a significant effect of Forward Quality Optimization Module in sustainable manufacturing. The Determining the root causes of quality problems within the workflow, and comparing the achieved product quality characteristics with the established standards; contributes to discover the gap and reduces deviations, which reduces the consumption of additional materials and more energy and positively affects sustainability. **Fifth,** there is a significant effect of **forward quality optimization Module in sustainable manufacturing,** designing

the standards of the "forward quality" according to market requirements helps to make an adjustment and evaluation of these standards from one time to another, which is positively reflected on customer and community satisfaction and enhances the social and technological aspect of sustainability. The researchers dealt with the issue of sustainable manufacturing from the environmental, social and economic aspects, and since the concept of sustainable manufacturing is still in the development stage, so there was a need to study sustainable manufacturing in an integrated framework to include technological and manufacturing aspects, especially in the field of manufacturing industry.

This study finds the Iraqi industrial sector must pay more attentions on the environmental, economic, social and technological aspects, as important factors for the success of organizations, and the need to apply the Intelligent systems and modern technologies in the factories; in order to achieve sustainable industrialization.

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