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ADDITIVE MANUFACTURING TECHNOLOGY AND SUSTAINABILITY A CASE STUDY IN IBN MAJID GENERAL INDUSTRIAL COMPANY

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Abstract

Additive manufacturing technology is one of the most important advanced manufacturing techniques, as it is one of the contemporary intellectual approaches in the field of production and operations management for its essential role in providing a set of economic, social, and environmental benefits to the organization using this technology. Hence, the current study was presented to focus on one of the advanced manufacturing techniques, which is the additive manufacturing technology, which is one of the cognitive and intellectual entrances under formation and cognitive and applied framing. Which contributes to improving the sustainability of the work of organizations. The problem of the current study was to measure the possibility of applying additive manufacturing technology in Iraqi industrial organizations and its impact on sustainability.

Key words: Sustainability, Additive Manufacturing Technology, Sustainable Organizations.

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Introduction:

Organizations today work in an industrial environment full of challenges and highly competitive. The Iraqi industrial environment is highly competitive, whether in the public or private sectors. Organizations are facing difficulty in obtaining and maintaining market share for a long time and as a result of the organizations' efforts to improve the response to requests submitted by customers more efficiently Recommended, acceleration, agility, and sustainability. Organizations seek to own advanced manufacturing technology to improve their competitiveness and improve their ability to respond to customer demands. Additive manufacturing is one of the advanced manufacturing techniques and is a rapidly developing technology that contributes to providing many advantages to several different industrial sectors providing freedom of design and environmental advantages and several other essential advantages. It essentially converts design files into fully functional products and offers many cost-effective and time-efficient ways to produce products with complex, bespoke geometric shapes and designs.

Contemporary literature in the field of production and operations management has focused on new and advanced manufacturing systems that address the requirements of sustainability and the fundamentals of sustainability (TBL). Among these advanced systems is the additive manufacturing system, which contributes to achieving many important advantages for organizations and helps them improve their competitiveness in the contemporary manufacturing environment. From the above, the problem of the study is determined by some questions, the most important of which are:

- What are the intellectual and conceptual frameworks for Additive Manufacturing Technology (AMT?)
- What are the strategic implications of additive manufacturing technology in achieving sustainability requirements in Iraqi industrial organizations?

The researchers relied on the descriptive-analytical approach, which is based on polling the opinions of the researched sample and then analyzing and interpreting the data obtained, processing and analyzing the information collected from the concerned party, which was obtained through documents and company records, and the survey form that was specifically designed to collect information from Research organization and through semi-structured personal interviews conducted by researchers at Ibn Majid General Industrial Company to contribute to the formation of a full understanding of the subject.

The current study also attempts to achieve a number of essential goals, the most important of which are the following:

Identify the mechanisms and pathways of applying additive manufacturing technology (AMT), the stages of its application, the factors that help in its successful application, and the most important challenges that prevent its application.

Study Problem

The results of the analytical review of the literature confirmed the need for business organizations to improve production and manufacturing processes with modern technologies in order to produce products of high quality, speed, reliability, and lowest costs. Among these technologies is Additive Manufacturing Technology (AMT), which appeared in 1980 and is one of the advanced manufacturing techniques that aim to reduce costs to achieve efficiency, strive towards sustainability, increase flexibility, freedom of discretion, and the ability to produce complex designs that are difficult to produce by traditional methods, as this technology contributed In enabling business organizations to produce products with designs that could not be produced before as a result of their complex designs and thus help to manufacture enterprises in general and local in particular to improve their competitiveness through the application of additive manufacturing technology.

Through field visits made by researchers at Ibn Majid Company for General Industry in Basra, as well as the results of the preliminary survey (pilot study) and based on the results of unstructured interviews conducted by researchers, it was found that there are a number of basic problems that hinder the application of additive manufacturing technology (AMT) Based on the foregoing, the study problem is determined by the following questions:

- o What are the intellectual and conceptual frameworks for Additive Manufacturing Technology (AMT)?
- o What are the strategic implications of additive manufacturing technology in achieving sustainability requirements (TBL) in Iraqi industrial organizations?
- o How can the strategic repercussions of additive manufacturing technology be evaluated in Iraqi industrial organizations?
- o What are the mechanisms for applying additive manufacturing technology in Iraqi industrial organizations?
- o What are the determinants of the application of additive manufacturing technology (AMT)?

Objectives study

The objectives of the study are summarized in the following points:

o Framing contemporary knowledge contributions in the field of additive manufacturing technology (AMT) and sustainability as one of the contemporary topics in the field of production and operations management.

o Identifying the mechanisms and pathways of applying additive manufacturing technology (AMT), the stages of its application, the factors that help in its successful application, and the most important challenges that prevent its application.

o Evaluating the strategic implications of additive manufacturing technology (AMT) in the Iraqi industrial organizations.

o Presenting a set of recommendations that contribute to improving the ability of Iraqi industrial organizations to implement Additive manufacturing technology.

o Diagnose and analyze the impact relationship between AMT and sustainability.

Study importance

The importance of the current study is summarized in two axes:

o The first axis: is the conceptual intellectual axis: The researchers attempted to present and discuss the contemporary knowledge contributions of additive manufacturing technology (AMT) and sustainability.

o The second axis: the applied axis:

This is embodied in the researcher's attempt to test and diagnose the role of additive manufacturing technology (AMT) in improving the foundations of building creative business models in the organization under study, leading to providing a set of recommendations that contribute to enabling it to understand the requirements and results of the transition to additive manufacturing technology.

Study Field

The researchers elected Ibn Majid Industrial Company as a field to test the hypothetical study model as it is the closest to the trends of additive manufacturing. At the level of manufacturing and customer service, in addition, these organizations are exposed to intense internal and external competition, which makes additive manufacturing or any other technology of increasing importance to them to help them strengthen their competitiveness.

Hypotheses Study Diagram

The following figure shows the hypothesis of the study and aims to clarify the relationship between the variables of the study, which is represented by additive manufacturing technology (AMT) as an independent variable consisting of five sub-components and IBM as a dependent variable and consists of five sub-components as well

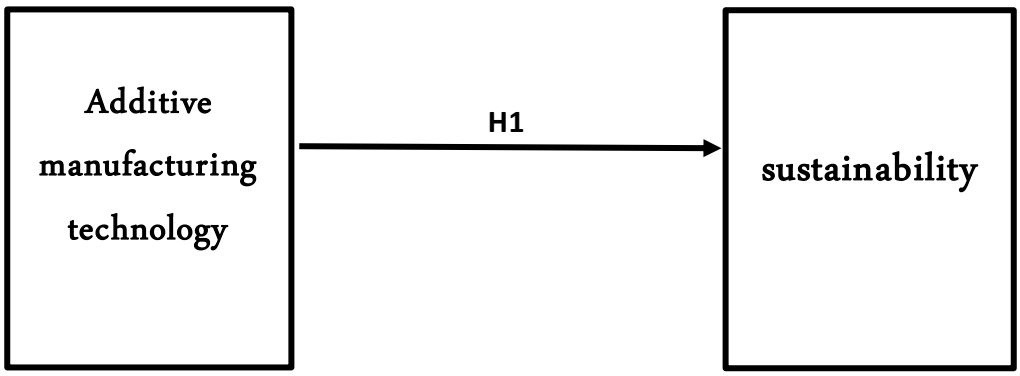

Figure 1 The hypothetical model of the research

Source: Prepared by the researcher.

Study Hypotheses

The hypothesis of the study was determined according to what was stated in the study problem and the hypothetical study scheme, and in the form of proof:

H1 The additive design technology has a statistically significant effect on improving sustainability.

Manufacturing Additive Concept

The additive manufacturing (AM) process, also known as 3D printing, is a digital technology to produce layer by layer of physical objects from a 3D computer-aided design (CAD) file. Three-dimensionality of the object in all its details and dimensions. Then, the 3D computer design file is split into 2D thin layers by a computer program. Then, the 2D layers are sent to a 3D printing machine one layer at a time. (Khajavi et.al, 2018:7) Additive manufacturing is an emerging technology according to experts and the hype around additive manufacturing will generate significant interest for manufacturing organizations in a variety of ways. of sectors. Currently, many manufacturing organizations are evaluating the possibilities of using growing manufacturing technology but do not have a clear overview of the impact and possibilities. Manufacturing organizations may not be able to translate them into tangible results because they do not have the knowledge or the mindset to find appropriate solutions that solve their problems. However, organizations cannot lean back, if so they may miss out and not recognize the potential additive manufacturing benefits that create a competitive advantage. (Haar, W., 2018:4).

According to the American Society for Testing and Materials (ASTM) additive manufacturing is defined as "the process of connecting materials to make objects from 3D model data typically layer upon layer rather than traditional manufacturing methodologies" It is a fairly fully automated process from the start to finish, requiring hardly any intervention. Manual through the process. (Solberg et.al, 2016:5) Additive manufacturing,

also known as "3D printing", is the umbrella term used to cover a variety of technologies that can directly produce complex 3D parts with almost complete design freedom. The term additive manufacturing has become widely accepted and recognized in international standards. In additive manufacturing the parts are fabricated layer by layer, using techniques such as jetting, powder sintering, or photopolymerization. Parts can be manufactured using complex and customizable geometries including parts that would be difficult to manufacture by traditional manufacturing techniques. Although still a fast-paced area of research, additive manufacturing already offers a range of manufacturing techniques capable of meeting many design criteria. (Capel, Andrew J., et al, 2013:43) Furthermore, additive manufacturing can be considered a manufacturing technology. AMT (Advanced Manufacturing Technologies) serves a wide range of users and purposes and includes any computer-based equipment used to design manufacture or control information related to the development and production of a product. There are three categories of advanced manufacturing techniques: design, management, and manufacturing. Additive manufacturing will belong to the latter category since it is primarily used to manufacture products. Additive manufacturing can also be considered a “radical manufacturing technology”: that is, manufacturing tools and techniques that have the potential to redefine an industry by disrupting existing competitive advantages, reducing the influence of organizations Existing manufacturing, and creating opportunities for new competitors to enter (van Dijk et.al, 2015:7) The literature has confirmed that AM has undergone important developments since its emergence as documented by (Charles Hull) in his patent for the year 1984.) to build parts using a photolinkable polymer. Since then many processes have been introduced, as summarized by the American Society for Testing and Materials (ASTM) which defined seven categories according to which a wide range of processes can be classified. Throughout the history of manufacturing, the design process has often been guided by the limitations of the manufacturing method. Existing free fabrication capabilities allow for a more flexible design space: Fewer design constraints provide entirely new opportunities for building and assembling objects of different length scales. Specifically, the additional complexity in product volume is now possible without negatively affecting production rate, cost, or quality. Furthermore, additive manufacturing allows simple, rapid, and economical design iterations while taking advantage of the effectiveness of non-linear design and optimization (Klein, John, et al., 2015:29).

Sustainability Business Model:

The extent to which sustainability principles will be incorporated into sustainable business models and generate impactful results from a three-fold point of view depends on the levels of ambition of decision-makers. Three strategies can be categorized to include sustainability in innovative business models: Defensive (focus on reducing risks/costs to maintain business as usual) Adaptive (focus on improving business models to reduce

impacts) and proactive (focus on entirely new designs for value logic). Proactive strategies are usually more impactful because they incorporate sustainability principles into the core logic of industrial organizations rethinking value proposition, delivery and creation systems, capturing them to maximize social and environmental benefits, not just economic profit (Pieroni et.al, 2019:200) Sustainable creative business models as adapting a business model to overcome barriers within an industrial organization and its environment to commercialize innovations in sustainable processes, products or services There are four types of sustainable creative business models: (1) Sustainable emerging organizations: creating a new organization with a sustainable business model (2) Transformation To a sustainable business model: The existing business model is changed resulting in a sustainable business model (3) Sustainable business model diversification: Without major changes to the organization's existing business models and the creation of an additional sustainable business model 4) Acquisition of a sustainable business model: An additional sustainable business model is identified acquiring and integrating it into the organization. (Geissdoerfer et.al, 2018:406) Integrating sustainability into business models requires a systematic vision that considers the global perspective and the different elements of the system and their interrelationships. Value network analysis provides such a view and can inform changes related to the business model of an industrial organization (Evans, Steve, et al, 2017:601) Business models are often viewed from the perspective of value creation that focuses on meeting customer needs, economic return, and compliance. To think about sustainability this focus is too narrow and heightens the need for a more holistic view of value that integrates social and environmental goals, to ensure a perfect balance or alignment of all stakeholder interests to deliver "sustainable value" creation. (Pedersen et.al, 2018:9) a sustainable business model as "a business model that creates a competitive advantage through superior customer value and contributes to the sustainable development of an industrial organization and society." Sustainable manufacturing and business models preserve the environment while continuing to improve the quality of human life. These sustainable business models use an industry organization-wide perspective and perspective and are based on the three-bottom approach to define the organization's purpose and measure performance, involve a wide range of stakeholders, and consider the environment and society as stakeholders. To scale this up, a sustainable business model aligns the interests of all stakeholder groups and explicitly considers the environment and society as key stakeholders. (Bocken et.al,2014:44) An organization trying to improve its sustainability performance has to change its business model no matter how incremental or radical which can be the deciding factor for success. (Schaltegger et.al, 2012:105) The very idea of an innovative business model that an industry organization can launch a new business model previously unimagined or transform an existing business model to disrupt an industry captivates business leaders and sustainability advocates alike (Clinton & Ryan , 2019:467) Innovative business models have gained a competitive advantage to improve the sustainability performance of organizations. The concept of a sustainable business model describes the rationale for how an organization can be created, delivered, and captured, in

economic, social, cultural, or other contexts, in a sustainable way. Building a sustainable business model is an innovative part of the business strategy. (Nosratabadi et.al,2019:1).

Analysis of the opinions of the researched sample of the additive manufacturing technology variable:

The results of the table (1) show the results of the preliminary statistical analysis of the study data, which shows the response of the sample to all paragraphs and dimensions of the independent variable (additive manufacturing technology), as it was relied on statistical indicators that give sufficient significance to descriptive statistics represented by (arithmetic mean, standard deviation and level of importance) Therefore, the level of response will be determined and the extent to which the values deviate from their arithmetic mean of the dimensions, paragraphs and at the total level, as well as diagnosing the level of importance for the purpose of identifying the order of each of the dimensions through which the variable was measured:

Table (1) Descriptive statistics indicators for the additive manufacturing technology variable

level of importance	SD	MEAN	default mean	MAX	MIN	N
						additive design
0.675	0.940	3.378	3.00	5.00	1.00	I1
0.660	1.130	3.304	3.00	5.00	1.00	I2
0.738	0.973	3.691	3.00	5.00	1.00	I3
0.733	1.009	3.668	3.00	5.00	1.00	I4
0.781	0.948	3.908	3.00	5.00	1.00	I5
0.583	1.020	2.917	3.00	5.00	1.00	I
0.695	**1.003**	**3.477**				
						additive Process
0.311	0.907	1.558	3.00	5.00	1.00	i7
0.498	1.202	2.493	3.00	5.00	1.00	i8
0.676	1.169	3.382	3.00	5.00	1.00	i9
0.355	1.125	1.779	3.00	5.00	1.00	i10
0.620	1.301	3.101	3.00	5.00	1.00	i11
0.413	1.186	2.069	3.00	5.00	1.00	i12

0.479	**1.148**	**2.397**				
						Additive SC
0.639	0.835	3.198	3.00	5.00	1.00	i13
0.66	0.821	3.300	3.00	5.00	1.00	i14
0.679	0.928	3.396	3.00	5.00	1.00	i15
0.669	0.960	3.346	3.00	5.00	1.00	i16
0.664	0.911	3.323	3.00	5.00	1.00	i17
0.672	0.919	3.364	3.00	5.00	1.00	i18
0.664	**0.895**	**3.321**				
						Additive IT
0.507	1.032	2.539	3.00	5.00	1.00	i19
0.594	0.971	2.972	3.00	5.00	1.00	i20
0.542	1.123	2.714	3.00	5.00	1.00	i21
0.524	1.245	2.622	3.00	5.00	1.00	i22
0.538	1.277	2.691	3.00	5.00	1.00	i23
0.676	1.133	3.382	3.00	5.00	1.00	i24
0.564	**1.130**	**2.82**				
0.574	**1.037**	**2.872**				**TOTAL**

Source: Prepared by the researcher based on the results of SPSS.V.20.

The results of the table (1) show that the independent variable (additive manufacturing technology) did not achieve an acceptable response, since the arithmetic mean achieved was less than the value of the hypothetical mean, at a rate of (2.87). The level of significance (0.574). As for the rates achieved at the level of each dimension with regard to the dimensions through which the variable was measured, the values of the statistical indicators reached as shown below:

1- The results show that the dimension (additive design) has achieved an arithmetic mean at a rate of (3.47) which is higher than the hypothetical mean, and the standard deviation value was (1.00) and at a significance level of (0.695), which made the dimension the dimension in the first order, while the response rates were With regard to each of the paragraphs, the response was acceptable, except for paragraph (I6) that did not achieve an acceptable rate as it is less than the hypothetical mean, while paragraph (I5) achieved the

highest response between the paragraphs as it achieved the highest arithmetic mean at a rate of (3.90.(

2- The level of response to the dimension (additive process) decreased, making it the last place among the other dimensions, and this is indicated by the arithmetic mean being (2.39), standard deviation (1.14), and significance level (0.479), while the response rates were rejected with regard to each paragraph of Paragraphs except for paragraph (I9) and paragraph (I11), as the value of the arithmetic mean for them exceeds the hypothetical mean.

3- The value of the arithmetic mean index of the dimension (added supply chains) increased to reach (3.32), which is higher than the hypothetical mean, with a standard deviation of (0.89) and a level of significance (0.664), which made the dimension second among the other dimensions, while the response rates were acceptable with regard to Each of the paragraphs is somewhat close, but paragraph (I15) achieved the highest response between the paragraphs, with an arithmetic mean (3.39.(

4-The (added information technology) has not yet achieved an acceptable response, since the arithmetic mean index value reached (2.82) with a standard deviation (1.13) and a significance level (0.564), which put the dimension in third place among the other dimensions, as for the response rates for each of the sub-paragraphs They were all rejected and somewhat close and did not achieve an acceptable arithmetic mean.

5- As for the last dimension (materials and machines), it also did not achieve an acceptable response, and this was indicated by the arithmetic mean value, which amounted to (2.34), as well as the standard deviation value (1.01) and the level of significance (0.496) and the dimension's arrangement was in the fourth and penultimate order. As for the response rates on the Each of the sub-paragraphs was rejected and somewhat close and did not achieve an acceptable arithmetic mean, except for paragraph (I26) and paragraph (I27), as the value of the arithmetic mean for them exceeds the hypothetical mean.

Table (2) descriptive statistics indicators for the sustainability variable

level of importance	SD	MEAN	default mean	MAX	MIN	N
			Sustainability			
0.456	1.114	2.281	3.00	5.00	1.00	i37
0.562	1.017	2.811	3.00	5.00	1.00	i38
0.585	1.016	2.926	3.00	5.00	1.00	i39
0.588	1.063	2.940	3.00	5.00	1.00	i40
0.597	1.188	2.986	3.00	5.00	1.00	i41
0.646	1.148	3.230	3.00	5.00	1.00	i42
0.572	**1.091**	**2.862**				

Source: Prepared by the researcher based on the results of SPSS.V.20.

1-The level of response to the dimension (sustainability of the business model in the company) decreased, making it the last rank among the other dimensions, and this is indicated by the arithmetic mean being (2.86), with a standard deviation of (1.09) and a level of significance (0.572), while the response rates were rejected with regard to Each of the paragraphs except for paragraph (I42), if the value of the arithmetic mean exceeds the hypothetical mean

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Conclusions and Recommendations:

1) The results of the in-depth study of literature in the field of production and operations management confirmed that the cognitive and applied overlap between additive manufacturing technology (AMT) and sustainability requirements is one of the controversial topics and problems, which is an issue of intellectual and cognitive transformation at the present time, as it is one of the contemporary issues that are still under construction and formation Theoretical, which needs many research contributions and applied studies.

2) The results of the statistical analysis showed that the Additive Design (AD) dimension (one of the five dimensions of additive manufacturing technology) has achieved the first rank in terms of relative importance in the application of the additive manufacturing technology system (AMS) in the region. Research organization, which in turn means the organization's need to develop and improve additive design techniques.

3) The Additive Supply Chain (ASC) dimension (one of the five dimensions of additive manufacturing technology) is ranked second in relative importance to the success of the AMS in a research organization, which in turn means that the organization needs to develop, improve and support its supply chains to make it Better able to meet the

requirements of applying and implementing advanced manufacturing technology in the organization.

4) The Additive Information Technology (AIT) dimension (one of the five dimensions of additive manufacturing technology) ranked third in relative importance in the success of the AMS in the research organization, which in turn means that the organization needs to focus on the use of integrated computer programs In the processes of production, design, handling and transportation to make the organization more expedited and agile in carrying out the work, completing and delivering it in the shortest time to its applicants and contributing to the meeting. Requirements for the application and implementation of additive manufacturing technology in the organization.

5) It became clear through the course of the study that contemporary organizations that seek to introduce modern and advanced technologies in manufacturing processes such as additive manufacturing technology are keen to apply the requirements of sustainability (TBL) as one of the main reasons for achieving competitive advantage..

5) The Additive Materials and Machines (AMM) dimension (one of the five dimensions of additive manufacturing technology) ranked fourth in terms of relative importance in the success of the implementation of the additive manufacturing system (AMS) in the research organization, which in turn means the organization's need to focus on using more powerful and graceful materials It can be easily remanufactured and recycled to contribute to meeting the requirements of sustainability and agility in products to contribute to meeting the requirements for the application and implementation of Additive Manufacturing Technology (AMT) in the organization.

6)After the additive process (AP) (one of the five dimensions of additive manufacturing technology), the fifth and last rank in terms of relative importance in the success of the implementation of the additive manufacturing system (AMS) in the researched organization, which in turn means the organization's need to focus on more sustainable, agile and curative production processes Efficiency and acceleration as Additive Manufacturing Technology (AMT) brings these advantages to the implementing organization.

Recommendations

The study presents a number of recommendations and proposals for the company under study in order to raise and strengthen its ability to localize additive manufacturing technology in improving Sustainability, as follows:

1)Theoretically, additive manufacturing technology is one of the latest technologies in the industry environment, as some considered it to represent the fourth industrial revolution.

2)The necessity for the company's management to seek to expand and develop the infrastructure necessary for the success of the process of gradual transformation of additive

manufacturing technology, especially since the company adopts a manufacturing on-demand (MTO) strategy for most of its industrial products and services.

3) Improving the added design system in the company by modernizing simultaneous design techniques through the effective involvement of simultaneous work teams from all disciplines to ensure an effective response to production orders and requests from customers and beneficiaries.

4) The success of the additive manufacturing system requires the company to restructure the manufacturing processes and processes by adopting cellular manufacturing plants, which in turn requires reorganizing the work stations, which contributes to accelerating the manufacturing processes and reducing the time of the production cycle.

5) Adapting and modifying the descending and rising supply chains in a way that contributes to accelerating and integrating the supply system to support the requirements of the transformation of additive manufacturing.

6) Employing cyber-information techniques to ensure the integration of the foundations of the additive manufacturing system and to facilitate the exchange and dissemination of customer and supplier information and company databases to secure the strategy of integrating the supply, design, and manufacturing operations in the company.

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