The Role Of Additive Manufacturing Technique In Supply Chain Performance By Mediation The Product Innovation

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Abstract

By utilizing the product innovation that was measured as a one-dimensional varible, the current research paper seeks to understand the role of additive manufacturing technique, which is represented by its dimensions (rapid prototyping, rapid manufacturing, and rapid tooling), in the supply chain performance, which contained four dimensions (quality, flexibility, cost, and delivery). The research was conducted as a with the main question: "What is the role of additive manufacturing technique in supply chain performance by mediating the product innovation?" The research paper also seeks to understand the nature of the correlation and influence relationships between its variables, and the questionnaire was used to collect data, which was then analyzed using statistical tools like the (arithmetic mean, standard deviation, linear correlation coefficient, simple and multiple regression coefficient), and (factor analysis). The technicians in engineering offices and medical laboratories in some Iraqi governorates completed the questionnaire and provided (192) responses. The study's conclusions were derived from the data using statistical software such as (SPSS.V.27) andb(Amos.V.26), and The connection between additive manufacturing technology and supply chain performance has increased as a result of mediation the product innovation.

Keywords: *Additive Manufacturing Technique, Product Innovation, Supply Chain Performance.*

I. INTRODUCTION

The industrial sector has developed at an accelerating pace in recent years and has become more dependent on technology and modern techniques, as contemporary industries have begun to adopt modern techniques that have affected their business environment in many ways, as manufactured products appeared with new production processes and methods that require new resources, and these technologies have provided many industries with the ability to Reducing product development costs, increasing production rates, innovation capacity, and rapid market access.

During the past few decades, the industrial sector has developed a new technique to produce innovative, highly customizable and sustainable products with a high level of complexity and technical requirements. It is called additive manufacturing technique (AMT), which can be defined as the process of producing a three-dimensional product from computer-aided design (CAD) data by combining Raw materials for this technology are put together and applied layer by layer, and this technology is characterized by the high precision of manufacturing processes, which allowed many industries to produce complex-designed products (Uriondo et al, 2015:1). In the context of the increasing digitization of production processes and their intertwining with humans, it was envisioned that it is possible to continuously generate value for organizations and customers by giving freedom to integrate creative thinking and transform it into innovative products, as these technologies provide the possibilities for manufacturing products with complex designs and allowing them to be tested before production and use. This embodies that these technologies It may generate innovations driven by the intertwining of information, knowledge and people (Gerlitz, 2015:181). In light of the complex business environment and the change in customer demands and the need for flexibility and rapid response to them, the industrial sectors seek to highlight advanced techiques in manufacturing in addition to innovations as a strategic tool to ensure good operational performance and the large investment in automation and in equipping with robots and machines to embrace more innovations and this may affect on the performance of the supply chain of these industries and their logistics services (Fatorachian & Kazemi, 2021:63). so The primary objective of the current research paper is to explain the variables that affect the relationship between additive manufacturing technique, product innovation, and supply chain performance, which this study aims to address by responding to the following query (the role of additive manufacturing technique in supply chain performance by mediating innovation the product). This main question has implicit repercussions. By presenting assumptions based on the intellectual and applied debate in previous studies, the study was able to build a conceptual and hypothetical model that frames the relationship between research variables in a way that gives it importance and adds intellectual value to studies of production and operations management and marketing management.

II. RESEARCH METHODOLOGY

1) THE RESEARCH PROBLEM

The contemporary industry environment promotes the integration of many smart techniques with production systems. Among these techniques, additive manufacturing technique plays a key role in meeting many requirements of the development of the industrial sector, responding to various challenges for the future of production, and creating more opportunities towards enhancing innovation in the product and trying to improve supply chains and because the environment The industrial industry usually generates many challenges and needs industries that are more flexible and effective in their response to the external variables that affect them. And workers and trying to find more solutions to these problems, given that this technique allows the production of three-dimensional products from a mathematical model designed with the help of a computer and converting it into a product consisting of consecutively and overlapping materials with a few steps or only one step, and this constitutes many opportunities for environments Industry However, for every opportunity, there is a challenge that this study tries to address, Basically this research primarily aims to address the question, "Is additive manufacturing technique a role in the supply chain performance by mediating the product innovation?" from which the following sub-questions emerge:-

1- Is there a clear understanding or perception of the importance of additive manufacturing technique, product innovation, supply chain performance, and what is the level of agreement and suitability of these dimensions among the technicians who working in the engineering offices and medical laboratories of the study sample?

-2What is the nature of the correlation and influence relationships between additive manufacturing technique, product innovation, and supply chain performance in engineering offices and medical laboratories, the study sample?

3- Does the role of additive manufacturing technique increase in supply chain performance by mediating the product innovation in engineering offices and medical laboratories the study population?

2) THE RESEARCH IMPORTANCE

1- The current research presents a number of topics in two important fields in the business environment, namely production and operations management and marketing management.

2- The importance of the research appears through its application of its main variables in two important fields that are considered one of the most developed and technically advanced fields within the industrial sector, which are engineering offices and medical laboratories.

3- The need to identify the impact caused by the additive manufacturing technology on the performance of the supply chain, and to define this effect for the technicians working in the engineering offices and medical laboratories who represent the study sample.

4- Provide an applied contribution that proves practically the nature of the relationship between the variables of the study (additive manufacturing technology, product innovation, and supply chain performance) in an attempt to bridge the knowledge gap between these topics.

3) RESEARCH OBJECTIVES

1- Identifying and defining the importance of the study variables (additive manufacturing technique, product innovation, and supply chain performance) in addition to revealing the level of agreement and suitability of these dimensions for technicians working in engineering offices and medical laboratories, the study sample.

2- To identify the nature of the correlation and influence relationships between additive manufacturing technique, product innovation and supply chain performance in engineering offices and medical laboratories the study population.

3- Exposing and identifying the role of additive manufacturing technique in supply chain performance by mediating the product innovation in engineering offices and medical laboratories the study population.

4) Hypothetical Study Scheme

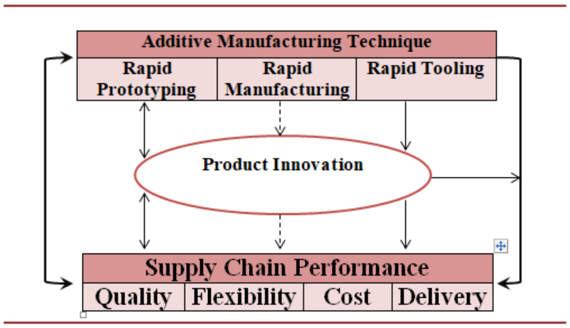
Figure 1 shows a hypothetical study outline that reflects the connection between the study's variables. As a result, the study's variables can be in the ways that follow:-

1- The independent variable: Additive manufacturing technique is represented in three dimensions (rapid prototyping, rapid manufacturing, and rapid tooling).

2- The intermediate variable: product innovation, and this is one-dimensional.

3- The dependent variable: - supply chain performance and is represented in four dimensions (Quality, Flexibility, cost, Delivery).

Figure 1 the hypothesis of the study



Source: Prepared by the Researcher

5) HYPOTHESIS OF RESEARCH

H0-1: There is a statistically significant correlation between additive manufacturing technique and product innovation.

H0_2: There is a statistically significant correlation between additive manufacturing technique and supply chain performance.

H0_3: There is a statistically significant correlation between product innovation and supply chain performance.

H0_4: There is a statistically significant effect relationship between additive manufacturing technique and product innovation.

H0_5: There is a statistically significant effect relationship of the additive manufacturing technique on supply chain performance.

H0_6: There is a statistically significant effect of product innovation on supply chain performance.

H0_7: There is a statistically significant effect relationship of the additive manufacturing technique on supply chain performance by mediating the product innovation.

III. study population and sample

The engineering offices and medical laboratories applying additive manufacturing technique (AMT), i.e. that use three-dimensional printing (3DP) in the manufacture of their products, represented the study population, They numbered (29) offices and laboratories, with (245) individuals working in them at various levels and specializations, And it was distributed (221) a questionnaire form with the same number of technical personnel who represent the study sample, and (192) valid questionnaire forms were analyzed.

First: Additive manufacturing technique

Traditionally, additive manufacturing technique (AMT) was introduced to the market as a technique in the mid-1980s, specifically in 1986 AD as a rapid prototype (RP), as (Charles Hull) invented the first 3D printer (3DP) and called it a stereoscopic printer, and over the years, models found Rapid Prototype (RP) has various applications in manufacturing such as the automotive, bioengineering, aerospace, food processing and industrial sectors. This technology has also expanded by making attempts in the field of building printing, and has slowly moved to printing complex ceramics, concrete components, plastic fixtures and fittings, nylon and other nano-products(Agenda,2017:9). And (Badiru et al,2017:4) pointed out that additive manufacturing technique , also known as or direct a 3D printing or digital manufacturing, is a process for making a physical object from a three-dimensional digital model, typically by laying down many successive thin layers of a material. And (Stevenson, 2021:257) states that additive manufacturing technology is a computer-aided design (CAD) process that involves processes that create three-dimensional products by applying successive layers of materials to form the product, and these materials can be of almost any size or shape. (Heizer et al:2020,204) refer to this technique as 3D printing and describe it as the layer-by-layer addition of raw elements while using a computer-aided design method. Plastic, metal, ceramic, glass, and even human flesh are examples of these elements. According to (Sun et al., 2022:1), this method has a special benefit in the production of complex elements that are challenging to acquire through conventional manufacturing.

Second: The importance of additive manufacturing technique

The industrial sector and the uses of creating tools and means to support production, particularly in the area of medical manufacturing and the creation of human prosthetics, have been significantly impacted by the use of additive manufacturing techniques, and the (AMT) labored to increase productivity, shorten lead periods for manufacturing, cut operating expenses, and create lightweight components (Al-makky & Mahmoud, 2016:1). And the additive manufacturing technique is crucial to an organization a number of reasons, including (Sossou et al,2018:4),(Gao et al,2015:67);-

1- almost any complicated geometric shape can be designed. This is in contrast to conventional manufacturing processes, which limit design because they require a variety of fixtures and tools and make it challenging to access hidden crevices in intricate geometric shapes.

2- The precision of the dimensions used in the computer-aided design's ultimate derivation.

3- With no need for additional tools, reinstallation, more seasoned operators, or even longer manufacturing times, it gives the creator the great ability to create intricate geometric shapes without incurring additional costs.

4- Efficiency in terms of production procedure time and cost.

Third: The Dimensions of additive manufacturing technique

1- Rapid Prototyping (RP)

The first successful attempts of the additive manufacturing technique (AMT), represented by rapid prototyping (RP), were made in the 1990s as a result of advances in laser technology and information and communication technology. Parts with limited functions were produced as visual aids for product designers, and the main benefit of this (rapid prototyping RP) is the ability to produce them very quickly from a 3D data set(Anderl et al,2017:9). (Najmon et al,2019:19) pointed out that rapid prototyping is These models enable the parameters of computer simulations of industrial parts to be verified. The majority of prototypes do not need to be manufactured from the same materials as the final products, but they still need to be sturdy and accurate enough to yield reliable test results. They are useful for identifying design flaws and openings that are only visible through the physical model. Models created by polymer-based (AMT) techniques like SLA or FDM are typically accurate enough to be tested as prototypes. Because AMT may forego relatively expensive metal-based processes, prototyping is a quick and affordable technique to assess physical characteristics and computational dynamic models. As for (Haar,2016:15) sees Finding a prototype that improves product design is one of the first applications of (AMT), which manufacturers and product developers previously believed to be a difficult, expensive, and time-consuming process that frequently hampered the stages of development and creativity while introducing a new product. Thus, the term "RP" was chosen because it was discovered that this process could be considerably accelerated.

2- Rapid Manufacturing (RM)

New application opportunities have arisen that define a second distinct classification for (AMT) techniques as they have matured in a variety of aspects such as quality, accuracy, speed, and cost. Many organizations are now effectively using additive manufacturing techniques to produce end-use or end-production components in quantities ranging from one to thousands thanks to these advancements as well as improvements in the variety of materials available (and their performance characteristics). Therefore, for this case, the designation of Rapid Manufacturing (RM) has been used (Eyers,2015:362). And (Ghazy,2012:7) indicated that rapid manufacturing is a method for using additive manufacturing to create product components or completed goods that consumers can use right away. As for (Busachi,2017:147) sees that The capacity of (AMT) to create and process complex engineering shapes designed in reasonable amounts of time and at reasonably low costs is where the term "rapid manufacturing" originated.

3- Rapid Tooling (RT)

Due to the pressures of extremely competitive markets, the industry is forced to compete effectively by reducing production times and costs while maintaining high quality goods and services. There is a lot of potential for creating one-of-a-kind products using rapid manufacturing methodologies, a word used to describe a variety of recent intelligent manufacturing techniques. When compared to traditional manufacturing techniques, these processes incorporate innovations like computer numerical control, These systems are used in tool manufacturing as well as fast prototyping and development. Rapid Tooling Technologies (RT) are new applications that shorten the time it takes for manufacturing and production procedures to reach the market, increasing competitive advantage (Afonso et al, 2019: 1). And (Whelan,2021:32) pointed out that Due to the continuing rise in demand for specialty production, there is a growing need for the cost-effective fabrication of tools capable of creating components in large numbers. It's anticipated that (AMT) will help businesses bridge the distance between the demand for new goods, which must be created as quickly and inexpensively as possible, and the associated costs and wait times required to do so. The claims state that within days of initial design, makers can effectively test components in completed materials using rapid tooling (RT) and additive manufacturing method (AMT) techniques.

Fourth: Product Innovation

Product innovation consistently boosts market share and solidifies leadership places across a range of sectors. It is a process whose effective management contributes to the success of the entire business organization while satisfying the criteria required to give the organization the capacity to transform business chances into innovative products (Trott, 2017:248). (Sinaga et al. 2021:1362) Sees that the product innovation is the introduction and creation of brand-new, high-quality products or services that stand out from the competition or cover the gaps left by older models, and the Innovation is a natural progression of creative thinking because companies can create bright ideas for the best products and services and enhance them. Innovation can be used to create a competitive edge and, as a result, improved business performance, which is crucial for both development and survival in the face of more intense competition because it is a basic need. And (Maier et al., 2019:823) defined it is launching a new, updated, or significantly enhanced good or service Product innovation by a business can take many different forms, such as developing a new product, changing the technological requirements and quality improvements made to the product, or adding new materials and useful features to already existing product components. According to (Ramadani et al., 2018:1), He categorizes product innovation into three categories: innovations in the product (providing a new or better good or service); innovations in the process (providing new ways to organize and integrate inputs into the production process); and innovations in organizational (providing new or improved organization of resources). And (Heij et al., 2020:1) recognizes that the innovation of new goods is a key indicator resulting from ongoing research and development processes that transform products into profitable and market-dominating ones.

Fifth: The importance of Product Innovation

Brands must invest in product innovation if they want to gain an advantage and prosper in the markets that are growing rapidly through offering better products and services enhances customer lives and promotes business and economic growth(Li,2021:3). according to (Kotler et al, 2020:279) the Organizations that consistently create new goods outperform non-innovation companies in terms of operating income growth and return on assets, with the latter increasing by three times as much as the former. Thus, the new product creation approach enhances the organization's chances of success and survival. As for (Agarwal, 2018:5) sees that the emergence of various new customer segments as a result of the social and cultural environment's change necessitated that organizations redirect their resources from products, distribution, and traditional communication methods to more innovative ideas, And these organizations must actively engage in the process of evolving their identity and utilizing technology to achieve this. and assert that the following three industries are those in which product invention is most crucial (Silva & Moreira, 2021:20(:-

1- Increasing organizational effectiveness and differentiation by diversifying the organization's product line.

2- Increasing sector-specific expertise while advancing technology.

3- Encourage suppliers to engage early.

Sixth: Supply Chain Performance

In order to prevent failures and missed goals, organizations have dedicated themselves more and more to assessing and monitoring their supply chain tasks, which is a crucial component of competitive advantage Because it allows the application of supply chain strategies that aid the organization in achieving its goals, supply chain performance is essential, and Finding evaluable and measurable performance components that provide input and support supply chain coherence is still difficult, though the ability to execute the best internal and external operational strategies without excluding any supply chain partners is another way that performance management boosts effectiveness (Sosa et al, 2019:69). According to (Ka et al. 2019:40) Supply Chain Performance is a framework for evaluating the effectiveness of the supply chain using potential methods that the authors and researchers have classified as a set of approaches and techniques after conducting a systematic review of the literature to achieve the supply chain's optimal performance of the participants. And (Mouhsene et al., 2019:6336) indicated to supply chain performance It is possible to define models for evaluating the supply chain relationship as a system consisting of key performance indicators in order to measure the effectiveness and efficiency of operations in order to achieve the levels of performance desired by the organization's strategy.

Seventh: Supply Chain Performance importance

Supply chain performance is essential and crucial for companies to formulate strategy, interact with it environment, and establish diagnostic control mechanisms through the performance of actual outcomes, and The following have been cited as objectives of performance measurement systems (Akyuz&Erkan,2010:5138):-

1- Establish achievement.

2- Examine whether the requirements of the customers have been fulfilled.

3- A clearer grasp of how things work.

4- Finding obstacles, issues, and chances for growth.

5- Make sensible choices.

6- Be able to progress.

7- Keep track of development.

8- Enabling more open and transparent collaboration and conversation.

And (Estampe, 2014:15) discovers that all supply chain management scholars share the three basic aims of performance systems—determining success, adhering to corporate strategies, and ensuring communication between all supply chain participants, and When making choices with a thorough strategy, systems in each situation must also take Processing chain efficiency into account. In this manner, the organization's goals must be in line with its outcomes and be assessed using objective success metrics.

Eighth: The dimensions of Supply Chain Performance

1- Quality

Quality is the ability of a good or service to meet the needs of the customer or go above and beyond the use that is meant. This idea is framed by eight qualities that can be used to define quality: Performance, features, dependability, connectedness, toughness, usability, appeal, and quality were all noted (Mitra, 2021:7). And according to (AminUllah, 2019:41) a concept known as "quality in the supply chain" integrates the system quality of the supplier, the internal system of the company, and the quality the consumer expects. Some examples of quality markers include a formal quality assurance system, continuous development, statistical process management, Six sigma limits, safe component monitoring, and inbound material quality assurance.

2- Flexibility

means being able to respond quickly to changes in customer demand volume, the variety of products or services the organization provides, changes in the features of products or services, or other variables that may be engaged in these changes, and High levels of adaptability can be a competitive benefit in a market that is changing quickly (Stevenson, 2021:42). And According to (AminUllah,2019:41). Supply chain flexibility is the capacity to respond swiftly to rapidly altering market circumstances in order to create or maintain a competitive edge. Flexibility is a performance element that takes into account how fast manufacturing firms can respond to the unique requirements of customers.

3- Cost

The cost of a framework for developing cost-based success measures for the key supply chain performance is provided by the supply chain. The supply chain can measure the performance of activities or individual operations, identify areas for further development or re-engineering, assess alternative supply chain structures or partner selection, and evaluate the effects of technological advancements, among other things through it (Lalonde&Pohlen,1996:11). Additionally, (Pettersson & Segerstedt, 2013:357) stated that The obsolete losses, transit losses, and theft losses are just a few examples of the costs included in the supply chain cost component, along with costs for order handling, packing, and wastage. These expenses are related to order handling, inventory and buy prices, distribution or transportation expenses, and storage expenses.

4- Delivery

Delivery, which entails organizing and handling the movement of products and services from the supplier through the manufacturing or service provider to the final consumer, is one of the most important roles for supply networks. Administration of the purchase, storage, and shipping are all included in delivery (Daya et al, 2019:4728). And (Choi et al., 2007:11) stated that the delivery is the time between when a consumer makes a purchase and the due date, and most delivery due date models presumptively establish each order's due date entirely externally, and the time is the date that the customer desires to obtain the items they ordered is known as the due date, which must be met , and the due date is typically flexible and the duty of the organization's marketing staff.

IV. The practical side of research

First: Coding and describing the study variables and their measures

The variables and dimensions of the study that were considered for the analysis are shown in the table (1) below in an adaptable way that makes it easier to analyze and comprehend the data and come to the conclusion that the study has accomplished its goal.

Table 1 variables and dimensions of Study, and stability factors

Variables	Cronbach's alpha variable	Dimensions	NO.	Cod	Cronbach's alpha Dimensions	Source
additive manufacturing technique	0.897	Rapid Prototyping	6	AMRP	0.887	)Eyers,2015:361(
		Rapid Manufacturing	6	AMRM	0.888	(Lianos,2019:11)
		Rapid Tooling	6	AMRT	0.893	
product innovation	0.891	One dimensional	12	PRI	0.891	(Aydin,2020:34) Alwattar,2021:45))
supply chain performance	0.899	Quality	5	SCQU	0.876	Krajewski&Mal)
		Flexibility	5	SCFL	0.887	hotra,2022:32)
		Cost	5	SCCO	0.891	
		Delivery	5	SCDE	0.893	(Miguel&Brito,2011:69)

Second: Confirmatory construct validity of additive manufacturing technique variable:

All the paragraphs of the additive manufacturing technique's variable reached saturations greater than 30% in three dimensions, as shown in table (2) below, and 18 paragraphs settled at a matching quality index that assigned the chi_square value (X2) to the freedom degree. (df). Its value is (1.240) in order to meet the necessary criterion of less than (5), with a good fit index (GFI) of 0.950 higher than (0.90), a corrected good fit index (AGFI) of 0.936 higher than (0.90), and an approximative root mean square error (RMSEA) of 0.073 higher than (0.05) and less than (0.08), demonstrating that all indicators meet the standards established by (Hair et al., 2010).

Table 2 Standard saturations for the variable of additive manufacturing technique

Path			Standard weights	Non-standard weights	S.E.	C.R.	P	Label
AMRP1	---->	Rapid Prototyping	.871	1.000				
AMRP2	---->	Rapid Prototyping	.884	1.496	.084	17.828	***	par_1
AMRP3	---->	Rapid Prototyping	.963	1.384	.063	21.838	***	par_2
AMRP4	---->	Rapid Prototyping	.984	1.363	.059	23.178	***	par_3
AMRP5	---->	Rapid Prototyping	.972	1.522	.068	22.423	***	par_4
AMRP6	---->	Rapid Prototyping	.974	1.271	.057	22.475	***	par_5
AMRM1	---->	Rapid Manufacturing	.960	1.000				
AMRM2	---->	Rapid Manufacturing	.980	1.033	.027	38.694	***	par_6
AMRM3	---->	Rapid Manufacturing	.940	.825	.028	29.450	***	par_7
AMRM4	---->	Rapid Manufacturing	.984	1.080	.027	40.122	***	par_8
AMRM5	---->	Rapid Manufacturing	.966	.890	.026	34.751	***	par_9
AMRM6	---->	Rapid Manufacturing	.936	1.054	.036	28.966	***	par_10
AMRT1	---->	Rapid Tooling	.960	1.000				
AMRT2	---->	Rapid Tooling	.979	1.121	.030	37.938	***	par_11
AMRT3	---->	Rapid Tooling	.960	1.043	.031	33.162	***	par_12
AMRT4	---->	Rapid Tooling	.982	1.153	.029	39.221	***	par_13
AMRT5	---->	Rapid Tooling	.929	1.208	.043	27.825	***	par_14
AMRT6	---->	Rapid Tooling	.954	1.093	.034	32.012	***	par_15

Third: Confirmatory construct validity of product innovation Variable

The findings show that the product innovation variable, which is a one-dimensional variable that was interpreted through (12) items to settle at a matching quality index, achieved saturations higher than 30% in every paragraph. 2.603) to meet the necessary criterion of less than (5), with a good fit index (GFI = 0.946) greater than (0.90), a corrected good fit index (AGFI = 0.922) greater than (0.90), and an approximative root mean square error index (RMSEA = (0.068) higher than (0.05) and less than (0.08), demonstrating that all indicators meet the standards established by (Hair et al., 2010). The accompanying table (3) explains this

Table 3 Standard saturations for variable of product innovation

Path			Standard weights	Non-standard weights	S.E.	C.R.	P	Label
PRI6	------->	product innovation	.986	1.000				
PRI7	------->	product innovation	.898	1.103	.042	26.352	***	par_1
PRI8	------->	product innovation	.951	.975	.026	36.925	***	par_2
PRI9	------->	product innovation	.932	.835	.026	32.549	***	par_3
PRI10	------->	product innovation	.980	1.015	.020	51.959	***	par_4
PRI11	------->	product innovation	.981	.964	.018	53.237	***	par_5
PRI12	------->	product innovation	.973	.963	.020	47.033	***	par_6
PRI5	------->	product innovation	.926	.937	.030	30.931	***	par_7
PRI4	------->	product innovation	.934	1.005	.030	33.007	***	par_8
PRI3	------->	product innovation	.938	1.018	.031	33.354	***	par_9
PRI2	------->	product innovation	.951	.902	.024	37.153	***	par_10
PRI1	------->	product innovation	.897	.798	.030	26.345	***	par_11

Fourth: Confirmatory construct validity of supply chain performance variable

The findings show that all of the paragraphs of the supply chain performance variable are characterized by four dimensions and twenty items, and they achieved saturations of over 30 percent to arrive at a matching quality index. The value of chi square (X2) was attributed to the degree of freedom (df) of (1.785) to achieve the necessary criterion less than (5), with a good fit index (GFI = 0.939) greater than (0.90), a corrected good fit index (AGFI = 0.928) greater than (0.90), and with an approximate root mean square error index (RMSEA = 0.066) higher than (0.05) and less than (0.08). this (Hair et al., 2010). The accompanying table (4) displays this

Table 4 Standard saturations for variable of supply chain performance

Path			Standard weights	Non-standard weights	S.E.	C.R.	P	Label
SCQU1	------->	Quality	.904	1.000				
SCQU2	------->	Quality	.932	1.052	.047	22.538	***	par_1
SCQU3	------->	Quality	.968	1.059	.042	25.327	***	par_2
SCQU4	------->	Quality	.970	1.084	.042	25.591	***	par_3
SCQU5	------->	Quality	.966	1.162	.046	25.042	***	par_4
SCFL1	------->	Flexibility	.975	1.000				
SCFL2	------->	Flexibility	.989	1.078	.022	50.002	***	par_5
SCFL3	------->	Flexibility	.973	.967	.023	42.134	***	par_6
SCFL4	------->	Flexibility	.982	1.141	.025	45.916	***	par_7
SCFL5	------->	Flexibility	.917	.940	.034	28.012	***	par_8
SCCO1	------->	Cost	.969	1.000				
SCCO2	------->	Cost	.982	1.103	.026	43.036	***	par_9
SCCO3	------->	Cost	.976	1.110	.027	40.533	***	par_10
SCCO4	------->	Cost	.976	1.161	.029	40.484	***	par_11
SCCO5	------->	Cost	.962	1.143	.032	35.805	***	par_12
SCDE1	------->	Delivery	.905	1.000				
SCDE2	------->	Delivery	.969	1.213	.047	25.820	***	par_13
SCDE3	------->	Delivery	.957	1.117	.046	24.542	***	par_14
SCDE4	------->	Delivery	.969	1.084	.042	25.851	***	par_15
SCDE5	------->	Delivery	.937	.939	.041	23.067	***	par_16

Fifth: Statistical description of the additive manufacturing technique variable

The responses of the study sample contained in Table (5) illustrate their understanding of the importance of the dimensions of additive manufacturing technique, as they show the interest of technicians in engineering offices and medical laboratories spread in some Iraqi governorates by applying the dimensions of additive manufacturing technique to obtain its commercial benefits for the organization by investing rapid prototypes in testing new products and investing Rapid manufacturing in accelerating production processes in addition to enhancing the capabilities of traditional manufacturing through the use of rapid tooling.

Table 5 Matrix of descriptive statistics for variable of additive manufacturing technique

S	Dimension	Arithmetic Mean	Standard deviation	Relative importance	Availability level,	Importance
1	Rapid Prototyping	4.11	0.771	82%	Available	1
2	Rapid Manufacturing	4.05	0.817	81%	Available	3
3	Rapid Tooling	4.09	0.805	82%	Available	2
Additive manufacturing technique variable						
Mean	4.08	Standard deviation	0.805	Relative importance	82%	

Sixth: Statistical description of product innovation variable

Based on the research's study results, technicians who work in engineering offices and medical laboratories deployed throughout some Iraqi governorates agreed with the product innovation variable and their relative importance it at 84%, which indicates a propensity for these workers to concentrate on introducing new products in a form that is continuing and motivating, and the following table (6) illustrates this.

Table 6 Descriptive statistics for variable of product innovation

product innovation variable					
Mean	4.21	Standard deviation	0.730	Relative importance	84%

Seventh: Statistical description of supply chain performance variable

It is clear from the responses of the study sample in Table No. (7) that the supply chain performance variable obtained the approval of the technicians working in the engineering offices and medical laboratories deployed in some Iraqi governorates to provide products with specifications that meet the expectations of customers with a quick response to their requests, reduce costs and adopt modern delivery methods that will not be the level of relative importance by (83%).

Table 7 Matrix of descriptive statistics for variable of supply chain performance

S	Dimension	Mean	Standard deviation	Relative importance	Availability level	Importance
1	Quality	4.26	0.702	85%	Available	1
2	Flexibility	4.07	0.832	81%	Available	4
3	Cost	4.09	0.874	82%	Available	3
4	Delivery	4.14	0.817	83%	Available	2
Supply chain performance variable						
Mean	4.14	Standard deviation	0.799	Relative importance	83%	

Eighth: Hypothesis testing

H0-1: There is a statistically significant correlation between additive manufacturing technique and product innovation.

It is noted from the results of Table (8) that there is a strong correlation between additive manufacturing technique and product innovation, and it was estimated strongly (0.776), and that's mean it suitable for processing, improving quality and promoting innovation in the product.

Table 8 Matrix of correlation between additive manufacturing technique and product innovation

variables	product innovation
Rapid Prototyping	0.776
Rapid Manufacturing	0762
Rapid Tooling	0.770
Additive manufacturing technique	**0.776**
****. Correlation is significant at the 0.01 level (2-tailed).**	

H0_2: There is a statistically significant correlation between additive manufacturing technique and supply chain performance.

It is noted from the results of Table (9) that there is a rather weak correlation between the additive manufacturing technique and supply chain performance, and it was estimated strongly (0.483), while the strength of the correlation between the additive manufacturing technology and the dimensions of the supply chain ranged from (0.459) for the quality dimension to (0.479) for the flexibility dimension. This means the interest of technicians working in engineering offices and medical laboratories spread in some Iraqi governorates in striving to provide products with specifications that meet or exceed customer expectations.

Table 9 Matrix of correlation between additive manufacturing technique and supply chain performance

variables	Quality	Flexibility	Cost	Delivery	Supply Chain Performance
Rapid Prototyping					
R	0.465**	0.461**	0.465**	0.471**	0.474**
Rapid Manufacturing					
R	0.451**	0.473**	0.479**	0.474**	0.479**
Rapid Tooling					
R	0.459**	0.479**	0.478**	0.478**	0.483**
Additive manufacturing technique					
R					
****. Correlation is significant at the 0.01 level (2-tailed).**					

H0_3: There is a statistically significant correlation between product innovation and supply chain performance.

It is noted from the results of Table (10) that there is a strong correlation between product innovation and supply chain performance and it was estimated strongly (0.780), while the strength of the correlation between product innovation and supply chain dimensions ranged from (0.760) for the flexibility dimension to (0.780) for the quality dimension, and this means the interest of technicians Workers in engineering offices and medical laboratories deployed in some Iraqi governorates seeking to improve the ability to respond to changes in the tastes and desires of customers.

Table 10 Matrix of correlation between product innovation and supply chain performance

variables	product innovation
Quality	0.780
Delivery	0.778
Cost	0.768
Flexibility	0.760
Supply chain performance	0.780
**. Correlation is significant at the 0.01 level (2-tailed).	

H0_4: There is a statistically significant effect relationship between additive manufacturing technique and product innovation.

It is noted from the results of Table (11) that the additive manufacturing technique model contributed to examining the amount and interpretation of the rapid prototyping dimension as a variable affecting the product innovation variable, to indicate that increasing product innovation by one unit leads to an improvement (0.909) so that technicians working in offices can Engineering and medical laboratories deployed in some Iraqi governorates to develop their capabilities towards providing high quality services by reducing the standard error rate (0.049) to the lowest possible extent and with a critical value higher than (1.96) to reach (18.551).

Table 11 Results of analyzing the effect of additive manufacturing technique on product innovation

Path			standard weights	standard error	critical value	R2	(P)
Additive manufacturing technique	⇢	product innovation	0.909	0.049	18.551	0.602	0.001

H0_5: There is a statistically significant effect relationship of the additive manufacturing technique on the performance of the supply chain.

It is noted from the results of Table (12) that the additive manufacturing technique dimensions model contributed to the interpretation of supply chain performance by (0.233), indicating that increasing the additive manufacturing technique by one unit leads to an improvement of (0.530) so that technicians working in engineering offices and medical laboratories can Deployed in some Iraqi governorates to develop their capabilities to provide products with specifications that meet customer expectations and exceed their expectations by reducing the standard error rate (0.035) to the lowest possible extent and with a critical value higher than (1.96) to reach (15.143).

Table 12 Results of analyzing the effect of additive manufacturing technique on supply chain performance

path			standard weights	standard error	critical value	R2	(P)
additive manufacturing technique	⇢	supply chain performance	0.530	0.035	15.143	0.233	0.001

H0_6: There is a statistically significant effect of product innovation on supply chain performance.

It is noted from the results of Table (13) that the product innovation model contributed to the interpretation of supply chain performance by (0.608), indicating that increasing product innovation by one unit leads to an improvement of (0.850) so that technicians working in engineering offices and medical laboratories deployed in some Iraqi governorates Encouraging a culture of innovation and innovation and presenting new ideas about products by reducing the standard error rate (0.044) to the lowest possible extent and with a critical value higher than (1.96) to reach (19.318).

Table 13 Results of analyzing the effect relationship between product innovation and supply chain performance

Path			standard weights	standard error	critical value	R2	(P)
product innovation	⇢	supply chain performance	0.850	0.044	19.318	0.608	0.001

H0_7: There is a statistically significant effect relationship of the additive manufacturing technique on supply chain performance by mediating the product innovation.

It is noted from the results of Table (14) the contribution of product innovation to improving the relationship between additive manufacturing technique (rapid prototyping, rapid manufacturing, and rapid tooling) and supply chain performance (quality, flexibility, cost, and delivery), and this indicates that the entry of product innovation as an intermediate variable Partially contributed to a positive improvement from (-0.078) to (0.696), meaning that the amount of improvement amounted to (0.618), and reduced the standard error from (0.039) to (0.007), meaning that the amount of improvement amounted to (0.032), and improved the critical value from (2).) to (99,429), pointing out that product innovation continuously develops new product features, as well as encouraging technicians working in engineering offices and medical laboratories to search for modern technologies offered by suppliers in the field of product innovation.

Table 14 Results of the effect of the mediating role of product innovation between additive manufacturing technique and supply chain performance

Path					Standard weights	standard error	critical value	regression coefficient	possibility
Without product innovation									
additive manufacturing technique	⇢	supply chain performance			-0.078	**0.039**	**2**	0.006	0.006
By the presence of product innovation									
additive manufacturing technique	⇢	product innovation	⇢	supply chain performance	0.696	0.007	99.429	0.974	0.001
The amount of improvement brought about by product innovation									

additive manufacturing technique	--->	product innovation	--->	supply chain performance	0.618	0.032	19.313	0.968	0.001

V. Conclusions and Recommendations

Conclusions

1. The results showed that there is a statistically significant correlation between additive manufacturing technique, product innovation and supply chain performance, due to the interest of the study sample in investing the capabilities of additive manufacturing technique (AMT) in identifying defects in product designs through rapid prototyping (RP) and processing them and providing products that are in line with customer expectations.

2. The existence of a direct effect relationship of the additive manufacturing technique in product innovation, as well as the existence of a direct effect relationship of product innovation in supply chain performance, which means that the study sample tends to provide high quality products with specifications that match what customers expect.

3. Existence of an indirect impact relationship of the additive manufacturing technique on supply chain performance contributes to its improvement by mediating product innovation, indicating that product innovation works to continuously develop new features of the products, which encourages the sample researched to search for modern techniques provided by suppliers, which is considered additive manufacturing technique from Most notable.

4. The clear realization of the study sample of the importance of investing additive manufacturing technique (AMT) in product innovation, as the researcher noticed that many medical laboratories specialized in the manufacture of dental molds are looking forward in the future to innovate products that fall outside their field of production specialization, such as producing (printing) organs and prosthetic limbs as an alternative to amputated limbs Or damaged by accidents such as (nose, ear), as well as many engineering offices that are looking to invest in additive manufacturing technique (AMT) in the field of construction and access to difficult corners and complex engineering designs.

5. Endeavor of engineering offices and medical laboratories that represent the study community to equip their centers with the latest 3D printers (3DP) and materials with internationally recognized standards from the best suppliers around the world, as well as their endeavor to open new distribution outlets for them in geographical areas that do not have an actual application of additive manufacturing technique (AMT) or by sending sales representatives to become more able to reach customers and potential customers, which contributes to improving supply chain performance.

Recommendations

1. The need for engineering offices and medical laboratories that are applying additive manufacturing technique (AMT), which seeks to enhance supply chain performance, to introduce innovation in the product through the development of its current products and the introduction of new features to them or the production of completely new products.

2. Increasing interest in additive manufacturing technique (AMT) as a tool to enhance product innovation and continuous improvements to its products through what this technique allows of manufacturing prototypes that simulate the final product to be manufactured and verifying customer opinions

towards the new product before commencing production.

3. Increasing the care of engineering offices and medical laboratories in searching for the latest techniques and resources offered by suppliers in the global markets, which contributes to enhancing the capabilities of these centers and supports their survival in highly competitive industrial environments.

4. The need to increase the focus of the engineering offices and medical laboratories under study on the dimensions of additive manufacturing technique (rapid prototyping, rapid manufacturing, rapid tooling) due to their importance in increasing the ability to adapt to the variables of the surrounding environment and to respond to the tastes and desires of customers.

5. Continuous striving to clarify the advantages of products manufactured with additive manufacturing technique to customers as a new technique that many customers may not trust and try to consolidate the relationship between these products and customers by showing their economic feasibility to the customer and the possibilities of their use.

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