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Diagnosing the reality of advanced manufacturing dimensions: A survey study of the opinions of workers in Badush Cement Factory in Nineveh Governorate

Ayman Mahmoud Al-Taie

Assist. Prof. Dr. Wijdan Hasan Hamoody

Administrative Technical College/
Northern Technical University

Administrative Technical College/
Northern Technical University

ayman.mahmoud@ntu.edu.iq

wijdanhassan@ntu.edu.iq

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Corresponding author:

Name: Ayman Mahmoud Al-Taie

Affiliation : Administrative Technical
College/

Email: ayman.mahmoud@ntu.edu.iq

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ABSTRACT

The current research aimed to diagnose the reality of advanced manufacturing and its dimensions (computer-aided manufacturing, computer-aided design, flexible manufacturing systems, material handling techniques) in Badush Cement Factory in Nineveh Governorate, within the framework of a research problem that reflects the availability of advanced manufacturing in the researched factory, to solve this problem a the hypothesis "The researched factory has an appropriate level of advanced manufacturing dimensions" was subjected, and to achieve the research goal a questionnaire form was adopted as a main tool for collecting data from the researched individuals consisting of (184) researchers of different functional levels, all validated responses were subjected to statistical analysis using the SPSS V.24 program. the most prominent conclusion that our research reached is the availability of dimensions at different levels in the researched factory, some recommendation was proposed to the factory, the most important of which is the need to pay attention to the advanced manufacturing approach and its expressive dimensions, to achieve the desired goals of the organization.

Keywords: Advanced manufacturing, Dimensions, Badush Cement Plant..



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Introduction: Amid rapid technological advancements, advanced manufacturing has become the cornerstone of industrial excellence. Badush Cement Factory stands as one of the leading entities in the cement industry, both locally and internationally. It continually strives to keep pace with technical and technological developments to ensure sustainability, excellence, and competitiveness in the market. Advanced manufacturing—encompassing computer-aided manufacturing, computer-aided design, flexible manufacturing systems, and material handling techniques—plays a crucial role in overcoming challenges in an increasingly dynamic environment. This necessitates a deep understanding of modern technologies, enabling organizations to enhance their production processes; this research is structured into four sections: the first outlines the research methodology, the second explores the theoretical framework, the third focuses on the practical aspect, and the fourth presents the conclusions and recommendation

Chapter One: Study Methodology

1. The study problem:

The research problem stems from the challenges industrial organizations face in an environment of rapidly evolving technology. Through field visits conducted by the researchers, it became evident that there is a critical need to understand advanced manufacturing by assessing the extent to which its key dimensions are present in the laboratory under study. This issue is encapsulated in the central research question: "To what extent are the dimensions of advanced manufacturing available in the laboratory under study?"

2. Importance of the Research

The significance of this research is highlighted through the following points first It contributes to the theoretical understanding of the advanced manufacturing approach while also offering a practical assessment of its dimensions within the studied laboratory and secondly it aims to evaluate the level of acceptance for implementing advanced manufacturing dimensions in the laboratory, ensuring its ability to maintain a competitive edge in technology and industrial progress.

3. Research Objectives

The study aims to achieve the following objectives:

- Assess the extent to which the dimensions of advanced manufacturing are present in the laboratory under study.
- Provide conclusions and recommendations to enhance workers' awareness of the importance of advanced manufacturing in the laboratory.

4. Research Hypothesis

This research is based on the hypothesis that the dimensions of advanced manufacturing—computer-aided manufacturing, computer-aided design, flexible manufacturing systems, and material handling technologies—are available at a macro level in Badush Cement Factory, located in Nineveh Governorate.

5. Research Boundaries

- Spatial Boundaries: The study focuses on Badush Cement Factory in Nineveh Governorate.
- Time Frame: The research was conducted between December 15, 2024, and January 20, 2025.

6. Research Population and Sample

The research population consists of employees working at Badush Cement Factory in Nineveh Governorate, totalling 460 individuals. A random sample of 210 employees was selected, and 184 valid questionnaire responses were retrieved for statistical analysis.

Table (1) Number and percentage of questionnaires distributed to the research sample

Community size	Number of distributed forms	Number of forms Valid form for analysis	
		number	%
460	210	184	88

Source: Prepared by the researchers

Section Two: The Theoretical Aspect

First: The concept of advanced manufacturing

Advanced manufacturing technology is a broad term that encompasses automated production technology, computer-aided manufacturing and design systems (CAM/CAD), flexible manufacturing systems, robotics, total quality control, and advancements in production management. These advancements include material requirements planning (MRP), manufacturing resource planning (MRP II), and just-in-time (JIT) production systems, which represent key developments in modern manufacturing (Boniface et al., 2013, 90).

(Brocal et al., 2019,32) define advanced manufacturing as a set of activities that integrate information, automation, computing, software, sensing, and networks, along with advanced materials and emerging capabilities from the physical and biological sciences while (Musebe, 2024, 95) describes it as a broad range of planning, design, and manufacturing techniques aimed at reducing costs, improving product quality, and enhancing performance in manufacturing organizations. Similarly, (Rajkumar et al., 2025,562) and other researchers agree that advanced manufacturing is an approach that relies on extensive computer and information technology integration, combined with a highly skilled and innovative workforce. This system enables the efficient and flexible production of a diverse mix of products in various sizes, ensuring rapid response to customer demands.

Second: Advanced manufacturing technologies

Advanced manufacturing technologies enhance industrial performance, reduce associated risks, and improve the effectiveness of industrial organizations. They enable industries to meet global demand more efficiently while accelerating manufacturing processes (Qing-Yuan et al., 2022, 89). These technologies include:

1. 3D Printing

Also known as additive manufacturing, 3D printing involves building three-dimensional objects layer by layer using digital design data (Huang et al., 2015, 1). It offers significant advantages in producing complex parts with high precision (Ngo et al., 2018, 173). One of its key benefits is the ability to create intricate internal features with high curvature, which reduces material waste and potential damage. Additionally, it provides the flexibility to manufacture multiple components using a shared raw material, allowing seamless integration of diverse materials (Mondal et al., 2024, 3).

2. Artificial Intelligence (AI)

AI is a rapidly advancing technology that is transforming various industries, driving a shift toward sustainable profitability (Hendar et al., 2020, 231). Jaber (2022, 310) defines AI as a branch of computer science that enables computers to simulate human behavior, assisting in scientific and technological advancements. AI enhances decision-making by solving complex tasks that require intensive knowledge, developing machines capable of performing human-like tasks, and creating self-learning systems. Furthermore, AI contributes to logistics optimization, material monitoring, and real-time tracking, improving overall operational efficiency (Fang et al., 2023, 1960).

3. Robots

Modern robots are self-controlled, programmable technological devices composed of electronic and mechanical components. To be classified as a robot, a machine must possess sensory capabilities, including the ability to detect light, sound, color, and location (Çaka, 2022, 180).

According to (Alqudsi & Makaraci, 2025,1), robotics technology has advanced significantly, equipping robots with unique capabilities and advantages, such as high-speed maneuverability, efficient coverage of large areas, interaction with other robots and their environment, adaptation inspired by biological organisms, and multitasking, scalability, durability, and adaptability; These advancements make robots indispensable in modern industries, enhancing automation, efficiency, and flexibility.

4. Internet of Things (IoT)

The Internet of Things (IoT) is a versatile system that enables the collaborative execution of complex tasks requiring advanced insights (Laghari et al., 2021,3). It represents a network of smart, interconnected elements that can enhance, transform, and optimize various aspects of life (Karthik et al., 2023, 344).

Artificial intelligence (AI) plays a crucial role in enhancing IoT systems by enabling:

- Data analysis
- Automated decision-making
- Process automation
- Improved security

This integration has driven remarkable advancements in several fields, including:

- Smart homes
- Healthcare
- Computing systems
- Industries
- Agriculture
- Education

As research on IoT continues to evolve, we can expect even more advanced and intelligent applications, further accelerating digital transformation and societal growth (Ezam et al., 2024, 157) and (Padhiary, 2025, 109) highlights that IoT technology introduces innovative learning methods through the integration of sensors and industrial machines, enhancing productivity, efficiency, and sustainability across various sectors.

Third: Dimensions of advanced manufacturing

1. Computer-Aided Manufacturing (CAM)

Computer-aided manufacturing (CAM) technologies have become increasingly essential in modern industries, particularly in the automotive, aerospace, and marine sectors. This technology significantly enhances the productivity of engineers and researchers while enabling them to achieve higher levels of performance in their research and development activities (Kyratsis et al., 2020, 1). The importance of CAM lies in its ability to optimize the workflow of automated tools in the manufacturing process, which is crucial for the successful production of high-quality parts (Feldhausen et al., 2022, 1). Additionally, CAM simplifies manufacturing workflows, improving efficiency and reducing production time (Stamenković et al., 2021, 1-2). (Hul, 2012, 7) and (Rasul, 2016, 465) highlight several key advantages of CAM, including:

- ❖ Lower production costs across the manufacturing process.
- ❖ Minimized wasted time and elimination of inefficiencies.
- ❖ Enhanced product accuracy and quality through precision engineering.
- ❖ Reduced human effort, leading to improved automation and efficiency

2-Computer-Aided Design (CAD)

The primary goal of automating the analytical stages of design is to ensure that parts and assemblies function as intended while adhering to design standards. CAD software enables the creation of computer models of parts, allows for their assembly and performance simulation, and facilitates expert evaluations to determine whether modifications are necessary (Saini, 2023, 1874). Computer-aided design (CAD) and computer-aided manufacturing (CAM) systems have transformed the modern manufacturing sector, improving production accuracy and consistency. CAD software allows designers to create, edit, and refine their designs using advanced computational tools, while also providing high-resolution graphics for precise visualization (Erdirinler & Koç, 2024, 86). (Okpala et al., 2020, 2) and (Khadka et al., 2023, 298) highlight several key advantages of CAD, including:

- ❖ High-precision drawing and design of product components.
- ❖ Significant time savings by expediting the drafting process.

- ❖ Reduction in manual procedures, streamlining the design workflow.
- ❖ Easy modification and adjustment of designs to meet performance and aesthetic standards.

3. Flexible Manufacturing Systems (FMS)

Flexible manufacturing is a systematic process aimed at eliminating all non-value-adding activities and practices, ensuring that only what is essential from the customer's perspective remains (Schroeder & Goldstein, 2018, 114). Recently, flexible manufacturing systems (FMS) have become a focal point in the manufacturing sector due to their exceptional ability to adapt to dynamic production demands. These systems enhance efficiency and productivity by seamlessly integrating machines, equipment, and computer-controlled systems to automate manufacturing processes. Their key advantage lies in their ability to rapidly reconfigure operations, allowing for the production of a variety of product groups without significant downtime. The importance of FMS is evident in its role in improving overall system efficiency, identifying areas for enhancement, and guiding informed decision-making in system design and operations (Bianchi et al., 2024, 1).

4. Material Handling Technologies

With the ever-growing and diverse demand for products in the manufacturing industry, the need for highly flexible and efficient material handling systems has become critical (Heragu & Ekren, 2009, 2). Automated handling technologies serve as a cornerstone of modern manufacturing, optimizing the movement and management of materials across production lines (Azizi et al., 2018, 186). Material handling is a crucial aspect of manufacturing organizations, encompassing various functions such as transportation, storage, monitoring, protection, packaging, and distribution (Zubair et al., 2019, 235; Soufi et al., 2022, 2). According to (Bianchi et al., 2024, 1-2), material handling technologies are widely used across multiple industries, including:

- ❖ Manufacturing: Ensuring smooth feeding of parts and their precise positioning on assembly lines, thereby enhancing production efficiency and accuracy.
- ❖ Logistics: Streamlining sorting, routing, and stacking of packages, significantly improving the speed and accuracy of handling operations.
- ❖ Biomedicine: Enabling the manipulation of delicate and microscopic biological samples, making them essential in medical research and healthcare applications.

The third section: The practical aspect

This section presents a detailed description and diagnosis of the advanced manufacturing variable, analyzing its key dimensions based on respondents' answers. The analysis evaluates each dimension through the responses collected, offering insights into how each aspect of advanced manufacturing is perceived and implemented. The following is a breakdown of the respondents' perspectives on the variables that define advanced manufacturing:

1-Computer-Aided Manufacturing

The data in Table (2) indicates a strong agreement among respondents regarding the computer-aided manufacturing dimension (statements X11–X14). The overall agreement rate

("strongly agree" and "agree") reached 77.85%, reflecting a predominantly positive perception based on the five-point Likert scale. Meanwhile, the overall disagreement rate ("disagree" and "strongly disagree") was 4.35%, while 17.80% of respondents remained neutral. The arithmetic mean for this dimension was 4.04, with a standard deviation of 0.89, and the relative importance rate was 80.70%, indicating a high level of importance attributed to this factor by respondents. At the individual level, paragraph (X11)—which assesses the factory management’s efforts to reduce costs through manufacturing processes—received the highest relative importance at 82.80%, with an arithmetic mean of 4.14 and a standard deviation of 0.74. Conversely, paragraph (X14)—which examines the factory’s adoption of low storage rates—had the lowest relative importance at 76.40%, with an arithmetic mean of 3.82 and a standard deviation of 0.82.

Table (2) Frequency distributions, arithmetic means, standard deviations, and relative importance of the dimension of computer-aided manufacturing

Paragraphs	Response scale										Arithmetic mean	Standard deviation	relative importance	Paragraph order
	I Strongly agree (5)		I agree (4)		Not sure (3)		I disagree (2)		strongly disagree (1)					
	number	%	number	%	Number	%	number	%	number	%				
X11	67	36.41	88	47.83	22	11.96	2	1.09	5	2.72	4.14	0.74	82.80	1
X12	64	34.78	91	49.46	24	13.04	1	0.54	4	2.17	4.14	1.13	82.80	2
X13	64	34.78	76	41.30	36	19.57	4	2.17	4	2.17	4.04	0.86	80.80	3
X14	41	22.28	82	44.57	49	26.63	11	5.98	1	0.54	3.82	0.82	76.40	4
Overall average		32.06		45.79		17.80		2.45		1.90	4.04	0.89	80.70	
the total	77.85		17.80		4.35									

Source: Prepared by the researchers based on the outputs of the (SPSS V.26) program n=184

2. Computer-Aided Design

The data in Table (3) indicates a strong agreement among respondents regarding the computer-aided design dimension (statements X21–X24). The overall agreement rate ("strongly agree" and "agree") reached 76.22%, suggesting a generally positive perception based on the five-point Likert scale. In contrast, the disagreement rate ("disagree" and "strongly disagree") was 3.26%, while 20.52% of respondents remained neutral.

The arithmetic mean for this dimension was 3.98, with a standard deviation of 0.89, and the relative importance rate was 79.55%, indicating a high level of importance attributed to this factor by respondents. At the individual level, paragraph (X21)—which assesses the laboratory management’s ability to protect data and designs from theft or misuse—received the highest relative importance at 82.20%, with an arithmetic mean of 4.11 and a standard deviation of 0.74. Conversely, paragraph (X23)—which evaluates the flexibility and diversity of the design process compared to manual methods—had the lowest relative importance at 77.60%, with an arithmetic mean of 3.88 and a standard deviation of 0.86.

Table (3) Frequency distributions, arithmetic means, standard deviations and relative importance of the computer-aided design dimension

Paragraphs	Response scale										Arithmetic mean	Standard deviation	relative importance	Paragraph order
	I Strongly agree (5)		I agree (4)		Not sure (3)		I disagree (2)		strongly disagree (1)					
	number	%	number	%	Number	%	Number	%	number	%				
X21	67	36.41	79	42.93	32	17.39	3	1.63	3	1.63	4.11	0.74	82.20	1
X22	44	23.91	96	52.17	38	20.65	3	1.63	3	1.63	3.95	1.13	79.00	3
X23	39	21.20	92	50.00	46	25.00	5	2.72	2	1.09	3.88	0.86	77.60	4
X24	42	22.83	102	55.43	35	19.02	2	1.09	3	1.63	3.97	0.82	79.40	2
Overall average		26.08		50.14		20.52		1.77		1.49	3.98	0.89	79.55	
the total	76.22				20.52		3.26							

Source: Prepared by the researchers based on the outputs of the (SPSS V.26) program, n= 184

3. Flexible Manufacturing Systems

The results from Table (4) indicate a high level of agreement among respondents regarding the flexible manufacturing systems dimension (statements X31–X34). The overall agreement rate ("strongly agree" and "agree") reached 76.22%, suggesting a positive perception based on the five-point Likert scale. Conversely, the disagreement rate ("disagree" and "strongly disagree") was 3.53%, while 20.24% of respondents remained neutral. The arithmetic mean for this dimension was 3.98, with a standard deviation of 0.89, and the relative importance rate stood at 79.70%, indicating a strong significance attributed to this factor by respondents. At the individual level, paragraph (X31)—which assesses the factory management’s efforts to reduce production cycle time and ensure timely delivery through manufacturing flexibility—received the highest relative importance at 81.00%, with an arithmetic mean of 4.05 and a standard deviation of 0.74. Meanwhile, paragraph (X32)—which evaluates the factory management’s objective of governing sales growth to increase market share—had the lowest relative importance at 78.80%, with an arithmetic mean of 3.94 and a standard deviation of 1.13.

Table (4) Frequency distributions, arithmetic means, standard deviations and relative importance of the flexible manufacturing systems dimension

Paragraphs	Response scale										Arithmetic mean	Standard deviation	relative importance	Paragraph order
	I Strongly agree (5)		I agree (4)		Not sure (3)		I disagree (2)		strongly disagree (1)					
	number	%	number	%	Number	%	Number	%	number	%				
X31	53	28.80	94	51.09	32	17.39	3	1.63	2	1.09	4.05	0.74	81.00	1
X32	41	22.28	97	52.72	41	22.28	4	2.17	1	0.54	3.94	1.13	78.80	4

X33	45	24.46	92	50.00	42	22.83	4	2.17	1	0.54	3.96	0.86	79.20	3
X34	55	29.89	84	45.65	34	18.48	10	5.43	1	0.54	3.99	0.82	79.80	2
Overall average		26.36		49.86		20.24		2.85		0.68	3.98	0.89	79.70	
the total	76.22				20.24		3.53							

Source: Prepared by the researchers based on the outputs of the (SPSS V.26) program n=184

4- Material Handling Techniques:

The results presented in Table (5) show a general agreement among the surveyed individuals regarding the Material Handling Techniques dimension (statements X41-X44). Specifically, the agreement rate for responses marked as "strongly agree" or "agree" was 80.30%. This indicates a positive tendency in the surveyed individuals' opinions based on the five-point Likert scale. The overall disagreement rate for the same dimension was 2.45%, while 17.25% of responses were marked as "unsure." The arithmetic mean for this dimension was 4.06, with a standard deviation of 0.89. The relative importance of the Material Handling Techniques dimension is 81.20%, reflecting a strong level of agreement among the respondents based on their personal views. At the item level, statement X41, which addresses the laboratory management's efforts to adopt material handling techniques that simplify workflow, received the highest relative importance of 83.40%, with an arithmetic mean of 4.17 and a standard deviation of 0.74. In contrast, statement X44, which focuses on laboratory management's efforts to optimize space utilization, had the lowest relative importance of 78.40%, with an arithmetic mean of 3.92 and a standard deviation of 0.82.

Table (5) Frequency distributions, arithmetic means, standard deviations and relative importance of the dimension of material handling techniques

Paragraphs	Response scale										Arithmetic mean	Standard deviation	relative importance	Paragraph order
	I Strongly agree (5)		I agree (4)		Not sure (3)		I disagree (2)		strongly disagree (1)					
	number	%	number	%	number	%	Number	%	number	%				
X41	61	33.15	98	53.26	22	11.96	1	0.54	2	1.09	4.17	0.74	83.40	1
X42	52	28.26	92	50.00	37	20.11	2	1.09	1	0.54	4.04	1.13	80.80	3
X43	59	32.07	90	48.91	31	16.85	3	1.63	1	0.54	4.10	0.86	82.00	2
X44	41	22.28	98	53.26	37	20.11	6	3.26	2	1.09	3.92	0.82	78.40	4
Overall average		28.94		51.36		17.25		1.63		0.82	4.06	0.89	81.20	
the total	80.30				17.25		2.45							

Source: Prepared by the researchers based on the outputs of the (SPSS V.26) program n=184

Based on the information above, it can be concluded that all answers for the dimensions of the advanced manufacturing variable were above the hypothetical arithmetic mean of 3. Table (6) presents the relative importance of the advanced manufacturing dimensions from the perspective of a sample of workers at Badush Cement Factory in Nineveh Governorate. By examining the arithmetic means, standard deviations, and relative importance values, it is

evident that the most important dimension of the advanced manufacturing variable, according to the workers' experience, is material handling techniques. This is supported by the arithmetic mean of 4.06, a standard deviation of 0.89, and a relative importance of 81.20%. The second most important dimension, in terms of relative importance, is computer-aided manufacturing, with an arithmetic mean of 4.04, a standard deviation of 0.89, and a relative importance of 80.70%. The third-ranking dimension is flexible manufacturing systems, with an arithmetic mean of 3.98, a standard deviation of 0.89, and a relative importance of 79.70%. The least important dimension is computer-aided design, with an arithmetic mean of 3.98, a standard deviation of 0.89, and a relative importance of 79.55%.

Table (6) Relative importance of advanced manufacturing dimensions

No.	The fourth	Arithmetic mean	Standard deviation	relative importance	Arrangement
1	computer-aided manufacturing	4.04	0.89	80.70	second
2	Computer-aided design	3.98	0.89	79.55	Fourth
3	Flexible Manufacturing Systems	3.98	0.89	79.70	third
4	Material Handling Techniques	4.06	0.89	81.20	first

Source: Prepared by the researchers based on the outputs of the (SPSS V.26) program n=184

Section Four: Conclusions and Recommendations

Conclusions:

1. Most respondents agreed that the dimension of material handling technologies ranked first, indicating that the adoption of this technology contributes significantly to the implementation of advanced manufacturing, thereby enhancing production efficiency and accuracy at Badush Cement Factory.
2. There was agreement among respondents that the dimension of computer-aided manufacturing ranked second, reflecting its importance in the adoption of advanced manufacturing at Badush Cement Factory, particularly for its role in improving manufacturing system efficiency.
3. The respondents' opinions indicated that the dimension of flexible manufacturing systems ranked third, highlighting its contribution to the advanced manufacturing approach at Badush Cement Factory by enabling adaptation to changing production requirements.
4. The respondents' agreement on the dimension of computer-aided design showed that it ranked last, suggesting that Badush Cement Factory focuses on implementing the core dimensions of advanced manufacturing, including design technologies that facilitate editing, improving, adjusting designs, and generating high-resolution drawings.

5. The adoption of advanced manufacturing leads to increased productivity, efficiency, and high quality, while also reducing risk in the studied factory.

Recommendation :

1. It is essential for the management of Badush Cement Factory to enhance the adoption of advanced manufacturing dimensions in the manufacturing process, especially in light of global developments, globalization, and the need to open up to international markets in order to meet customer demands.
2. The factory should benefit from other production organizations in the same industry by learning about the latest manufacturing methods and drawing on their experiences to foster creativity and excellence in the industrial sector.
3. It is crucial for the management of Badush Cement Factory to strive to stay up-to-date with global developments and modern technologies in the cement industry.

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