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THE IMPACT OF ARTIFICIAL INTELLIGENCE ON MANUFACTURING FLEXIBILITY: AN ANALYTICAL STUDY OF THE GENERAL COMPANY FOR AUTOMOTIVE AND EQUIPMENT MANUFACTURING IN IRAQ

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ABSTRACT

This research seeks to highlight the smart technologies available at the General Company for Car and Equipment Manufacturing and to demonstrate the extent of their deployment in the manufacturing sector. To achieve this goal, a virtual model was designed to reflect the impact of artificial intelligence on manufacturing flexibility and its different dimensions, which are machine flexibility, volume flexibility, and handling flexibility. Based on this model, a set of main and sub-hypotheses were formulated to test the nature of the relationship between the study variables. The research adopted the descriptive-analytical approach and used a questionnaire as the main tool for data collection. An electronic questionnaire was distributed to a purposive sample consisting of (23) individuals from experienced leaders and engineers at the General Company for Car and Equipment Manufacturing in Alexandria (the research field). For data analysis, a number of statistical methods were employed, including Cronbach's alpha coefficient to measure reliability, the arithmetic mean, standard deviation, in addition to simple linear regression analysis to test the hypotheses. The research arrived at a set of results, the most prominent of which is the existence of a positive impact of artificial intelligence on manufacturing flexibility in general, with a strong impact appearing in handling flexibility, compared to a weaker impact on both machine flexibility and volume flexibility.

INTRODUCTION

The importance of technology application is increasing in various fields, and among these fields is the impact of artificial intelligence on manufacturing flexibility. The automotive industry is one of the sectors that greatly benefits from the application of smart technologies to enhance its efficiency and improve the quality of its products. In this context, our research aims to study the impact of artificial intelligence on manufacturing flexibility in the General Company for Automotive Industry in Iraq, specifically in the city of Alexandria.

This research will focus on three main aspects of manufacturing flexibility: machine flexibility, volume flexibility, and material handling flexibility. We will analyze the variable of flexibility and its related dimensions, and how they are affected by artificial intelligence in terms of efficiency in production processes.

Through this research, we will seek to understand how smart technologies, such as artificial intelligence, can be used to improve manufacturing flexibility and increase the company's ability to adapt to changing challenges in the automotive market. This will help in directing efforts towards improving processes and enhancing competitive advantage. The research includes four chapters: methodology, theoretical framework, practical framework, and conclusions and recommendations.

1. RESEARCH PROBLEM

As technology advances and artificial intelligence becomes widespread in the manufacturing sector, business organizations, especially [specify what kind of companies, e.g., SMEs or automotive manufacturers], have begun to leverage smart technologies to enhance their manufacturing processes and make them more flexible. Nonetheless, the application of artificial intelligence to gain manufacturing flexibility has numerous challenges to such companies as [high costs, skill gaps, data security concerns]. The analyzed firm is not an exception. Thus, the issue needs to be thoroughly researched to learn how artificial intelligence influences the flexibility of manufacturing and what challenges can be expected by the companies when implementing the use of these modern technologies. In order to explore the origins of the issue and solve these problems, the following questions are developed:

(0) Does the company in question implement artificial intelligence systems and applications into the field of work?

- Does artificial intelligence have an effect on manufacturing flexibility?
- Do we have any weaknesses that prevent this technology to be implemented properly?

2. IMPORTANCE OF RESEARCH

The subjects of artificial intelligence and enterprises possessing manufacturing adaptability are regarded as current and engaging themes within the domain of modern management concepts. Whether at the scholarly theoretical plane or practical execution, there is persistent discourse and conversation concerning these dual matters. Moreover, advancements and novelties in the area of artificial intelligence and organizations with production adaptability are constant and ceaseless. Thus, examining these two topics and connecting them is of considerable import from the perspective of researchers. The importance of the investigation encompasses the ensuing facets:

- The analysis assists in illuminating the extant clever technologies within the firm and the degree of their utilization in the realm of production.
- The work aids in broadening comprehension regarding the effect of artificial intelligence upon manufacturing agility.

- The conclusions derived from the research may help foster technical progress and enhance production methods.

Research Objectives

Based on the problem questions raised, the main objectives of the research can be identified as follows:

- Determine the extent to which the company under study relies on artificial intelligence systems and applications in its field of work.
- Identify the extent of the impact of artificial intelligence on the manufacturing flexibility of the company under study.
- Reveal potential weaknesses in the field of its application.

3. HYPOTHETICAL RESEARCH FRAMEWORK

Systematic processing requires designing a hypothetical framework that defines the relationships and influences between the research variables to provide a clear and expressive picture of the research idea that the study is trying to reach. Figure (1) illustrates the hypothetical research framework.

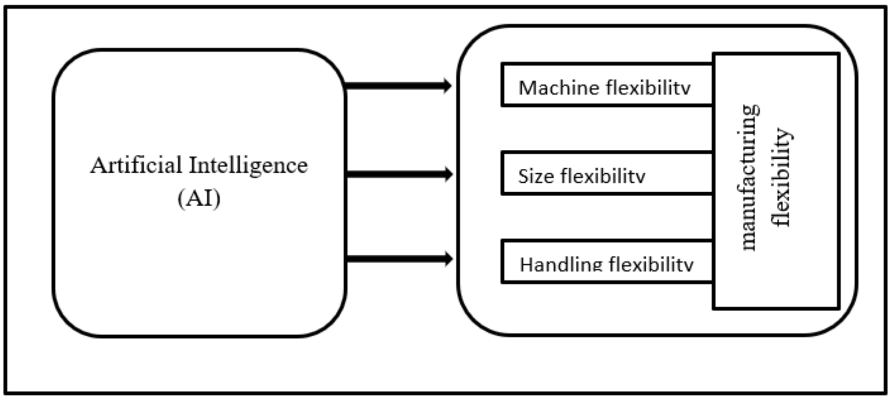

***Figure (1)** Hypothetical research chart*

Research Hypotheses

Based on the research questions, objectives, and its planned hypothesis, the main hypothesis is formulated as follows:

3.1.1. Main Hypothesis: There is a significant meaningful impact of artificial intelligence on manufacturing flexibility. This main hypothesis branches into the following sub-hypotheses:

- Sub-Hypothesis 1: There is a statistically significant impact of artificial intelligence on machine flexibility.
- Sub-Hypothesis 2: There is a statistically significant impact of artificial intelligence on volume flexibility.
- Sub-Hypothesis 3: There is a statistically significant impact of artificial intelligence on handling flexibility.

4. RESEARCH POPULATION AND SAMPLE

The research community included all employees of the General Company for Automotive and Equipment Industry in Iraq, which comprises approximately 175 employees. A purposive sample was selected from this community, representing the management and engineers working in the factory, with a total of 23 individuals, to represent them and survey their opinions on the level of the company's interest in the research variables. The number of retrieved questionnaire forms after distributing them to all members of the community was 23 valid survey forms, which represents 100% of the total research sample.

5. RESEARCH TOOL

The survey was used as a primary tool to collect data about the research problem. It included two dimensions: the first dimension represented personal information (social gender, age, educational qualification, years of service), while the second dimension consisted of questions related to research variables. It included 20 items formulated according to a five-point Likert scale. Table 1 illustrates the variables, the number of items for each variable, and the sources used to construct these items.

Table (1): *Questionnaire Construction Scale*

Main variables	number of items	source of scale
Artificial Intelligence	10	(Ajam, 2018)
Manufacturing flexibility	10	(Sultan, 2015) (Purwanto et al,2015)
Total	20	

Source: *Prepared by the researchers based on the sources mentioned in the table.*

6. STATISTICAL METHODS USED

The researchers relied on a set of statistical methods and measures to analyze the data, as follows:

- Cronbach's Alpha Test: To determine the reliability of the questionnaire items.
- Percentage: A mathematical method used to compare two or more quantities of the same type and equals the quotient of the part divided by the whole multiplied by 100%.
- Weighted Mean: To measure the level of responses of the sample and to know the level of the variables in order to conduct analysis and comparison.
- Standard Deviation: To know the level of dispersion in the sample responses.
- Simple Linear Regression analysis: To measure the effect of the independent variable on the dependent variable

7. CONCEPT AND DEFINITIONS OF ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) is an area of computer science that seeks to create software and apparatus able to mimic human conduct and intellect. It covers diverse domains such as games, sophisticated apparatus, neural networks, language handling, and robotics. Its inception dates to 1951 when the Ferranti Mark I at the University of Manchester generated the initial AI application for playing chess (Singh, 2019: 566-567).

AI is a fairly recent domain that involves coding computers to play games, comprehend and react to natural language, replicate neural networks similar to those present in people, and display responsiveness (hearing, sight, motion, and engagement with the setting) comparable to humans (robots) (al-qahtani, 2019: 1). It concentrates on formulating novel programming techniques intended to allow computers to execute responsibilities and reach judgments that progressively approach human capacities (Saleh, 2009: 34).

The initial application of the phrase "artificial intelligence" is credited to John McCarthy in 1956 at a scientific gathering at Dartmouth University. He described AI as the discipline of designing intelligent machines, especially computer applications, in a manner that rivals humans' capability to execute specific functions. ROJAS defined it as the science aiming to develop programs or machines that can ponder and resolve issues more effectively than people (ROJAS, 2015: 2). It has likewise been referenced as an intricate data system with the proficiency to undertake human jobs comparably, such as thinking, reasoning, and acquiring knowledge (Almalki, 2023: 96).

Types of Artificial Intelligence

Scientists have classified artificial intelligence into three categories (Almalki, 2023: 96):

Weak or Narrow Artificial Intelligence: This type of AI is considered the simplest and most widespread. It is limited to performing a single task for which it is programmed and does not go beyond that. It does not attempt to mimic the human mind but focuses on specific, well-defined tasks.

Strong or General Artificial Intelligence: In this type of AI, technologies evolve to a level that makes them equivalent to the human mind and capable of performing diverse tasks. This type allows learning from data, experiences, and expertise, enabling systems to make autonomous and independent decisions similar to humans.

Super Artificial Intelligence: This type of AI is considered one of the most dangerous forms and is still under experimentation. It aims to develop machines that surpass human intelligence and learning capabilities. Such AI could potentially be used in all areas of human intelligence.

7.1. Goals of Artificial Intelligence

According to a study conducted by the Arab British Academy in 2019, it was confirmed that Artificial Intelligence contributes to many aspects, including (Al-Ashwal, 2022: 102): Developing software capable of performing human functions: This allows devices to perform tasks that require human thinking, such as logical inference, which enhances device intelligence and makes them more productive. Simulating human capabilities: Artificial intelligence seeks to imitate and possibly surpass human capabilities in various areas, such as problem-solving, knowledge acquisition, and decision-making. Addressing problems that require extensive expertise: AI systems can be trained and provided with vast amounts of data and expertise, enabling them to deal with complex challenges that are difficult for humans to solve. Enhancing human-device interaction: Artificial intelligence plays a vital role in improving communication between humans and machines, whether through dialogue between people or between users and computing platforms. This includes areas such as spoken language analysis, user interface design, and collaborative robotics. Increasing the ability of devices to process data in a manner similar to human thought: Artificial intelligence aims to create machines capable of processing information, acquiring understanding, and solving problems in ways that resemble human cognition, including parallel processing and flexible skill acquisition. Deep understanding of the mechanisms of the human mind: By studying and understanding the processes occurring in the human mind, AI research can contribute to a deeper appreciation of human intelligence itself.

This can later be used to better develop AI technologies and potentially create devices that surpass human mental capabilities.

Dimensions of Artificial Intelligence

9.3.1. Expert Systems

I've always found it wild how expert systems basically pretend to be a specialist in whatever field you need. They use computer technology that gotten really advanced, to think and analyze stuff at a level close to what a actual human expert can do (Alshare, 2019: 2). Its not just about handing you information the whole point is helping people like me think through problems and make better decisions. Software is what makes all this possible, it carries the expert knowledge and handles tasks that would of been way too complex otherwise. The rules you put into these systems is what drives everything; they take that inputted knowledge and uses it to make decisions that gets you to whatever goal you was trying to reach in the first place (Ajam, 2018: 92).

Neural Networks

Artificial neural networks are computational frameworks motivated by the operation of the human mind. They echo the brain's approach to studying and resolving issues. Made up of linked elements called neurons, these components handle data in a parallel fashion, akin to what happens in the human cerebrum (Cross et al., 1995: 1976).

An artificial neural network comprises several tiers of neurons. The initial tier (input level) takes in the preliminary data and forwards it through various concealed tiers for handling and alteration until it gets to the concluding tier (output level), which furnishes the final outcome. The neural network progresses via exposure to data by modifying the intensity of links amongst neurons. The more information and coaching the network encounters, the better its precision in tackling problems and making judgments.

Because of their capacity to gather knowledge from data, neural networks are employed in a broad array of uses, like scientific exploration, health-related choosing, monetary review, automatic translation, and visual and auditory perception (Sadanand et al., 2023: 300).

9.3.2. Intelligent Agents

In the field of artificial intelligence, the term "intelligent agents" refers to software entities or computer systems that possess the ability to make intelligent decisions and interact with their surrounding environment. An intelligent agent analyzes and processes information, taking appropriate actions based on defined goals and current conditions (Nurhafihz et al., 2021: 1021).

The intelligent agent relies on an internal knowledge base about a specific process to make decisions and execute tasks in a way that achieves the user's objectives (Kot & Leszczyński, 2019: 30). Russell & Norvig (1995: 31) view an intelligent agent as an entity capable of perceiving its environment through sensors and taking appropriate actions to interact with that environment (Baltzan & Phillips, 2008: 46). Baltzan & Phillips (2008: 46) also believe that intelligent agents are software applications that facilitate company tasks, particularly in relation to buying and selling operations. These applications also alert users when important events occur.

8. THE CONCEPT OF MANUFACTURING FLEXIBILITY

Production agility holds a vital position in boosting enterprise effectiveness and results, as well as in adopting lean production methods, as shown by many prior investigations. The common grasp of agility is the capacity of entities to embrace internal and external shifts and the resources accessible to them to manage evolving situations and unexpected or unplanned shifts. This raises the hazard aspect to secure the entity's endurance and rivalry in the marketplace.

Therefore, there exists no solitary unified meaning of production agility among academics and authors because of the distinct character and functions of entities and the shifting era. Nevertheless, some concur that production agility is the extent of readiness and swiftness with which an entity can adjust to alterations in market and surrounding settings (Cox, 1989: 69).

Production agility is characterized as the capability of a production framework to successfully adjust to shifts in the ambient setting by altering item specifics and making methods. Furthermore, it also relates to the power to create a range of goods with varying specifications and layouts according to market and client demands" (Sultan, 2015: 8).

Lastly, it has been recognized as an essential production capacity, holding the force to tangibly impact the competitive and trade standing of the concern" (Tan & Lim, 2019: 309).

Rooted in the foregoing, we can characterize production agility as the power to conform and alter making procedures and supply chains swiftly and effectively to satisfy evolving market requirements and varied obstacles.

8.1. The Importance of Manufacturing Flexibility

Flexibility in manufacturing is a concept that I am often thinking about- more than ever. It essentially means that factories are able to change rapidly when the products that they are producing require change, and all the sumps that the environment throws at them or the odd changes in the process. I observed how it could so easily reorganize all your production materials in such a way that they can make all sorts of various products without compromising on quality, and they can make such shifts without busting their budget, or falling behind schedule either.

What bothers me most is that it also causes companies to turn their entire priorities upside down - commercial, competitive, strategic, all that. They are able to stroll into markets in a manner that no one even imagined possible. And then there is the disruption, that every factory has to deal with at some time. It is flexibility that enables companies to sail through them issues without everything coming to a standstill, largely due to the fact that the appropriate machines is being used correctly at the correct time and place (Jain et al., 2013: 5948).

Goals of Manufacturing Flexibility

It actually benefits you, as I understand, to make more flexibilities in manufacturing so that you can end up achieving a bunch of different goals simultaneously (Al-Nimah, 2023: 13).

First thing it makes me have is a much better understanding of what strategic and operational plans is already in place such as, flexibility makes you really dig into their plans and identify where things can be made more flexible. Then there is the entire concept of preempting the occurrence of problems even during the manufacturing, which I believe is immense. When you have an idea of what challenges you are going to face you are in a position to correct them early enough and all just flows better.

I also found it make you dig more into the most important matters and the processes that in fact promotes flexibility, so as to determine how to attain adaptability even more than it already is. And on top of that it makes you get straight into the obstacles directly in your path - what is inhibiting the flexibility, would be something that I think is simply critical in case you want to continue improving and remain agile.

Another thing that I have found very interesting is how it assists in constructing and testing structures to make decisions, as well as the tools that aid that process. Them tools is what will assist you in reacting quicker when the things around you continuously keep on changing. Then, as a cap to it all, the entire thing falls into place when you realize what the most significant ones are that can make flexibility easier to develop in manufacturing- as soon as I know what that factors is, it becomes a lot easier to concentrate my effort in the right areas.

Factors Supporting Manufacturing Flexibility

Production agility is something I genuinely believe makes a massive difference — it let companies put out really high quality products that customers actually wants, and they can do it fast and without wasting resources (Singh & Solke, 2018). From what I've read in earlier research, most of the focus been on figuring out what elements leads to achieving that agility, and from what I seen it mostly comes down to two big things.

The first one is strategic integration, which to me just means making sure your production plans is lined up with everything else the business is trying to do. When it all connects together properly I noticed that production activities ends up naturally supporting the bigger goals of the whole company instead of just running on its own.

Then there's organizational structure, and honestly this one feels like the foundation of everything else. Its basically all the components that gives the organization what it need to function properly and lets the people inside it do their jobs well (Mkhaimer et al., 2015: 7). Things like who's leading, how information is managed, and how the whole structure is actually built — all of them plays a role. What I find most interesting is how a clear organizational layout make it easier for people to speak up, work together, and make good decisions, and without them three things I don't think agility is something any company could really achieve.

10.4 Dimensions of Manufacturing Flexibility

Rivalry in the present marketplace necessitates that entities possess the aptitude for ongoing adjustment and novelty. Exchanges concerning agility and invention are vital to commercial discussions, particularly in fields such as the vehicle sector. Firms need to modernize their technologies, either via internal exploration and progress or by utilizing outside expertise. The firm's proficiency to embrace these shifts is pivotal, mirroring its potential to recognize, incorporate, convert, and utilize outside knowledge in its novelty procedures (Sanchez et al., 2019: 2).

Numerous investigators and academics, including Khoobiyan et al. (2017: 1561), Raj & Jain (2013: 126-127), Mayer et al. (1995: 28), Stockton & Bateman (2023: 6), Abdul Karim & Muhammad (2019: 452), and Ngamsirijit (2008: 21), have concurred upon the subsequent aspects of production adaptability:

Volume Flexibility

Production volume adaptability is one of the most vital forms of agility in manufacturing processes, and it has garnered heightened focus since the late 1980s. Numerous theoretical and empirical investigations concentrate on boosting the system's capability to adjust to volume shifts as a measure of their operational effectiveness at various output levels.

Scholars characterize volume adaptability as the capacity to swiftly and affordably transition from small-scale to large-scale output and the reverse (Meredith & Shafer, 2011: 35). Abdul Karim & Muhammad (2019: 452) likewise define it as the power of a production framework to modify output quantity swiftly and capably in reaction to alterations in market needs or manufacturing circumstances.

8.1.1. Machine Flexibility

Equipment adaptability describes the capacity of a machine to execute diverse jobs on the identical apparatus. Typically, dedicated machines are the least adaptable, since they are engineered to carry out just one particular function. Conversely, versatile or broad-scope machines exhibit greater adaptability, possessing the potential to complete numerous distinct procedures.

Machine adaptability facilitates the manufacturing of minor quantities of goods, cutting down inventory expenditures and boosting effective equipment usage, whilst also enhancing the standard of the end item (Talib and Awadi, 2020: 11). It is the aptitude to conduct a selection of functions utilizing the same hardware or apparatus without needing to expend substantial duration and funds on altering configurations or setting up for every fresh operation. Fundamentally, effectiveness depends on streamlining manufacturing processes and lessening downtime so that peak output can be attained with minimal means and expenses (Khoobiyan et al., 2017: 1561).

Material Handling Flexibility

This concept relates to the number of possible paths between processing centers and the variety of materials that can be transported through these paths without significant errors or drastic changes in system performance (Lucas & Kirillova, 2011: 19). Stockton & Bateman (1995: 28) define material handling flexibility as the ability of a material handling system to adapt and handle a diverse range of products efficiently and effectively within the production system. This flexibility can be crucial for companies operating in a rapidly changing industrial environment or producing a variety of products.

Abdul Karim & Muhammad (2019: 452) define material handling flexibility as the ability to move materials efficiently and effectively, both within and outside the production process, by organizing and coordinating specialized processes and technologies designed to ensure a smooth flow and continuous supply chain.

9. MEASURING QUESTIONNAIRE RELIABILITY

Questionnaire reliability refers to the consistency of the questionnaire in yielding the same results if applied multiple times at different time intervals. To ensure this, Cronbach's alpha, the most commonly used measure of reliability, was employed. Cronbach's alpha ranges from 0 to 1, and according to Hair et al. (2014: 90), the minimum acceptable value for reliability is 0.60. Table (2) displays the results of the questionnaire reliability measurement.

***Table (2)** Measurement of Questionnaire Reliability*

Scale	Number of Items	Reliability Coefficient
Artificial Intelligence Scale	10	0.63
Manufacturing Flexibility Scale	10	0.84
Overall Scale	20	0.82

***Source:** Prepared by the researchers based on the outputs of the SPSS V.26 program.*

As observed in Table (2), all coefficients are greater than 0.60, indicating high and statistically significant reliability. Therefore, these scales can be reliably used to survey the opinions of the sample.

10. RESULTS OF DESCRIPTIVE STATISTICAL ANALYSIS OF THE STUDY VARIABLES

10.1. Results of Descriptive Statistical Analysis of the Independent Variable (Artificial Intelligence) and its Dimensions

***Table (3)** Results of Descriptive Statistical Analysis of the Independent Variable (Artificial Intelligence) and its Dimensions*

Dimension		**Item**	**Mean**	**Standard Deviation**	**Relative Importance**
Expert Systems (ES)	1	Expert systems contribute to knowledge acquisition in specialized areas that support manufacturing decisions.	4.26	0.689	85.2
	2	Expert systems in machines act as a consultant expert for the user in decision-making.	3.61	0.783	72.2
	3	Expert systems contribute to knowledge acquisition in specific areas that can enhance manufacturing flexibility.	3.91	0.515	78.2
Total			3.93	0.414	
Neural Networks (NN)	1	Neural networks assist the organization in analyzing large amounts of information to create characteristics in specific situations in manufacturing processes.	3.78	0.671	75.6
	2	Neural networks function similarly to human nerves and the brain's way of processing information.	3.39	0.839	67.8
	3	Neural networks rely on the learning characteristic as in human cases and the ability to derive meanings from the adopted data.	3.26	0.81	65.2
	4	Neural networks provide the organization with multiple options due to their high ability to analyze information.	3.61	0.941	72.2
Total			3.51	0.508	
Intelligent Agents (IA)	1	Intelligent agents assist in making decisions on behalf of the manufacturing process manager in specific situations.	3.61	0.988	72.2
	2	Intelligent agents reduce the time used by the user to reach the desired goal.	4.13	1.058	82.6
	3	Intelligent agents help the organization make decisions based on their stored knowledge base.	4.00	0.905	80
Total			3.91	0.799	
Overall AI			3.75	0.403	75

Table (3) shows that the mean value of this variable reached (3.75), which is greater than the hypothetical mean (3), confirming that the sample's answers tend towards agreement. The standard deviation value of (0.403) is less than (1), indicating homogeneity in the research sample's answers. The relative importance of this variable was (75%), reflecting the research sample's agreement on the dimensions of artificial intelligence, which are (expert systems, neural networks, intelligent agents). These dimensions recorded mean values of (3.93), (3.51), and (3.91) respectively, with standard deviations of (0.414), (0.508), and (0.799). Figure (2) illustrates the distribution of artificial intelligence dimensions according to their relative importance.

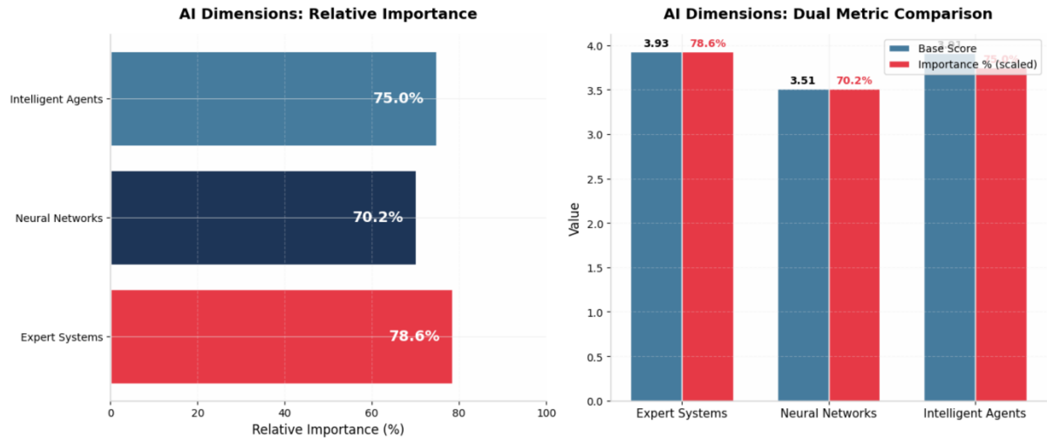

Figure (2) *Distribution of the relative importance of artificial intelligence dimensions*

Figure (2) illustrates that expert systems emerged with a relative importance of (78.6%), ranking highest among the dimensions constituting artificial intelligence. Conversely, the dimension of neural networks recorded the lowest level of importance at (70.2%).

10.2. Results of the descriptive statistical analysis of the dependent variable (manufacturing flexibility) and its dimensions

Table (4) *Results of the descriptive statistical analysis of the dependent variable (manufacturing flexibility) and its dimensions.*

Dimension		**Item**	**Mean**	**Standard Deviation**	**Relative Importance**
Machine Flexibility (MF)	1	The company owns machines that can perform multiple manufacturing processes within the factory.	3.74	0.915	74.8
	2	Machines can transition from one process to another without incurring additional operating costs.	3.61	0.656	72.2
	3	Machines can be set up and prepared for production quickly.	3.7	0.926	74
Total			3.68	0.693	73.6
Machine Flexibility (MF)	1	The company has the capability to offer different sizes of diverse products from time to time.	3.91	0.848	78.2
	2	The company has the ability to increase production volume while maintaining or improving quality levels.	3.74	0.915	74.8
	3	The company has the ability to easily change production volume in the manufacturing process.	3.7	0.926	74
Total			3.78	0.715	75.6

Material Handling Flexibility (HF)	1	The current handling equipment or machinery is compatible with the requirements of the current production system.	3.13	0.869	62.6
	2	The current handling system has high capabilities that enable easy transportation and movement of materials from one place to another.	3.17	0.834	63.4
	3	The handling system can easily connect each machine to another.	3.39	0.941	67.8
	4	The material handling equipment or machinery can be quickly changed or replaced.	3.3	0.822	66
Total			3.25	0.723	65
Overall			3.53	0.557	70.6

From Table (4), it is clear that the mean value of this variable reached (3.53), which is greater than the hypothetical mean (3), confirming that the sample's answers tend towards agreement. The standard deviation value of (0.557) is less than (1), indicating homogeneity in the research sample's answers. The relative importance of this variable was (70.6%), reflecting the research sample's agreement on the dimensions of manufacturing flexibility, which are (machine flexibility, volume flexibility, routing flexibility). These dimensions recorded mean values of (3.68), (3.78), and (3.25) respectively, with standard deviations of (0.693), (0.715), and (0.723). Figure () illustrates the distribution of manufacturing flexibility dimensions according to their relative importance.

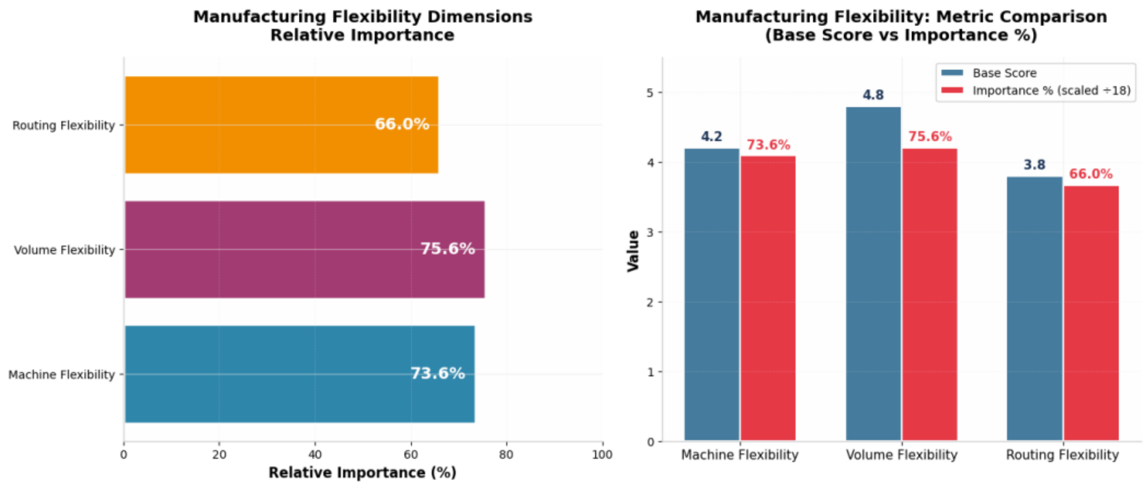

***Figure (3)** Distribution of the relative importance of manufacturing flexibility dimensions*

It is clear from Figure (3) that the volume flexibility dimension came with a relative importance of (75.6%), which is the highest rank among the constituent dimensions of manufacturing flexibility, while the routing flexibility dimension recorded the lowest level of importance (66%).

11. RESULTS OF TESTING THE HYPOTHESES OF INFLUENCE BETWEEN RESEARCH VARIABLES

This section aims to test the main research hypothesis related to examining the influence between the research variables: (artificial intelligence), the independent variable, and (manufacturing flexibility), the dependent variable, and the hypotheses branching from it using simple linear regression analysis. The results are as shown in Table (5).

Table (5) *Results of the Simple Linear Regression Test for the Main Hypothesis and its Sub-hypotheses*

Dependent Variable (Manufacturing Flexibility) Y	Results of the Simple Linear Regression Test						
	Independent Variable (Artificial Intelligence	Coefficient of Determination R2	Regression Coefficient (Effect) β	Calculated t-value	Calculated F-value	Significance Level P	Nature of the Relationship
Machine Flexibility	Artificial Intelligence	0.097	0.535	1.503	2.259	0.148	Not Significant
Volume Flexibility	Artificial Intelligence	0.022	0.265	0.694	0.481	0.495	Not Significant
Material Handling Flexibility	Artificial Intelligence	0.302	0.986	3.015	9.091	0.007	Highly Significant
Manufacturing Flexibility	Artificial Intelligence	0.211	0.634	2.367	5.604	0.028	Highly Significant

Source: *Prepared by the researchers using (SPSS V.26) software*

From Table (5), for the main hypothesis, the value of the coefficient of determination (R2) reached (0.211). This indicates that artificial intelligence contributes to 21.1% of the variance occurring in manufacturing flexibility. The remaining percentage of 78.95% is attributed to other factors do not present in the model. The regression coefficient (β) reached a value of (0.535). This value suggests that any improvement in artificial intelligence systems within the researched factory by one unit leads to a 53.5% improvement in manufacturing flexibility. The calculated t-value reached (2.367), which is greater than its tabular counterpart at a significance level of (0.02). Meanwhile, the calculated F-value reached (5.604), which is greater than its tabular counterpart at a significance level of (0.02) and less than the significance level of 0.05. This confirms that focusing on artificial intelligence systems leads to increased manufacturing flexibility, meaning the main hypothesis is accepted: (There is a statistically significant effect of artificial intelligence on manufacturing flexibility).

As for the sub-hypotheses of the main hypothesis, the results of the simple linear regression test showed the following:

Regarding the initial sub-hypothesis, it is apparent that the regression model possesses a very weak merit, as the coefficient of determination (R^2) reached (0.097). This suggests that artificial intelligence only accounts for 9.7% of the variation in the (machine flexibility) metric. The residual 90.3% is ascribed to other elements not present in the evaluation framework. The regression factor (B) achieved a magnitude of (0.535); nevertheless, it is not at an adequate point of importance to assert that this element exerts a notable influence on machine flexibility. The computed T-value attained (1.503) with a significance threshold of (0.150), which exceeds the significance benchmark of 0.05. Concurrently, the computed F-value reached (2.259), which is smaller than its tabulated equivalent at a significance level of (0.148) and greater than the significance benchmark of 0.05. Consequently, it is not statistically important. This signifies a lack of association between artificial intelligence and machine flexibility, thus dismissing the supposition.

Pertaining to the second sub-hypothesis, it is clear that the regression model has a very weak standing, as the coefficient of determination (R^2) arrived at (0.022). This implies that artificial intelligence solely clarifies 2.2% of the dispersion in the (volume flexibility) measure. The leftover 97.8% is credited to other constituents absent from the tested structure. The regression factor (B) attained a figure of (0.265); yet, it is not at a 3- adequate degree of consequence to state that this component has a significant bearing on the dependent measure. The calculated T-value reached (0.694) with a significance level of (0.495), which surpasses the significance benchmark of 0.05. Simultaneously, the computed F-value reached (0.481), which is lower than its tabular counterpart at a significance level of (0.495) and exceeds the significance benchmark of 0.05. Therefore, it is not statistically relevant. This indicates no impact between artificial intelligence and volume flexibility, thereby refuting the assumption.

The measure of the coefficient of determination (R^2) reached (0.303), showing that artificial intelligence explains 30.3% of the variance occurring in routing flexibility. The remaining 69.7% is credited to unfamiliar elements not present in the structure. The regression coefficient (β) reached a value of (0.986), implying that every enhancement in artificial intelligence by a single unit causes a 98.6 enrichment in routing flexibility. The calculated t-value reached (3.015), which surpasses its tabular equivalent at a significance level of (0.007). Meanwhile, the calculated F-value reached (9.091), which is greater than its tabular counterpart at a significance level of (0.007) and less than the significance benchmark of 0.05. This validates that a focus on artificial intelligence systems results in a favorable improvement in routing flexibility, meaning the first sub-hypothesis is sustained: (There is a statistically significant effect between artificial intelligence and routing flexibility).

CONCLUSIONS

The study shows that the company does not ignore the implementation of AI systems in its factory, showing a definite desire to embrace technological changes. Nonetheless, this focus is not spread equally on all AI dimensions. A majority of resources and attention are on the expert systems and relatively less attention is given to neural networks. This selective investment implies that the company puts more emphasis on some AI technologies depending on the perceived contribution to improving manufacturing flexibility.

In general, the factory is doing a good job manufacturing flexibly, but there are dimensions that are more robust than others. Flexibility of machines and volumes seems to dominate, which is a sign of a planned management initiative to expand the capability of operations and responsiveness to production needs especially in terms of efficiency in equipment and production throughput.

The findings also suggest that AI has a positive effect on the flexibility of manufacturing, but this effect has a different magnitude depending on dimensions. The impact of AI on routing flexibility is the greatest, and machine and volume flexibility respond to it more humbly. This gap indicates that the full AI technologies potential is not achieved in various areas of operation.

Lastly, the factory shows a high emphasis on viable AI solutions, such as big data analytics, machine learning, and robotics, as result-oriented solutions to streamline production performance. However, it might be required to move further than the existing technologies and use some more advanced AI applications in case the company wants to become even more flexible in the future.

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