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Digitalization, automation, and technological efficiency among manufacturing firms: Basis for an enhanced innovative strategy

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Abstract

The rapid advancement of digitalization has greatly changed the methods of manufacturing, availing new prospects for more efficiency and productivity. This study aims to explain the relationship between digitalization, automation, and technological efficiency of manufacturing firms. In doing so, the research seeks to research such elements in order to develop the best technological automation enhanced strategy that can help in achieving operational excellence and enhance competitiveness of a manufacturing sector. Descriptive design was used in the present study as it aims primarily at describing and understanding the present status of the manufacturing companies' digitalization, automation, and technological efficiency. It is very common in collecting data concerning the status of a particular subject and even more in outlining its trends and patterns. A self-made questionnaire was used as the data gathering instrument tool as it enables the researcher to design the questions in accordance with the specific. This guarantees that the data collected is relevant and directly addresses the research objectives. The study used 400 participants composed of employees and managers of five manufacturing firms and ensured relevant information were disclosed to create strategies for technological innovation. Based on the findings, the respondents generally agreed that manufacturing companies adopted digitalization as a process, product and business model. They agreed on the automation process in terms of efficiency and productivity, automation strategy and competitive advantage. The study also found agreement on technological efficiency in terms of output and process quality, innovation and adaptability and data-driven decision making. No significant relationship was found between digitalization, automation and technological efficiency. An enhanced technological automation strategy was developed for manufacturing firms.

Keywords: automation, digitalization, enhanced technological automation strategy, technological efficiency

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1. Introduction

In the manufacturing sector, the development of new digital technologies and the optimization of manufacturing processes has marked the beginning of a more productive, more flexible, and more competitive industrial system. Digital transformation and the adoption of innovation have changed Chinese manufacturing in several ways. Digitalization has allowed manufacturers to streamline production, control processes and make better management decisions based on analysis of the available data. Li, et al., (2021) disclosed that the growing application of the Internet of Things technology allows production lines to be monitored at real-time and hence maintenance is conducted in a responsive manner before breakdown of equipment takes place (Li et al., 2021).

The concept of digitalization has changed the manufacturing sector, by incorporating the elements of digital technologies into every detail of the production process. In respect to the above mentioned aspects, digitalization makes it possible for the manufacturers to make the best use of resources, enhance the quality control systems and maximize efficiency of the whole process. For example, the Internet of Things (IoT) which is a system of interrelated computing devices, sensors, and advanced analytics, includes real-time monitoring of the production lines where any interruptions are likely to occur thus enabling effective maintenance management (Zhang et al., 2021).

Automation has been one of the vital aspects of industry for a long period. The word stands for technosystems doing the job, which was previously done by people. Today, however, the degree of automation in production has changed; better robots, artificial intelligence, and machine learning have all developed in recent years. These days, stand-alone systems are also able to accomplish complex tasks much faster and more accurately than humans, cutting on labor costs, enhancing uniformity of production and paving the way for continuous operations (Kwon et al., 2019). Automation in large part supported by the developments of robotics and AI-driven manufacturing systems has raised production levels and lessened human labor. The introduction of automated assembly lines and robot-enabled systems has sped up the processes, increased the uniformity of the products, and made it possible to run production non-stop (Wang et al., 2020). The combination of digitalization and automation has resulted in the enhancement of overall technological effectiveness. In this way, the manufacturers of China adopted the technologies and processes to improve the utilization of resources and reduce the wastes thereby traveling with their improvement in productive efficiency. According to Chen et al. (2019), analytics fueled by artificial intelligence integrated into the manufacturing techniques has enabled companies to manage their inventories in a more efficient manner, that is, it has helped cut expenses and avoid the dangers of stock outs.

Technological efficiency, which is the joint effect of digitalization and automation, is an index characterizing technology utilization effectiveness in a particular manufacturing corporation. With the adoption of data and processes, the manufacturers are focused on knowing the areas that need improvement, making the processes more efficient, and decreasing the expenses. For instance, due to applications of IoT and data analytics equipment, predictive maintenance practices are able to correlate with the occurrence of breakdowns and hence delays in services are avoided by carrying out maintenance before the failure occurs (Schroeder et al., 2020). Digitalization, automation, and technological efficiency have all become critical support pillars for every manufacturing business within the present environment. This study investigates the relationship between these factors in detail assessing their effect on manufacturing processes and potential for increased technological automation.

However, the availability of relevant information pertaining to manufacturing systems, technology usage,

and various performance indicators is not always easy. The collection of data from several sources and ensuring its uniformity and accuracy is tough because the firms may have different data even on the same subject. Identifying the right figures to capture the concepts of digitalization, automation, technology efficiency and performance is often difficult, even more so because they are not homogeneous and may differ from one company to another. Further, proving that technological changes led to certain performance results is often complicated because other variables such as prevailing market conditions, the overall economic environment and management choices can also produce results. The positive or negative consequences in regard to digitalization, automation and efficiency of technology can differ by sector and size of enterprises thus causing difficulties. Technologies may be adopted and used or utilized effectively depending on cultural and institutional variations across regions.

The study of digitalization, automation, and technological efficiency in manufacturing firms provides a clear scope for the proponent as it is an avenue to add in the ever-expanding discourse on industrial change and advancement. As for the manufacturing companies, it is important to know how to derive the benefits of and cope with the challenges brought about by digitalization, automation, and technological efficiency, so as to improve competitiveness and streamline processes. There are options to influence practices, including the ones linked to the utilization of digital technologies and automation, with an aim to enhance productivity or, lower expenses, to be proactive towards macroeconomic processes. In this regard, the analysis of the enhancing digital transformation in the organization brings success stories which can be learnt by many on what to do and what not to do in manufacturing industries but also helps them assess what risks are likely to occur when introducing new systems.

Objectives of the Study - This study sought to examine the digitization practices, automation process, and technological efficiency among manufacturing firms in Beijing, China. Specifically, it determined the digitalization process as to process digitalization, product digitalization, and business model digitalization; assessed the automation practices in terms of efficiency and productivity, automation strategy and competitive advantage; described the technological efficiency in terms of output and process quality, innovation and adaptability and data-driven decision making; tested the significant relationship between digitalization practices, automation process and technological efficiency; and developed an enhanced innovative strategy for manufacturing firms

2. Methods

Research Design - The descriptive method of research was employed in this study. It seeks to precisely and methodically characterize a population, circumstance, or phenomena. This type of research also provides a detailed picture of the characteristics and behavior of a particular group of people or a particular phenomenon. This initial understanding is important for researchers to dig deeper into the “why” behind things. A survey was employed to determine the digitalization practices, automation process, and technological efficiency among manufacturing firms in Beijing, China. Descriptive design was used in the studies on digitalization, automation, and technological efficiency in manufacturing firms because it aims to describe the current state of these variables. This approach is particularly used in providing a baseline understanding of the existing practices, challenges, and opportunities in the field.

Participants of the Study - The study selected 350 managers and employees from the 5 selected production/manufacturing companies in Beijing, China. The managers are tasked with ensuring the effective running of the organization in terms of its strategic direction, one of the elements being the incorporation of new technologies. They appreciate the various aspects of why technology is adopted, the advantages and disadvantages faced, and the overall effect on organizational efficiency. Further, the employees take part in the daily activities of production firms and come into contact with the technologies. Hence, they are in a position to offer insight on some of the practical issues, merits, and risks of digitalization and automation, and how it affects their work and the organization in general. Beijing has a well-developed industrial sector, therefore giving the

researcher an easy access to the manufacturing firms within the vicinity. This easy access has made it easier to source for participants in such firms. Convenience-purposive sampling was used in order to ensure that companies which had more than average representativeness of the population of interest were included in the study. Purposive sampling allowed the researcher to select companies that were representative of the target population and could provide valuable information.

Instrument of the Study - This study used the questionnaire as the instrument to collect data. This was a self-made questionnaire to specifically address the objectives of the study. The questionnaire is composed of three (3) parts. Part I is the digitalization process as to process digitalization, product digitalization and business model digitalization; Part II is the automation practices in terms of efficiency and productivity, automation strategy and competitive advantage; and Part III is technological efficiency in terms of resource utilization, output and process quality and innovation and adaptability. The questionnaire was pilot tested to a small group of respondents to check its reliability.

Table 1

Reliability Summary Table – Digitalization, Automation and Technological Efficiency Among Manufacturing Firms Instrument

Indicators	Cronbach Alpha	Remarks
Digitalization, Automation and Technological Efficiency Among Manufacturing Firms Instrument	.978	Excellent
Per variable		
Digitalization Process	.941	Excellent
Process Digitalization	.779	Acceptable
Product Digitalization	.924	Excellent
Business Model Digitalization	.858	Good
Automation Process	.952	Excellent
Efficiency and Productivity	.828	Good
Automation Strategy	.906	Excellent
Competitive Advantage	.895	Good
Technological Efficiency	.957	Excellent
Output and Process Quality	.874	Good
Innovation and Adaptability	.927	Excellent
Data Driven Decision Making	.917	Excellent

George and Mallery (2003) provide the following rules of thumb: "_ > .9 – Excellent, _ > .8 – Good, _ > .7 – Acceptable, _ > .6 – Questionable, _ > .5 – Poor, and _ < .5 – Unacceptable"

Based on the result, the Digitalization, Automation and Technological Efficiency Among Manufacturing Firms Instrument has an Excellent consistency as exhibited by the Cronbach's Alpha value of (.941). This was validated by the Excellent remark from Digitalization Process (.863); it was confirmed by the Acceptable result from Process Digitalization (.779), Excellent result from Product Digitalization (.924), and Good result from Business Model Digitalization (.858). Also, it was validated by the Excellent remark from Automation Process (.952); it was confirmed by the Good result from Efficiency and Productivity (.828), and Competitive Advantage (.895), and Excellent result from Automation Strategy (.906). It was further validated by the Excellent result from Technology Efficiency (.957); it was confirmed by the Good result from Output and Process Quality (.874), and Excellent results from Innovation and Adaptability (.927), and Data Driven Decision Making (.917); which shows that the instrument at hand passed the reliability index test.

Data Gathering Procedure - The self-made questionnaire was validated to ensure that the question items represent adequately what is being measured. The items were assessed for their relevance, clarity, and comprehensiveness by a group of experts in the field. Further, pilot testing involves administering the questionnaire to a small sample of individuals similar to the target population. This helped identify potential problems in the questionnaire, such as unclear questions, confusing instructions, or excessive time requirements. It also provided an opportunity to assess the reliability of the questionnaire, which refers to consistency over time and different samples. The questionnaire was administered to 350 managers from 5 selected production/manufacturing companies in Beijing, China. The responses gathered were submitted for Cronbach

alpha for its reliability. The researcher asked permission to the owners of the manufacturing companies for the questionnaire to be distributed to the targeted respondents. Respondents were assured that all information gathered will remain under full confidentiality and will solely be used for this research.

Data Analysis - Weighted mean and rank were used to describe the digitalization process as to process digitalization, product digitalization, and business model digitalization; to determine the automation practices in terms of efficiency and productivity, automation strategy and competitive advantage; and to assess the technological efficiency in terms of output and process quality, innovation and adaptability and data-driven decision making. The result of Shapiro-Wilk Test showed that p-values of all variables were less than 0.05 which means that the data set was not normally distributed. Therefore, Spearman rho was used as part of the non-parametric tests to determine the significant relationship. All analyses were performed using SPSS version 28.

Ethical Considerations - In order to get their informed consent, respondents were informed about the goal of the study, the nature of their involvement, and the intended use of the findings. The proponent got informed consent from participants, protected their welfare and rights, practiced integrity and honesty in the research, and optimized benefits to risks. Policies and procedures were implemented to guarantee the confidentiality of each respondent's answers. In addition, research with the highest ethical standards particularly involving human subjects was subjected for review and approval by the Ethics committee in the university. These principles were observed and the proponent carried out the research in an ethical manner.

3. Results and discussion

Table 2

Summary Table on Digitalization Process

Key Result Areas	Composite Mean	VI	Rank
Process Digitalization	3.22	Agree	2
Product Digitalization	3.17	Agree	3
Business Model Digitalization	3.30	Agree	1
Grand Composite Mean	3.23	Agree	

Legend:3.50-4.00=Strongly Agree;2.50-3.49=Agree;1.50-2.49=Disagree;1.00-1.49=Strongly Disagree

Table 2 shows the summary of the digitalization process with a grand composite mean of 3.23 and with verbal interpretation of agree. This means that respondents have great expectations on the digitalization process of their manufacturing firms in terms of process, product and business models. This indicates a promising groundwork for the company to invest in digital technologies and processes to enhance its overall productivity, efficiency, and competitiveness in the dynamic manufacturing landscape. Business Model Digitalization which got the highest ranked, indicates a strong emphasis on data-driven decision-making and a culture of continuous improvement. Business model digitalization is a comprehensive transformation that goes beyond adding digital input into the existing operations. It is adopting digital technologies to thoroughly reshape every aspect of how a company produces, delivers, and captures value. This involves re-imagining customer touch-points and developing entirely new value propositions and optimizing internal processes. By converting into digitalization, companies open enhance efficiency, new growth opportunities and gain a competitive edge in the digital era.

Process Digitalization (3.22) got the second rank. It advocates a strategic prioritization of reforming the company's primary structure for the digital age before enhancing internal operations. This approach is beneficial if the current business model is a main barrier for digital transformation. However, it's important to strike a balance. Neglecting process digitalization for a long time can generate bottlenecks and inefficiencies that hinder the overall digitalization journey. Even a well-designed digital business model will struggle to deliver results if internal processes are slow, cumbersome, and reliant on outdated technologies. Product Digitalization (3.17) got the lowest-ranked. While it has a positive perception, there is a possible loophole between acknowledging the importance of product digitalization and actively implementing a comprehensive strategy. This may be due to the

fact that the company is taking initial steps, such as adding basic digital features to existing processes. However, they might not be fully implementing the transformative possibilities of digital products and services which involve creating entirely new product categories built around digital technologies, leveraging data to personalize user experiences, or developing subscription models for ongoing product value.

Table 3

Summary Table on Automation Practices

Key Result Areas	Composite Mean	VI	Rank
Efficiency and Productivity	3.50	Strongly Agree	1
Automation Strategy	3.11	Agree	2.5
Competitive Advantage	3.11	Agree	2.5
Grand Composite Mean	3.24	Agree	

Legend:3.50-4.00=Strongly Agree;2.50-3.49=Agree;1.50-2.49=Disagree;1.00-1.49=Strongly Disagree

Table 3 reveals the positive outlook of the employees on the automation practices of their company. Efficiency and productivity high score (3.50) This indicates that manufacturers across the board acknowledge the considerable influence of automation on their operational efficiency and productivity. They recognize the revolutionary ability of automation technologies to streamline processes, reduce errors, and boost output. Adopting automation can result in reduced expenses, enhanced work quality, and more efficient allocation of resources in enterprises. In summary, this acknowledgment highlights the growing significance of automation in contemporary business strategies as a crucial catalyst for competitiveness and achievement in the swiftly changing market environment of today. Subsequently, the Automation Strategy and Competitive Advantage indicators either have a composite mean of 3.11 and tie for second place. This illustrates a consensus agreement among manufacturers that having a well-defined automation strategy is necessary for maintaining a competitive edge in the market. The overall results of this table reflect a generally positive attitude towards automation practices among manufacturing companies. It indicates that while there is strong agreement on the benefits of automation, there is also room for growth and improvement in how these technologies are adopted and integrated into business processes. Organizations need a dynamic automation capability that allows them to continuously identify new automation opportunities, adapt their strategies, and refine their automation practices. This ensures they remain competitive and capitalize on the latest advancements in automation technology.

Table 4

Summary Table on Technological Efficiency

Key Result Areas	Composite Mean	VI	Rank
Output and Process Quality	3.10	Agree	1.5
Innovation and Adaptability	3.10	Agree	1.5
Data-driven Decision Making	2.99	Agree	3
Grand Composite Mean	3.06	Agree	

Legend:3.50-4.00=Strongly Agree;2.50-3.49=Agree;1.50-2.49=Disagree;1.00-1.49=Strongly Disagree

This summary table concise an overview of technological efficiency within a manufacturing firm. The highest ranked KRAs are Output and Process Quality, and Innovation and Adaptability, both with a composite mean of 3.10, indicating an overall agreement among respondents on their importance. These indicators serve as essential in verifying that technological processes and their outcomes are followed with the set standards. Moreover, they are also accountable for enabling these processes to effectively adjust to and take advantage of new challenges and opportunities that may arise. This highlights the importance of effectively managing and ensuring the proper functioning of various sectors to facilitate the overall success and expansion of technical operations. Innovation and Adaptability, sharing the top rank, underscore the necessity for organizations to be flexible and responsive to change. This statement is supported by a 2020 report by the World Economic Forum, which emphasizes that businesses exhibiting strong innovation capabilities tend to rise above their competitors in terms of market share and profitability. Adaptability is especially vital in the context of technological disruptions and evolving market demands, as it allows organizations to pivot efficiently and take advantage of new

developments in technology. The third-ranked key result area is the Data-driven Decision Making, with a composite mean of 2.99, implies a general agreement on its importance, although it is slightly lower than the top two areas. Data-driven decision-making is integral to attaining technological efficiency, as it allows organizations to make informed choices based on empirical evidence rather than intuition.

Table 5

Relationship Between Digitalization Process and Automation Process

Variables	rho	p-value	Interpretation
Process Digitalization			
Efficiency and Productivity	0.029	0.568	Not Significant
Automation Strategy	0.073	0.147	Not Significant
Competitive Advantage	0.034	0.501	Not Significant
Product Digitalization			
Efficiency and Productivity	-0.079	0.116	Not Significant
Automation Strategy	0.026	0.609	Not Significant
Competitive Advantage	-0.099*	0.047	Significant
Business Model Digitalization			
Efficiency and Productivity	-0.038	0.454	Not Significant
Automation Strategy	-0.057	0.255	Not Significant
Competitive Advantage	0.002	0.963	Not Significant

**. Correlation is significant at the 0.05 level*

The computed rho-values ranging from 0.029 to 0.073 indicate a very weak direct relationship between process digitalization and the sub variables of automation process. There was no statistically significant relationship between process digitalization and the sub variables of automation process because the obtained p-values were greater than 0.05. This indicates that improvements in process digitalization do not necessarily lead to significant changes in efficiency, productivity, automation strategy, or competitive advantage. The computed rho-values ranging from -0.079 to -0.099 indicate a very weak indirect relationship between product digitalization and the sub variables of automation process namely efficiency and productivity, and competitive advantage while the computed rho-value of 0.026 indicates a very weak direct relationship between product digitalization and automation strategy. There was a statistically significant relationship between product digitalization and competitive advantage because the obtained p-value was less than 0.05. This indicates that product digitalization can have a nuanced impact on competitive advantage.

The computed rho-values ranging from -0.038 to -0.057 indicate a very weak indirect relationship between business model digitalization and the sub variables of automation process namely efficiency and productivity, and automation strategy while the computed rho-value of 0.002 indicates a very weak direct relationship between business model digitalization and competitive advantage. There was no statistically significant relationship between business model digitalization and the sub variables of automation process because the obtained p-values were greater than 0.05. This implies that changes in automation process sub-variables not significantly affected the business model digitalization alone. The influence of digitalizing business models on performance measures such as efficiency and strategy implementation calls for a complete approach that takes into account workforce readiness, organizational culture, and technology acceptance.

As shown in table 6, the computed rho-values ranging from -0.001 to -0.041 indicate a very weak indirect relationship between process digitalization and the sub variables of technological efficiency namely output and process quality, and data-driven decision-making while the computed rho-value of 0.007 indicates very weak direct relationship between process digitalization and innovation and adaptability. These values indicate limited or negligible impact of process digitalization on these factors. This aligns in the study of Vial's (2019) which highlights the importance of considering the organizational context and technological infrastructure when assessing the benefits of process digitalization. It suggests that while digitalizing processes can lead to efficiency improvements, there are also potential complexities that need to be taken into account. It would be beneficial to further discuss how organizations can navigate these complexities and maximize the benefits of process

digitalization while minimizing any drawbacks.

Table 6

Relationship Between Digitalization Process and Technological Efficiency

Variables	rho	p-value	Interpretation
Process Digitalization			
Output and Process Quality	-0.041	0.419	Not Significant
Innovation and Adaptability	0.007	0.896	Not Significant
Data-driven Decision Making	-0.001	0.980	Not Significant
Product Digitalization			
Output and Process Quality	-0.015	0.758	Not Significant
Innovation and Adaptability	0.035	0.486	Not Significant
Data-driven Decision Making	-0.094	0.060	Not Significant
Business Model Digitalization			
Output and Process Quality	0.052	0.302	Not Significant
Innovation and Adaptability	-0.025	0.625	Not Significant
Data-driven Decision Making	0.043	0.389	Not Significant

**. Correlation is significant at the 0.05 level*

The computed rho-values ranging from -0.015 to -0.094 indicate a very weak indirect relationship between product digitalization and the sub variables of technological efficiency namely output and process quality, and data-driven decision-making while the computed rho-value of 0.035 indicates a very weak direct relationship between product digitalization and innovation and adaptability. This indicates that focusing solely on adding digital features to products might not directly improve output & process quality, data-driven decision-making, or necessarily enhance innovation & adaptability. There's a need to ensure these features are well-designed and aligned with broader strategic goals. The computed rho-values ranging from 0.043 to 0.052 indicate a very weak direct relationship between business model digitalization and the sub variables of technological efficiency namely output and process quality, and while the computed rho-value of -0.025 indicates a very weak indirect relationship between business model digitalization and innovation and adaptability. This indicates a limited direct influence. While digital business models can potentially improve efficiency and output, the impact on innovation might be less straightforward. This highlights the importance of carefully considering the potential impact of digital business models on all aspects of technological efficiency. There was no statistically significant relationship between digitalization process and technological efficiency because the obtained p-values were greater than 0.05.

Table 7

Relationship Between Automation Process and Technological Efficiency

Variables	rho	p-value	Interpretation
Efficiency and Productivity			
Output and Process Quality	-0.008	0.879	Not Significant
Innovation and Adaptability	-0.026	0.607	Not Significant
Data-driven Decision Making	0.008	0.867	Not Significant
Automation Strategy			
Output and Process Quality	-0.047	0.343	Not Significant
Innovation and Adaptability	0.021	0.670	Not Significant
Data-driven Decision Making	-0.032	0.523	Not Significant
Competitive Advantage			
Output and Process Quality	-0.050	0.321	Not Significant
Innovation and Adaptability	-0.087	0.082	Not Significant
Data-driven Decision Making	-0.027	0.596	Not Significant

**. Correlation is significant at the 0.05 level*

The computed rho-values ranging from -0.008 to -0.026 indicate a very weak indirect relationship between efficiency and productivity and the sub variables of technological efficiency namely output and process quality, and innovation and adaptability while the computed rho-value of 0.008 indicates a very weak direct relationship between efficiency and productivity and data-driven decision-making. This indicates that a narrow focus on

increasing efficiency or productivity in isolation might not guarantee improvements in output & process quality, innovation & adaptability, or data-driven decision making. This supports the idea that while automation can enhance productivity, the quality of output and process improvements might not be directly impacted in a statistically significant manner. The computed rho-values ranging from -0.032 to -0.047 indicate a very weak indirect relationship between automation strategy and the sub variables of technological efficiency namely output and process quality and data-driven decision-making while the computed rho-value of 0.021 indicates a very weak direct relationship between automation strategy and innovation and adaptability. This indicates that having an automation strategy in place is not a guarantee for improvements in output & process quality, data-driven decision-making, or competitive advantage. However, a well-defined and well-executed automation strategy can significantly increase the likelihood of achieving these improvements.

The computed rho-values ranging from -0.027 to -0.087 indicate a very weak indirect relationship between competitive advantage and the sub variables of technological efficiency. This indicates that automation processes and efficiency/productivity gains alone are not enough to secure a sustainable competitive advantage in today's dynamic business environment. This aligns with the growing recognition that achieving a sustainable competitive advantage requires a multi-faceted approach that goes beyond just technological advancements. There was no statistically significant relationship between automation process and technological efficiency because the obtained p-values were greater than 0.05.

An Enhanced Technological Automation Strategy

An upgraded technological automation strategy is a holistic approach that uses digital technologies and automation to make manufacturing more efficient and productive. It results from the interaction of digitalization, automation, and technological efficiency within firms that have something to do with manufacturing.

An enhanced technological automation strategy provides the manufacturing firms with more benefits. This is because digital technologies and automation can be used to improve the efficiency, quality, and competitiveness of a company. With automation, the processes get streamlined, waste reduced, and efficiency improved upon, ensuring increased output while lowering costs. These streamlined products through advanced technology will ensure more accuracy and consistency; therefore, the company will ensure that its products meet the expectations set by the target customers. Not the least, automation provides savings in manpower, energy, as well as material expenses and waste. The automated systems are more sensitive to variations in demand and product specification than human ones; thus firms can quickly respond to market fluctuations. In embracing new technologies, manufacturing firms can acquire a competitive edge and differentiate themselves from the others, which might attract new customers. Hence, an enhanced technological automation strategy is a very influential tool in the manufacturing industry for enhancing competitiveness, improving quality and, of course, promoting efficiency.

Table 8

Enhanced Innovative Strategy

Key Result Area/Findings	Objectives	Strategy	Expected Outcome
Product Digitalization Providing efficient production line adjustments to meet evolving customer needs.	Enhance manufacturing flexibility and efficiency	Install production lines that are easily adjustable to different product requirements and output levels. Utilize technologies such as automation, robotics, and artificial intelligence to streamline production processes and enable rapid adjustments.	Reduced lead times and timely supply of goods to customers. Firms may offer a wider range of products to meet diverse customer preferences.

Automation Strategy Upskilling and reskilling for automation	Develop a skilled workforce capable of operating and maintaining automated systems.	Carry out an in-depth analysis of the existing workforce in order to determine the relevant skills for the operation and maintenance of the automated systems. Develop company-specific training interventions to help close the gaps in the existing workforce which will address areas such as automation, programming, data analysis, and critical thinking.	carry out the operation and management of such systems leading to a high rate of efficiency and productivity. Training of employees will address the issues of repair of automated machines hence minimizing delays caused by breakdowns.
Competitive Advantage Culture of innovation through automation strategy	Foster a culture of innovation and experimentation within the manufacturing firm.	Create a workplace culture where employees are not afraid to attempt new ideas and ideas less conventional than every day's routine. Delegate funds for R&D and give already employees the means and the education for finding creative ways of using automation.	organization to introduce the new products in the market within a short span of time, hence trumping competition. Through more advanced manufacturing processes, Automation can also allow the creation of better products.
Technological Efficiency (Data-driven making) Data-driven decision-making at all levels	Establish a strong data management infrastructure and provide employees with the tools and training necessary to leverage data-driven decision-making.	Install a sound data management system which will be capable of gathering, storing and arranging all the required data from several sources such as the production line, the clients and the market trends. Provide for advanced tools for data analytics: Provide the workers with simple to use software and tools for data analytics that will help in processing rough data into usable information.	Better decision making: Decisions will be made based on the proper economic reasoning rather than 'guessing' as is still the case in many manufacturing firms. Achieved operational efficiency: Various forms of data can assist in elimination of inefficiencies, improvement of practices and management of resources hence enhancing efficiency and productivity.

4. Conclusions and recommendations

Majority of the respondents generally agreed on the process of digitalization used in the firms in terms of process digitalization, product digitalization, and business model digitalization. The respondents have general agreement on the automation practices as to efficiency and productivity, automation strategy and competitive advantage. Most of the respondents agreed on the technological efficiency as to output and process quality, innovation and adaptability and data-driven decision making. There are no significant relationships between digitalization, automation practices and technological efficiency. An enhanced technological automation strategy for manufacturing firms was developed. In pursuing operational excellence, manufacturing industries can greatly adopt and utilize Industry 4.0 technologies such as the incorporation of digital twins, cloud technology, use of data for better decision-making, cybersecurity, employee training, and working with technology partners. The manufacturing managers may continuously use the automation appropriately in manufacturing firms which can greatly enhance their competitive edge. This can be achieved through process selection, technology investment, and systematic plan formulation. Top management of manufacturing firms may improve their level of competitiveness through the use of data analytics and business intelligence enhancement tools to understand how production activities, customer practices and the markets operate for purposes of making more accurate and efficient decisions. The enhanced technological automation strategy may be used by manufacturing firms to improve productivity. Future researchers may delve on merging technologies, Industry 4.0, human-machine collaboration, and ethics which will make great contributions. In this way, researchers will further the knowledge base concerning the ability of digitalization and automation to change the face of manufacturing.

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