AN EXAMINATION OF THE DIFFICULTIES LINKED TO THE INTEGRATION OF INDUSTRY 5.0 INTO THE MANUFACTURING PROCESSES OF MACHINERY AND ELECTRONICS.

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ABSTRACT

The goal of the fresh approach to manufacturing known as "Industry 5.0" is to completely alter the product development, design, and production processes. Understanding how technological complexity impacts production processes was the focus of this research, which took place within the context of Industry 5.0 in the machine manufacturing industry. Individuals need to understand how increasingly complex technologies impact industrial outcomes since Industry 5.0 is pushing for human-centredness, better robotics, and digital integration. Industrial processes, such as resource management, efficiency, and optimisation, are examined in relation to the effects of technological complexity, which includes automation, cyber-physical systems, and human-robot interaction. As part of quantitative research, 686 participants were polled using 5-point Likert scale questions, and the results were evaluated using SPSS version 25. Testing the hypothesis that technological complexity significantly affects production processes was the primary goal of the study. This proves that process management, adaptability, and efficiency in production are all improved with increasing technological complexity. However, the findings also highlighted problems that emerged due to increasing system integration costs, difficulties in troubleshooting, and the need for seasoned personnel capable of running complex electronics. Research shows that the output of Industry 5.0 increases as the technology gets more complicated. However, at this level of complexity, workers need to be trained, and systems need to be integrated. Businesses should use technology to their advantage while also fixing problems with operations and people management to build production that can handle changes and keep running smoothly. Henceforth, the respective study has concluded that there is a significant relationship among high implementation costs and manufacturing processes of electronics.

Keywords: Industry 5.0; manufacturing process of electronics; high implementation cost; production procedures; difficulties of integration.

INTRODUCTION

A significant transformation is imminent for the manufacturing industry with the arrival of the fifth industrial revolution. This new paradigm is striving to bring about a change in product creation, production, and distribution. The term "Industry 4.0" refers to a significant deviation from the normal procedures of mass manufacturing that were in place at the time. It comprises a fundamental move towards an approach that is more flexible and individualised, making use of the most recent advancements in artificial intelligence (AI), robots, and the Internet of Things (IoT). This is in stark contrast to these traditional ways. On the other hand, there are several major difficulties associated with Industry 5.0 (Massaro, 2021). Integration of several systems and maintenance of data security are two technical problems that must be overcome to ensure the successful deployment of Industry 5.0. To top everything off, the move to Industry 5.0 necessitates a significant financial commitment in both hardware and software. Smaller businesses may find this to be a challenging situation. Human resource difficulties are an additional challenge since Industry 5.0 calls for employees who possess a high level of expertise and are also skilled at working with emerging technology. Implementing this may prove to be challenging because of the high cost and the time commitment required to learn new skills, both of which vary depending on the company and the location. Before society has an opportunity to incorporate the social difficulties that have been brought about by the fifth industrial revolution, significant study must be given to the topic. An exemplification that assists in putting this notion into further perspective is the possibility that some workers may be required to leave their current positions of employment. Purchasing raw materials and designing components are the first steps in the electronics manufacturing process. The next steps are the production of semiconductors and printed circuit boards (PCBs) (Dehghan et al., 2025). Following the installation of components utilising surface mount technology (SMT) or throughout-hole methods, these PCBs must endure extensive verification and quality assurance procedures. Everything is put together in the final configuration, or "box-built," beforehand it is packaged and sent to the customer.

BACKGROUND OF THE STUDY

For the last fourteen years running, China's manufacturing sector has ranked first globally. With a value of 5.57 trillion USD in 2023, the manufacturing industry is clearly significant. The "Little Giant" also alludes to the ways in which SMEs have maintained their competitive advantage, expanded their customer bases, and raised production via the use of cutting-edge technology. Industry and industrial sectors are the focus of the fifth aim, which emphasises the significance of integrating cutting-edge technology and novel approaches. Industrial operations may become more efficient, productive, and environmentally sustainable by implementing Sustainable Production (SusP) and Connected Enterprise operations (CEPs) (Xiang et al., 2023). Programmes like CEPs and Sustainable Production (SusP) strive to build smarter, more eco-conscious, and more interconnected production systems, and this goal is at their core. The main goals of CEPs are process simplification, real-time communication quality enhancement, and digital integration of all production stages. Green resources, waste reduction, and eco-friendly practices are the pillars around which SusP builds its advocacy for sustainable industrial advancement. More efficient, productive, and environmentally friendly corporate operations are the end aim of these methods. Their ultimate objective is to establish a prosperous manufacturing sector that contributes positively to both the environment and economic growth. The purpose of these endeavours is to advance industry via the use of digital transformation, environmental consciousness, and robots to make it more competitive. As individuals go from the first stage of mechanisation into the fifth stage of customisation, the rapid application of information technology in production is really propelling the industrial revolution forward (Li et al., 2024). Although evolution has many positive effects, it also brings new challenges for humans to overcome. Getting to know the real possibilities of more successfully integrating more information technology into their operations is the biggest challenge that SusP faces when adopting industry 5.0.

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PURPOSE OF THE RESEARCH

The title of the article suggested that the author has the intention of investigating the principal difficulties that manufacturers encounter when they endeavour to incorporate the tenets of Industry 5.0 into the manufacturing procedures that they are already utilising. This paper analyses the technical, operational, organisational, and human factors that may impede the integration of Industry 5.0 technologies into the manufacturing of equipment and electronics. These technical advancements included the utilisation of cyber-physical systems, sophisticated automation, HMI, and AI. Researchers utilised this information to come up with ideas and solutions that may help people move to the smarter, more adaptable, and more environmentally friendly methods of creating goods that were common in Industry 5.0. These solutions may also make it easier for consumers to adopt new technology. The main goal of the study is to help people who work in the industry find good ways to deal with problems and make the most of Industry 5.0's features to improve the quality of things, get workers more involved, and make production more efficient.

LITERATURE REVIEW

Requirements and technological possibilities determined the nature of the human-computer interaction. Modifications regarding manufacturing concepts and subsequent technological developments show how this link has evolved over time. There was a shift in the connection because of how technology was developing. Considering the outcomes and results presented in a variety of recent publications, a literature study was conducted for a prior study. Scientists have compiled a laundry list of innovations that make up Industry 5.0 and that improve upon Industry 4.0. Security of data and technological development were two of the many problems that Industry 4.0 attempted to solve, and these are now part of Industry 5.0. One of the most important features of Industry 5.0, which paved the way for hyper-personalization and the development of custom items to meet the demands of different consumers, is resiliency (Khan et al., 2023). Industry 5.0 succeeded where Industry 4.0 failed because this investigation laid the groundwork for investigators and companies to learn about Industry 4.0's innovations, problems, and developments in technology. This paper also includes a compilation of the most recent uses of these developments, which can give a good sense of how to put them into practice. Transformation in the machine-human interaction was the focus of an earlier article that attempted to assess its current state and to point to its future trajectory. The essay encompasses an analysis of literature that examines the human and machine connection via the viewpoint of Industry 5.0 (Pizoń & Gola, 2023). Considering the advancements regarding technology brought about by Industry 4.0 and the fifth industrial revolution, the human element is being given its rightful place in manufacturing. As a result, this study's approach draws from a wide range of sources, including both specialised papers and review articles that provide an overview of the topic at hand. To show the connections between the problems that served as the inspiration for constructing the plan. Investigations of businesses that have effectively used Industry 5.0 were also featured in the article. In addition to discussing possible future academic and technological paths, this article also looks at the possible effects on the community and production. Also covered are the legislative consequences of Industry 5.0, such as the necessity of governmental backing to ease the transition to this newer model (George & George, 2023). This study concludes with an extensive review of the opportunities and threats posed by Industry 5.0. It looks at how this new paradigm might affect humanity and the production sector, and it pinpoints the major obstacles that need to be overcome before Industry 5.0 can be completely realised.

RESEARCH QUESTION

What is the impact of high implementation costs on manufacturing processes of electronics?

RESEARCH METHODOLOGY

Research Design: This study used a quantitative research technique for the examination. The statistical analysis was performed with SPSS version 25. The demographic data was elucidated using descriptive statistics. The researcher examined odds ratios (OR) with a 95% confidence interval (CI) to determine the intensity and direction of the connections. A p-value < 0.05 indicates statistical significance of the findings. The capacity of quantitative methods to do comprehensive statistical analyses and systematic evaluations of survey data is resulting in their heightened utilisation.

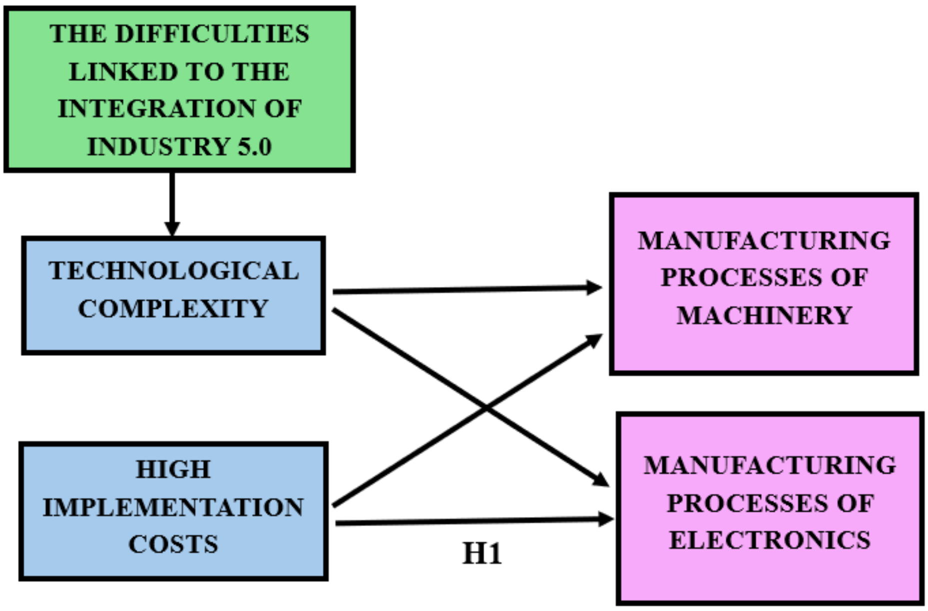
Sampling: To correctly depict the study population, researchers used a basic random sampling method. A minimum of 635 individuals was required for a viable sample, as per the Rao-soft methodology. Researchers administered seven hundred fifty questionnaires. 16 out of 702 responses were discarded due to incompleteness. Consequently, 686 valid responses were included in the total sample.

Data and Measurement: The main source of information for the study was surveys. The poll included a 5-point Likert scale examining conventional and digital media concerns, while part A gathered fundamental demographic information. Secondary data was mostly gathered from several online and offline sources.

Statistical Software: The researchers performed the statistical analysis using SPSS 25 and MS Excel.

Statistical Tools: A descriptive technique was used to meticulously analyse the data. Factor analysis is the optimal method for evaluating reliability.

CONCEPTUAL FRAMEWORK



RESULT

Factor Analysis: Factor Analysis (FA) seeks to uncover unknown components by utilising publicly available data. When there are no obvious visible or diagnostic signs, evaluations often depend on regression coefficients. Our primary goal in doing this research is to identify any potentially detectable connections, vulnerabilities, or breaches. Multiple regression studies provide the datasets utilised in Kaiser-Meyer-Olkin (KMO) tests. Both the theoretical model and its sample parameters produce reliable predictions, according to the results. It is possible to find data entries that are duplicates. Simplifying the proportions enhances the readability of the data. From a range of 0 to 1, KMO assigns a number to the researcher. A sufficient sample size is defined as having a KMO value between 0.8 and 1.

These levels are deemed appropriate by Kaiser: According to Kaiser's specifications, the following are the prerequisites for approval: An appalling 0.050 to 0.059, well below the usual range of 0.60 to 0.69. The typical range for middle grades is between 0.70 and 0.79. A quality point score between 0.80 and 0.89. The interval from 0.90 to 1.00 astounds them.

According to the Kaiser-Meyer-Olkin scale: 0.875

The results of Bartlett's test of Sphericity are as follows: 4523.721 is the approximate chi-square value

190 is degrees of freedom (df); sig = 0.000.

Table 1. Examination of KMO and Bartlett's Sampling Adequacy.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.875
Bartlett's Test of Sphericity	**Approx. Chi-Square**	4523.721
	df	190
	Sig.	0.000

In most cases, this makes applying sample criteria easier. To determine if the correlation matrices were statistically significant, the researcher used Bartlett's Test of Sphericity. A sufficiently large sample is defined as one with a Kaiser-Meyer-Olkin value of 0.875. The results of Bartlett's Sphericity test are 0.00. It can be concluded that the correlation matrix is not original as Bartlett's Sphericity test produced a positive result.

INDEPENDENT VARIABLE

Difficulties linked to the integration of industry 5.0: There are a lot of obstacles to integrating Industry 5.0, such as high expenditure expenses, a shortage of qualified workers, worries about cybersecurity caused by increased communication, the difficulty of improving present manufacturing processes, problems with adjusting human-focused operating models, and complicated regulatory environments (Mazhar et al., 2024). Obtaining specialised distribution networks, mitigating the adverse environmental effects of increasing energy consumption, and achieving widespread implementation across a variety of business types and industries are additional obstacles. Human intelligence is combined with the delicacy and effectiveness of robots in the sphere of industrial manufacturing using AI, which is how Industry 5.0 is implemented. The fifth stage of industrial development, known as Industry 5.0, was created to address issues that had emerged during the fourth stage by encouraging human interaction and fulfilling the demands of community. It possesses the capacity to diminish or eliminate the lack of consistency that exists between the needs of humanity and the manufacturing of items for sale (Sharma et al., 2022). The fifth industrial revolution is going to require intricate structures such as smart houses, cobots, and networking data from sensors integration, among other technological advances. Cooperative robots, which are often referred to as cobots, can help controllers achieve greater quickness and accuracy. Giving workers responsibilities that are more rewarding and influential in the fabrication and commercial manufacturing domains is one of the priorities of Industry 5.0.

FACTOR

High implementation costs: The high expenses associated with implementation in the electronics industry are caused by several factors. These include the need for a highly qualified personnel member, precise quality assurance and inspection procedures, specialised packages, sophisticated printed circuit board (PCB) production, purchasing of complicated and costly materials (such as semiconductors), and specialised equipment. There are a lot of costs, both initial and perpetual, associated with logistics instability, keeping up with fast technology changes, complying with regulations, and protecting proprietary information (Wagner et al., 2020). The necessity for innovative technology, specialised machinery, and ongoing innovation frequently results in expensive installation expenses in electronics production procedures. To build manufacturing lines that fulfil stringent quality requirements, it is necessary to spend heavily in robotics, precise equipment, and sterile infrastructure. As a result of the need to keep up with ever-evolving technology, costs related to research, and development also add to the already substantial initial investments (Gold et al., 2022). Additional expenses are caused by the need for trained workers, expensive education, and the need to comply with global regulations. Environmental procedures, managing the supply chain, and procuring supplies from suppliers all contribute to higher costs. The smaller companies may find it difficult to compete with these high costs, which force big manufacturers to find ways to maximise effectiveness.

DEPENDENT VARIABLE

Manufacturing processes of electronics: With the goal to create electronics that can compete on a worldwide scale in terms of quality, dependability, and effectiveness, manufacturers employ several complex and technically sophisticated procedures. Technicians create circuitry designs and evaluate their efficiency during the conceptualisation and experimentation step, which usually begins with the procedure (Wiklund et al., 2021). The manufacture of semiconductors takes place in cleanrooms after the designs have been finalised, guaranteeing that there is minimum contamination. The process of fabricating semiconductors on silicon wafers involves photolithography, engraving, coating, and depositing. After that, electronic parts are assembled and supported by PCBs. The placement and soldering of elements on PCBs are accomplished with great precision using SMT and hole-punching manufacturing methods (Khan et al., 2020). When it comes to large manufacturing, sophisticated automation—which includes robotics—is crucial for achieving swiftness, precision, and reliability. To find problems quickly and keep the goods reliable, surveillance and monitoring are incorporated into the whole process. Afterward, items like desktops, gadgets for consumers, and handsets are put together by packing, marking, and integrating their individual parts. Processes are being influenced by sustainability and ecological problems increasingly, which has resulted in initiatives such as recycling and energy-saving techniques. To keep up with the increasing needs of an ever-growing sector, the production of electronics necessitates heavy spending on R&D, trained workers, and new technology.

Relationship between high implementation costs and manufacturing processes of electronics: Due to the sector's emphasis on modern technology, accuracy, and creativity, there is an immediate connection between advanced production procedures and high implementation costs. The production of electronics necessitates the use of expensive and complex machinery, including cleanroom facilities, computerised machine shops, and fabrication of semiconductors equipment. Businesses must evolve regularly to match customer requirements for quicker, lighter, more effective and affordable devices, which means the expenses aren't restricted to network but also extended to R&D (Kumar et al., 2024). Excellent accuracy and cutting-edge equipment are required for the procedures themselves, which include PCB assemblage, interface mounting innovation, and the production of semiconductors. Because a highly specialised staff is required to ensure excellence and effectiveness, the cost of skilled labour and ongoing training is high. The burden of money is further increased by the need for conformity to global criteria and comply with regulations, particularly those pertaining to security and sustainability. Composting and renewable energy manufacturing are two examples of ecologically conscious initiatives that necessitate substantial investments in new technology. Smaller companies may find it difficult to remain competitive with larger companies in the industry if execution costs are high (Pizoń & Gola, 2023). To keep up with the rapidly changing market, larger firms are forcing themselves to automate more of their processes, optimise their expenses, and take advantage of efficiencies of magnitude.

The researcher has developed the following hypothesis considering the foregoing discussion to assess the relationship between high implementation costs and manufacturing processes of electronics:

"H_{01}: There is no significant relationship between high implementation costs and manufacturing processes of electronics."

"H_1: There is a significant relationship between high implementation costs and manufacturing processes of electronics."

Table 2. H1 ANOVA Test.

ANOVA					
Sum					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	36,487. 840	320	4576.587	925.432	0.000
Within Groups	320.770	365	7.286		
Total	36,808.61	685			

This inquiry has yielded substantial findings. With a p-value of 0.000 and an F-value of 925.587, both of which are lower than the 0.05 alpha level, statistical significance is shown. The results determines that the **"H1: There is a significant relationship between high implementation costs and manufacturing processes of electronics"** has been accepted, and the null hypothesis has been rejected.

DISCUSSION

Within the context of Industry 5.0, the study examined how technological complexity affects machine manufacturing production processes. The results demonstrated a strong correlation between these factors, lending credence to the theory that more complicated technologies improve production processes. More automation, integrated cyber-physical systems, and robotic and human collaboration are all signs that industrial processes have grown more effective and adaptive as technological complexity has increased. Other research has shown that more complicated technologies lead to improved process management, predictive maintenance, and resource optimisation; our findings support this. There are certain drawbacks to increasing complexity that the research highlighted. These include the need for more experienced workers and the difficulty of addressing some challenges. Although technology has the potential to increase efficiency and adaptability, the results demonstrated that substantial financial investment is still required to integrate systems and educate personnel. Both the influence of technological complexity on modern production processes and the significance of incorporating new technology into Industry 5.0 frameworks were brought to light by the study's conclusions. Pay particular attention to the consequences of this research's conclusions if individuals are an industry stakeholder who wants to increase operational efficiency using new technology while keeping costs and complexity in control.

CONCLUSION

Lastly, the study looked at how business 5.0 frameworks affect machine manufacturing production processes as a function of technological complexity. According to the research, technical complexity had a major impact on industrial processes, but increased automation and new technology made them more predictable and easier to govern. There was a strong correlation between technical complexity and production processes, as shown by the study's findings (including a huge F-value and a p-value that was statistically significant). The data show that as technology complexity rose, greater process management led to higher manufacturing outputs. This invention has presented other hurdles, including troubleshooting and maintenance, due to the complex and interconnected equipment. The study emphasised the need to achieve equilibrium between operational flexibility and technological progress. It underscored the need for highly competent individuals with remarkable problem-solving capabilities to manage escalating complexity. The research concluded that technological complexity has a major effect on production procedures. This led to the development of more intelligent, flexible, and efficient production methods that were in line with Industry 5.0 standards. With this data in hand, factories may use cutting-edge tech to fix problems and construct more robust and long-lasting production spaces.

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