AN ANALYSIS OF THE CHALLENGES ASSOCIATED WITH INCORPORATING INDUSTRY 5.0 INTO THE PRODUCTION PROCEDURES OF MACHINE AND ELECTRONIC MANUFACTURE.

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ABSTRACT

In the setting of Industry 5.0 in the machine manufacturing sector, this study looked at how the complexity of technology affects the ways things are made. As Industry 5.0 pushes for human-centredness, improved robotics, and digital integration, it is important to know how industrial results are affected by more complicated technologies. The study investigated the manner in which technological complexity—which comprises automation, cyber-physical systems, and human-robot cooperation—has an impact on industrial processes, including the management, efficiency, and optimisation of resources. By using a quantitative study method, questions with a 5-point Likert scale were sent to 686 people, and data were gathered and analysed using SPSS version 25. The research examined the premise that the level of technical complexity has a substantial impact on manufacturing operations. The results showed a strong, statistically significant association, which was proven by an F-value of 1135.563 and a p-value of .000. This indicates that greater technical complexity has a favourable effect on manufacturing efficiency, flexibility, and process management. The results, on the other hand, also drew attention to the issues that arose as a result of the increased system integration costs, troubleshooting obstacles, and the need for experienced individuals who were capable of operating complicated equipment. Studies show that technical complexity increases Industry 5.0 production, but it also calls for system integration and employee education. It is advised that industry participants use technology while simultaneously tackling operational and human resource issues in order to create sustainable, effective, and resilient production.

Keywords: Industry 5.0, machine manufacturing, electronic manufacturing, technological complexity, production procedures.

INTRODUCTION

The manufacturing industry is on the cusp of experiencing a substantial transition as a result of the emergence of sector 5.0. The objective of this completely new paradigm is to bring about a change in the way that things are designed, produced, and brought to market. This is a considerable divergence from the conventional mass manufacturing techniques that were used during the time that is referred to as Industry 4.0. As opposed to these traditional techniques, it includes a significant change in the direction of an approach that is more adaptive and tailored to the person, capitalising on the most current innovations in artificial intelligence, robots, and the Internet of Things (IoT) (George & George, 2023). On the other hand, there are also major obstacles linked with Industry 5.0. In order to ensure the effective implementation of Industry 5.0, technical difficulties such as the integration of different systems and the maintenance of data security must be overcome. On top of that, there is a large amount of capital that must be invested in both hardware and software in order to make the shift to Industry 5.0. Smaller businesses may find this to be a hurdle. There are additional challenges related to human resources since Industry 5.0 necessitates employees who are not just highly qualified but also able to deal with emerging technology. Depending on the organisation or region, this may be a challenge to put into practice since it will be necessary to invest a significant amount of time and money in order to acquire and cultivate new abilities. The fifth industrial revolution brings with it social considerations that have to be carefully considered when it is brought into society. The likelihood that some employees might be forced to leave their existing roles is one example that serves to highlight this point (Dehghan et al., 2025).

BACKGROUND OF THE STUDY

In China, the production sector has been the best in the world for fourteen years in a row. It is clear that the manufacturing sector is important because it hit a value of 5.57 trillion USD in 2023. The "Little Giant" also refers to how small and medium-sized businesses have increased their output by using innovative technology, created special markets, and kept their competitive edge. The fifth goal is all about the industry and industrial areas, and putting innovative technology and new ways of doing things together is very important. Employing Connected Enterprise operations (CEPs) and Sustainable Production (SusP) may enhance the efficiency, productivity, and environmental sustainability of industrial operations. This objective is central to programmes such as Sustainable Production (SusP) and Connected Enterprise Processes (CEPs), which aim to create more intelligent, environmentally aware, and linked manufacturing systems (Wen et al., 2022). The primary aims of CEPs are the digital integration of all production stages, the improvement of real-time communication quality, and the streamlining of processes. To support long-term progress in industry, SusP pushes for green resources, reducing waste, and environmentally friendly methods. The goal of these approaches is to make business processes more efficient, productive, and good for the environment. Their long-term goal is to build a successful industrial sector that is good for the environment and can keep the economy growing. The goal of these activities is to make industry more competitive and move it forward by using robotics, digital change, and environmental responsibility. Going beyond the first phase of mechanisation and into the fifth phase of personalisation, the industrial revolution is really being propelled ahead by the manufacturing industry's fast use of information technology. This evolution not only produces beneficial outcomes, but it also presents obstacles for people. The greatest obstacle that SusP has while using I5.0 is becoming familiar with the true potential of more effectively incorporating added information technology into their operations (Guo & Xu, 2021).

PURPOSE OF THE RESEARCH

The research topic "An Analysis of the Challenges Associated with Incorporating Industry 5.0 into the Production Procedures of Machine and Electronic Manufacturing" aims to look into the main problems and issues that manufacturers face when they try to use Industry 5.0 ideas in their current production methods. This study examines the technical, operational, organisational, and human factors that may impede the integration of Industry 5.0 technologies into the manufacturing of machinery and electronics. Some of these technologies included cyber-physical systems, sophisticated automation, human-robot interaction, and AI. Researchers were able to utilise this information in order to come up with ideas and solutions that may make it simpler for people to make the transition to the smarter, more adaptable, and more ecologically responsible manufacturing processes that were characteristic of Industry 5.0, as well as make it easier for consumers to adopt new technology. The main goal of the research is to assist individuals who work in the industry in coming up with effective solutions to hurdles and to make the most use of Industry 5.0's capabilities in order to increase the quality of goods, the involvement of workers, and the efficiency of production.

LITERATURE REVIEW

Combining smart grids with Industry 5.0 technologies is quite hard. Concerns like standardisation, scalability, and compatibility are all part of this group. There is no guaranteed way to integrate since diverse technologies and devices do not all use the same communication protocols. Also, the high initial costs of installing smart grid parts like sensors, AMI, and energy storage systems make it extremely hard for small and medium-sized businesses (SMEs) to do so. Potential solutions to these obstacles including the use of open standards to ensure interoperability, staggered implementation plans in order to decrease costs, and funds from the government to encourage research and deployment. Furthermore, vendor cooperation platforms and public-private partnerships are essential in tackling these problems via the exchange of resources and the acceleration of technology innovation. Incorporating electric cars into microgrids is a viable option that improves both energy optimisation and system scalability (Sharma et al., 2022). Productivity in Industrial 5.0 may be improved by implementing the primary approach of optimisation, which consists of two distinct categories: machine-level optimisation and general system optimisation. The usage of algorithms using artificial intelligence for the development of online process parameters is of significant importance when it comes to increasing the performance and efficiency of industrial processes. A production technique is made up of a wide range of industrial equipment, whereas an assembly line is composed of a number of different production systems.

Equipment maintenance expenses might be decreased or optimised as a result of this. Personnel expenditures, in addition to maintenance, renewal, and replacement charges, are among the several components into which costs are broken down. The expenditures fluctuate in accordance with the condition of the equipment (Bhat & Parvez, 2024). Systems must adapt and change to keep up with the current trends in production settings, which are changing at a fast pace. The ability to adjust to changes in procedure conditions, the number of components to be built, quality requirements, and readily accessible components are all part of those requirements. To keep up their excellent standards of workmanship, efficacy, and effectiveness, they will have to be agile when challenged with novel innovations, volatile markets, and unplanned interruptions. Maintaining competitive and meeting the changing expectations of businesses and clients in the modern marketplace requires intelligent, strong, and consistently efficient factory operations in complex production environments (Martini et al., 2024).

RESEARCH QUESTION

How does technology complexity impact the production procedure of machine manufacturing?

RESEARCH METHODOLOGY

Research Design: A quantitative research strategy was used to conduct the investigation in this study. The statistical analysis was conducted using SPSS version 25. The demographic data was made more understandable by the use of descriptive statistics. To find out the strength of and in what direction the relationships were, the researcher looked at odds ratios (OR) with a 95% confidence interval (CI). When the p-value is below 0.05, the results are considered statistically significant. The ability of quantitative techniques to conduct thorough statistical analyses and systematic assessments of survey results is leading to their increased use.

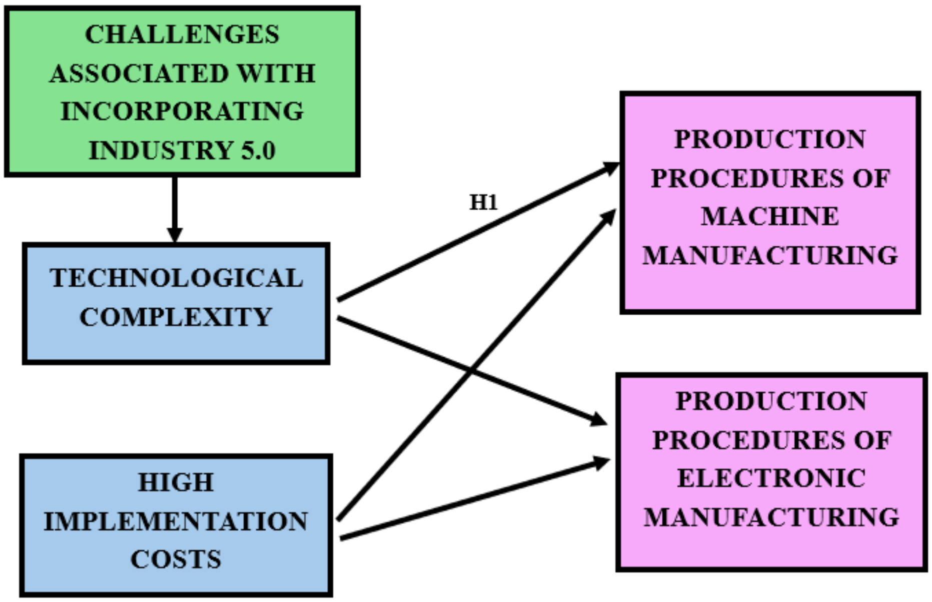
Sampling: In order to accurately represent the study population, researchers used a simple random sampling approach. A minimum of 635 persons was needed for a valid sample, according to the Rao-soft approach. Researchers distributed seven hundred fifty surveys. Due to incompleteness, sixteen out of 702 replies were rejected. As a result, 686 legitimate replies were included in the overall sample.

Data and Measurement: The majority of the information for the research came from surveys. A 5-point Likert scale addressing issues related to traditional and digital media was part of the survey, while part A collected basic demographic information. Secondary data was mostly culled from a variety of online and offline resources.

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

Statistical Tools: To thoroughly examine the data, a method based on descriptions was used. When assessing dependability, factor analysis is the way to go.

CONCEPTUAL FRAMEWORK



RESULT

Factor Analysis: The essential foundation of a group of measuring items may be checked using factor analysis (FA). The idea that hidden effects could influence the outcomes of apparent ones is a prevalent misconception. Precision analysis (FA) is a framework-based method. Identifying the nature and source of measurement errors and their relationship to observed events is a primary objective of this endeavour. The data may be shown suitable for factor analysis by using the Kaiser-Meyer-Olkin (KMO) method. To make sure there is enough data for the whole model, the scientists double-check that each component has a large enough sample. The findings show that the variances of some of the components are close to one another. Applying factor approximation to reduced datasets improves results. A number between zero and one is the output of the KMO technique. If the KMO number is between 0.8 and 1, testing should be done.

Scientists must rectify the issue promptly, since they have identified a sample that is inadequate (KMO = 0.6). Measurements often vary from 0.5 to 0.6. Enquiring about the consensus among writers is prudent prior to making a definitive selection. Consequently, 0.5 is often used.

When the proportion of incomplete encounters in total connections reaches a statistically significant level, the KMO score approaches zero. Evaluating parts gets much more challenging when important connections are involved.

From 0.050 to 0.059, frequency ranges vary immensely.

• The range of 0.60 to 0.69 is quite adequate.

The median rating ranges between 0.70 and 0.79.

The typical range for point values is 0.80 to 0.89.

When the value is between 0.90 and 1.00, a very unlikely event takes place.

Valued at 0.861 on the Kaiser-Meyer-Olkin scale.

The results of Bartlett's test of Sphericity are as follows: 3252.968 is the approximate chi-square value; 190 is degrees of freedom (df); sig =.000.

Table 1. Evaluating the Appropriateness of KMO and Bartlett's Sampling Method.

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.861
Bartlett's Test of Sphericity	**Approx. Chi-Square**	3252.968
	df	190
	Sig.	.000

A robust correlation between the matrices was shown by the Bartlett's sphericity test. A sample adequacy of 0.861 has been shown by Kaiser-Meyer-Olkin. The researchers obtained a p-value of 0.00 using Bartlett's sphericity test. The sphericity study by Bartlett indicates that the association matrix is incorrect.

INDEPENDENT VARIABLE

Challenges associated with incorporating Industry 5.0: Using artificial intelligence in the field of industrial production, Industry 5.0 brings together human intellect with the accuracy and efficiency of robots. The purpose of developing Industry 5.0 was to provide a solution for the problems that had arisen in Industry 4.0 by fostering human centricity and meeting the requirements of society. It has the potential to reduce or remove the incongruence between the requirements of society and the production of manufactured goods. Network sensor data interoperability, smart homes, cobots, and other advanced systems are all examples of the kind of complex systems that are necessary for the fifth industrial revolution. Operators may increase their speed and accuracy by using collaborative robots, often known as cobots. Industry 5.0 prioritises human beings in the manufacturing and industrial production sectors, offering employees positions that are more fulfilling and impactful (Mourtzis et al., 2022).

FACTOR

Technological complexity: In a nutshell, technical complexity is an essential component and a deciding element with regard to progress. Nonetheless, it is still only implicitly present in the efforts to provide an explanation for the expansion of the economy. Technology is presented in a fairly generic fashion or its richness is reduced, despite the fact that there are clear variations between the technical progress of various nations and the possible ramifications that these differences may have for economic growth (Nepelski & De Prato, 2020). This article offers a framework for the construction of a global technology space and the derivation of complexity indicators that place nations in this space. The extent to which nations' technology portfolios include technologies that are ubiquitous in addition to the measurements of technological diversity are further employed as an input to understand the role of technological complexity in countries' economic progress and wealth (Mewes & Broekel, 2022).

DEPENDENT VARIABLE

Production procedures of machine manufacturing: Thanks to the manufacturing industry's attempts to digitise, more and more people are using machine learning and optimisation methods on the shop floor to improve production processes. Customers are also more willing to try new things when they do not have a lot of resources. For example, they could use machine learning to cut lower on waste, energy use, and time spent on jobs. The current shortage of raw resources, energy, and skilled labour has accelerated the adoption of new methods. It saves money and advances sustainability goals to employ machine learning models to optimise energy consumption, enhance industrial processes, and cut waste. Advanced analytics, adaptive changes, and assertive maintenance save waste and time and help consumption. Businesses in today's resource-constrained world must adopt these cutting-edge ideas if they are to survive (Kumar et al., 2023).

Relationship between technological complexity and production procedures of machine manufacturing: The degree of technical complexity has a moderating influence on the manufacturing process. There are several ways to describe technical difficulty. It is the degree to which robots accomplish the same goals as humans in a given manufacturing process. It was said that manufacturing outcomes could be better predicted and process flows could be better controlled as technological complexity rose. Nevertheless, with increasing automation comes more complex equipment, which in turn makes troubleshooting equipment issues more challenging (Jilke, 2021). It becomes more challenging to identify and repair equipment issues in a highly automated plant due to the interconnected nature of the machinery, the constraints of computer controls, and the elevated level of expertise needed. Project, job shop, batch, assembly line, and continuous flow are the five types of industrial production processes. Nevertheless, by outlining the features of the scale's extremities—job-shop technology and continuous flow technology—the impacts of the various degrees of technical complexity may be made apparent in actual production processes (Guo & Xu, 2021).

In regard to the above discussion, the experimenter in this study set out to assess the following hypothesis on the connection between technological complexity and production procedures of machine manufacturing:

“H_{01}: There is no significant relationship between technological complexity and production procedures of machine manufacturing.”

“H_1: There is a significant relationship between technological complexity and production procedures of machine manufacturing.”

Table 2. H1 ANOVA Test.

ANOVA					
Sum					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	39151.357	361	5857.237	1135.563	.000
Within Groups	365.483	324	5.158		
Total	43725.714	685			

Noteworthy results are produced by this query. An F-value of 1135.563 and a p-value of .000, both of which are lower than the .05 alpha level, indicate importance. This theory, **"H_1: There is a significant relationship between technological complexity and production procedures of machine manufacturing"** is received, whilst denying the null hypothesis.

DISCUSSION

The research evaluated the influence of technical complexity on production processes in the machine manufacturing industry within the framework of Industry 5.0. The findings supported the idea that increased technological complexity has a positive effect on manufacturing processes by showing a significant link between these variables. With a p-value of .000 and an F-value of 1135.563, the statistical analysis indicated an extremely significant connection at the 0.05 level. This indicated that industrial processes evolved to become more effective and adaptable as technological complexity rose, as seen by more automation, linked cyber-physical systems, and robotic and human cooperation. The results corroborated other studies that found increased technological complexity promotes better process management, predictive maintenance, and resource optimisation. The study did point out some of the negative aspects of increased complexity, however, including the necessity for more skilled individuals and the difficulty of overcoming some problems. The findings showed that while technology may make things more flexible and efficient, it still needs a lot of money to integrate systems and train people. The study's findings highlighted the importance of implementing novel technologies into Industry 5.0 frameworks and the impact of technical complexity on contemporary manufacturing processes. Stakeholders in the industry who seek to improve operational efficiency with modern technologies while keeping costs and complexity in check should pay close attention to the implications of this research's results.

CONCLUSION

Finally, the research examined the effects of technical complexity on machine manufacturing production processes within the framework of business 5.0. Increased automation and the incorporation of innovative technology improved process control and predictability, as shown in the study, demonstrating that technical complexity significantly affected industrial processes. The study's results, including the statistically significant p-value and large F-value, supported the premise of a substantial relationship between technological complexity and production processes. Manufacturing results improved as a result of better process management as technological complexity increased, according to the statistics. Nevertheless, because to the interconnected and intricate nature of the devices, this advancement has also introduced new challenges, such as maintenance and troubleshooting. Finding a happy medium between operational flexibility and technical innovation was emphasised in the research. Additionally, it emphasised the necessity for highly trained personnel with superior problem-solving ability when dealing with increasingly complicated issues. According to the study's findings, technological complexity significantly impacted the manufacturing processes. As a result, Industry 5.0-compliant manufacturing processes that were smarter, able to adapt, and more efficient came into being. With this information as a foundation, manufacturers could use modern technology to address issues and build manufacturing environments that were more stable and long-lasting.

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