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Impact of Digital Transformation on Firm Performance: Benedictions and Impediments

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Abstract

This study conducts a systematic literature review to address the imperative of digital transformation in the current fast-paced, fiercely competitive economy. It emphasizes the critical role of digital technology adoption for organizations seeking performance enhancement and competitive advantage. Focusing on the manufacturing sector, the research delves into principal challenges surrounding digital transformation, employing an extensive literature study to explore industrial evolution, success-failure dynamics, and performance indicators. The study employs the Antecedents, Decisions, and Outcomes (ADO) framework, offering a structured evaluation of digital transformation's facets and implications. This work contributes recommendations for future research in the manufacturing sector, aiming at untapped potentials. Studying 86 articles, the paper advances scholarly discourse in digital transformation. The review underscores a robust association between manufacturing firm productivity and digital technology, a result of transformative digital integration.

Keywords: Digital technology, Digital Transformation, Firm Performance, Manufacturing Industry.

Introduction

Technology has significantly impacted the rapidly expanding economy of the twenty-first century. As a result of this immense disruption, referred to as "digital transformation", entirely new methods of conducting business are emerging, as well as new ways of providing services and creating value. The manufacturing industry has experienced a paradigm shift, which has created new opportunities for gaining a competitive edge. This research examines the challenging influence of digital transformation tasks in the manufacturing sector and how they address cost difficulties while demonstrating their tangible effects on firm output through digital technology (1).

Digital transformation (DT) in manufacturing refers to the integration of advanced technologies, such as the Internet of Things (IoT), Machine learning, Artificial intelligence (AI), Cloud Manufacturing (CM), and data analytics, into various aspects of production processes. The implementation of these digital technologies in manufacturing processes offers numerous benefits that significantly enhance firm productivity. However, manufacturing firms that adopt DT often face several challenges, primarily related to cost reduction (2). The adoption and integration of advanced technologies necessitate substantial upfront investments in hardware, software, skilled employee training, and infrastructure changes. It is essential to balance the costs and benefits to achieve higher productivity and efficiency. Moreover, digital technology requires ongoing maintenance, upgrades, and security enhancements, which can negatively impact operating budgets.

This study focuses on the integration of advanced technologies as part of digital transformation (DT) within the manufacturing sector. Specifically, the research examines the role of the Internet of Things (IoT), Artificial Intelligence (AI), and Cloud Manufacturing (CM) in enhancing production processes. These technologies were chosen due to their widespread adoption and significant impact on improving efficiency, enabling real-time data analysis, and optimizing resource management in manufacturing. While other emerging technologies, such as Blockchain and 3D printing, big data also contribute to digital transformation, this study deliberately narrows its focus to IoT, AI, and CM. These technologies have demonstrated a more direct and measurable influence on firm performance in the manufacturing industry.

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By narrowing the focus to these specific areas, the research aims to offer a more profound and thorough understanding of how digital transformation can boost firm productivity and operational efficiency, rather than diluting the analysis by including less relevant or nascent technologies. This concentrated approach will enable clearer insights into the challenges and advantages associated with digital transformation within the manufacturing context.

The main objective of this study is to examine and discuss the current state of the literature on digital technology (DT) and to explain how implementing digital technology can improve firm performance. The study aims to focus on articles centred on DT within the context of firm performance in the manufacturing sector to produce more reliable research on the topic. This review has three research objectives. The first objective is to explore the influence of DT on improving firm performance in manufacturing firms. The second objective is to describe the benefits of digital technology in manufacturing firms. The third objective is to understand how digital tools and platforms enhance firm performance in the manufacturing industry. This research aims to provide a better understanding by addressing the following questions: How did the digital revolution occur and what impact does it have on industrial development?, How does DT provide a competitive advantage to manufacturing firms?, What are the major difficulties or impediments of DT?, Why does DT fail, and why is it crucial to understand the best methods?.

This review holds both theoretical and practical significance. In the academic realm, first, it demonstrates the influence of DT on the manufacturing sector, synthesizing the literature regarding various countries and methodologies. Second, an integrated conceptual framework is proposed based on the literature synthesis, illustrating the factors that contribute to firm performance through DT. Lastly, the systematic literature review uncovers neglected areas in DT research and provides valuable directions to advance research in this domain. Practically, this review offers insights into how DT affects output maximization and cost minimization, ultimately impacting firm performance.

The remainder of this review is organized as follows. The subsequent section outlines the methodology used in this research effort. It is followed by the review analysis, and the following section presents the conclusion. Afterwards, limitations and findings are discussed, which summarize the synthesis of DT's impact on firm performance.

Methodology

Our study employed a Boolean search method, which utilized OR and AND logic operators to connect various terms. The search was focused on articles published between 2005 and 2023, as this time period encompasses significant developments in the field of study. A collection of relevant keywords was selected from prior publications and articles in the same or similar domains. Keywords, abstracts, and titles were thoroughly examined for various term compositions. The search string used was ("Digital Transformation" OR "Smart Factory") AND ("Manufacturing Industry"). To analyze the relationship between digital transformation, firm decisions, and outcomes, we utilized the ADO framework (3). This framework consists of three components: antecedents, decisions, and outcomes. Antecedents refer to the digital transformation in which firms operate, decisions refer to the choices made in adopting and integrating digital technology, and outcomes refer to the impact of these decisions on firm performance. The ADO framework provides a structured approach to digital transformation, guiding firms from identifying the need for change to realizing the benefits of technology integration.

Extraction

The objective of this review is to offer a comprehensive summary of the research domains that address the challenges associated with DT contexts and assess their influence on the manufacturing industry. To achieve this goal, we conducted a thorough analysis of the search results, using various quality criteria. Initially, we manually reviewed the content of the papers, abstracts, and titles, and then established specific criteria for selecting or rejecting studies.

Inclusion and Exclusion Criteria

The review must pertain to DT and its impact on firm performance. The methodology employed in the study must be clear and transparent. The research must be grounded in reliable sources and periodicals. The articles must have been published between 2005 and 2023, and written in English. Only peer-reviewed articles and conference papers were considered, while editorials, unpublished articles, and books that were not peer-reviewed were excluded. Utilizing the Scopus database search query, a total of 1014 papers were generated. The abstract, keywords, and title were used to select publications that would support the conceptual model. After implementing the exclusion strategy, the Scopus database yielded 376 papers. Finally, a total of 86 papers were thoroughly examined in the systematic literature review, based on their relevance to the research objective.

Conceptual Framework

Digital technology is crucial for achieving two primary objectives, output maximization and cost minimization. These objectives can impede the enhancement of manufacturing firm performance, as demonstrated in Figure 1. Output maximization entails increasing the quantity or quality of products/services, while cost minimization involves reducing operational expenses. The ultimate goal is to improve the overall performance of the manufacturing firm by integrating digital technologies strategically, which promote efficiency, innovation, and competitiveness. The Resource-Based View (RBV) and Dynamic Capabilities theory provides a sound theoretical basis for understanding how digital technology, enabled by digital technologies, can lead to output maximization, cost minimization, and improved firm performance.

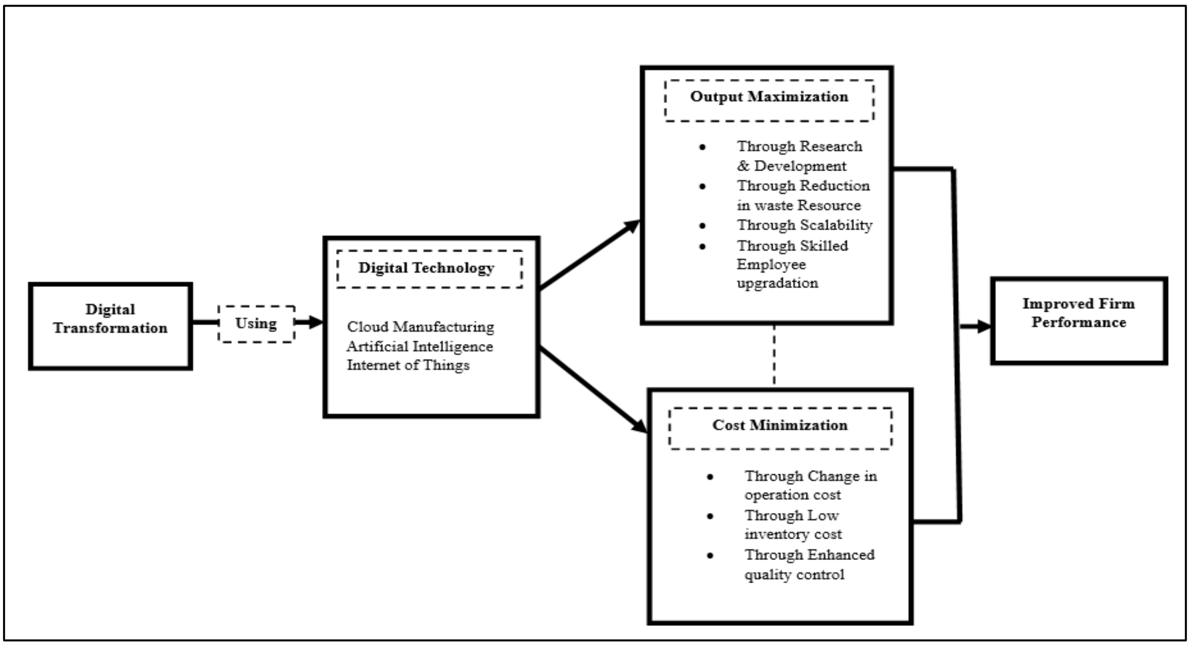

Figure 1: Conceptual Framework of Impact of Digital Transformation on Firm Performance

The Resource-Based View posits that an organization's resources and capabilities are crucial for achieving competitive advantage. In this context, technology innovation enhances operational processes, providing firms with unique capabilities that can lead to superior performance. This technological advancement improves staff adaptation by equipping employees with the necessary tools and training to effectively engage with new systems, thus leveraging these resources to their fullest potential. Moreover, the Dynamic Capabilities Theory emphasizes the importance of an organization's ability to adapt, integrate, and reconfigure internal and external competencies to address rapidly changing environments. A well-adapted workforce is integral to this adaptability, enabling organizations to enhance customer engagement through proficient use of digital tools that meet evolving customer needs and expectations.

By mapping these interrelationships, this model demonstrates how digital transformation enhances efficiency, innovation, and competitiveness within organizations. This framework serves as a valuable reference for researchers and practitioners alike, guiding empirical research by framing hypotheses and informing data collection methods. Ultimately, theoretical model illustrates the interconnectedness of these variables and emphasizes the vital role of digital transformation in driving organizational effectiveness and improving performance outcomes. This comprehensive approach promotes continuous improvement and fosters communication among stakeholders, ensuring alignment of goals and strategies related to digital transformation within the organization.

Analyzing the effects of digital transformation on these particular dimensions would be highly advantageous, especially in the manufacturing sector, where digital technology encompasses the use of advanced tools and solutions to revolutionize and optimize various aspects of the production process. Digital transformation in manufacturing fosters enhanced performance, competitiveness, and growth by maximizing output and minimizing costs. Our research highlights that technologies such as Cloud Manufacturing (CM), artificial intelligence (AI), and the Internet of Things (IoT) play pivotal roles in driving key processes, including research and development, waste resource reduction, scalability, and employee skill upgradation. These advancements not only improve operational efficiency but also contribute significantly to overall firm performance, positioning organizations for long-term success in an increasingly competitive market. By focusing on these dimensions, manufacturers can unlock the full potential of digital technologies to foster innovation and sustainable growth.

Results and Discussion

Publication of Papers from 2005 to 2023

Each year, a substantial number of publications are released on DT, as illustrated by the significant rise in the number of papers published on this topic since 2018, with an annual increase of 40 articles, as depicted in Figure 2. The steady growth in the total number of papers published on DT is expected to continue, as projected in Scopus. By the end of 2022, it is anticipated that the largest proportion of papers produced will be 27%, while the lowest will be 1% in 2015.

Distribution of Scholarly Articles by Country of Publication

Additionally, an index of the countries that have made the most significant contributions to the field was generated using the Scopus database and depicted in Figure 3. Over the past decade, it has been observed that so-called industrialized countries, such as China, India, and Germany, with contributions of 24%, 19%, and 10%, respectively, have made the greatest contributions. China, India, and Germany occupy the top three positions in the ranking. Among the top five are the United States and Italy. The research utilized the author's home country as a basis for examining the role that various countries play in the literature on digital transformation in manufacturing firms.

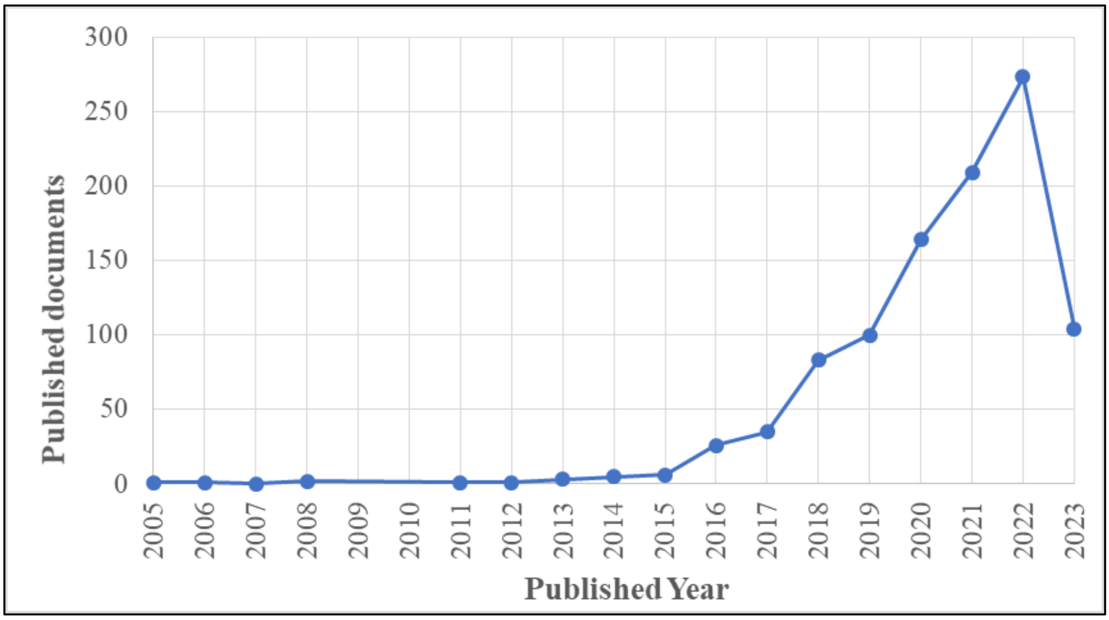

Figure 2: The number of papers published each year (n=1014) used by Authors in selected Literature

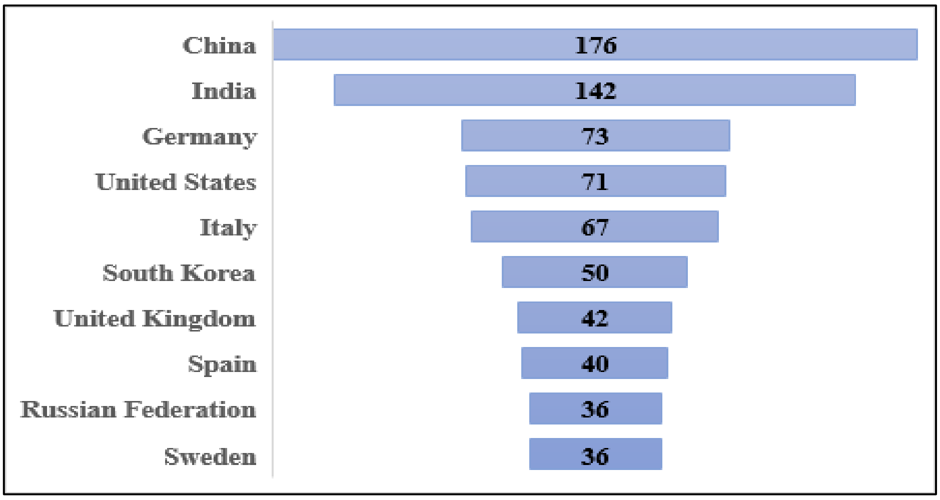

Figure 3: Articles Published by Author Countries

Analytical Methods Used in Articles

Among the studies that were included in the review, 37 of them employed a quantitative method, while 36 studies utilized a qualitative method. Only 7 studies used a mixed method approach. These details are depicted in Figure 4 and Figure 5. In the research on digital transformation's impact on firm performance, several analysis techniques were utilized. In 27 of the studies, systematic literature reviews were the most commonly used method. Additionally, Structural Equation Modeling (SEM) emerged as the second most frequently utilized methodology in the investigation of digital transformation, having been employed in 15 studies. Furthermore, regression analysis was used in 8 studies.

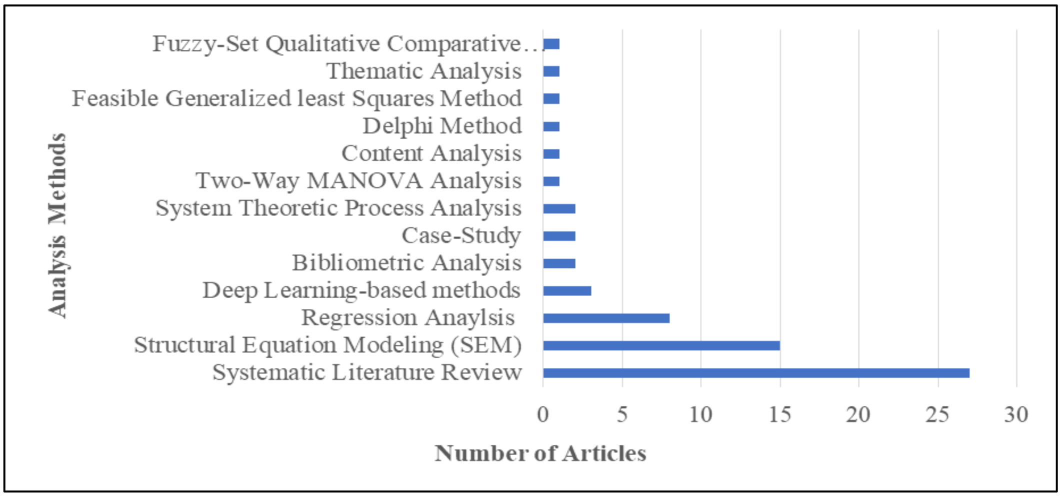

Figure 4: Analysis Techniques used by Authors in Selected Literature

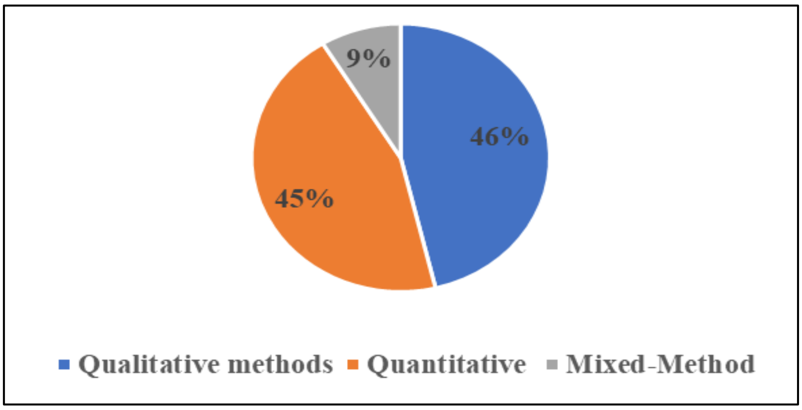

Figure 5: Research Methods used by Authors in Selected Literature

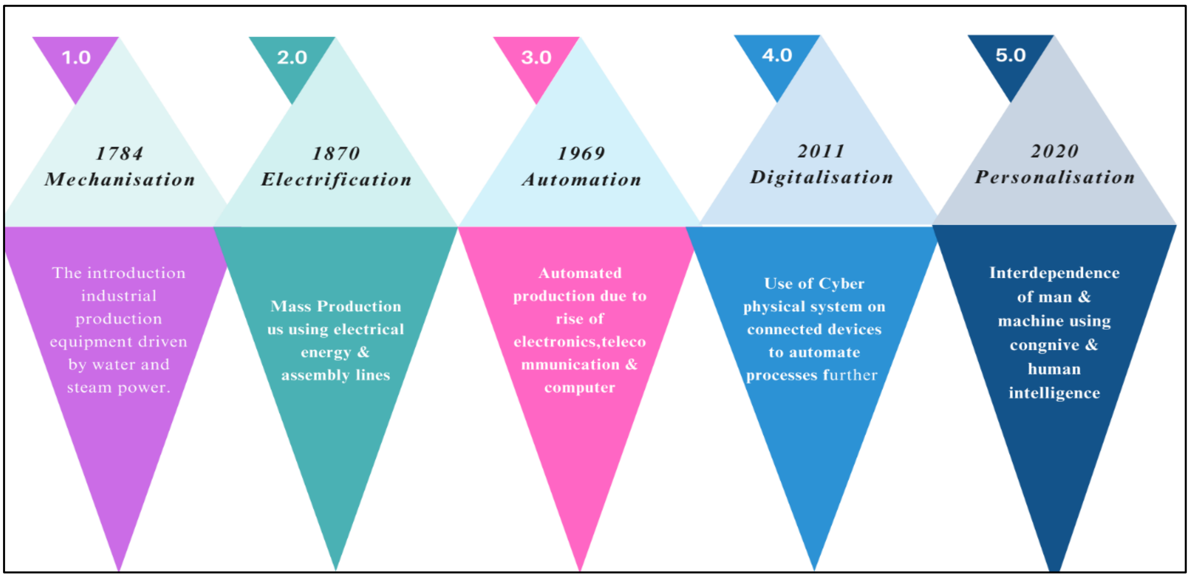

Figure 6: Illustration of Industrial Evolution

Digital Revolution on Industrial Development

Process industries have embraced digital technology since the 1980s to improve efficiency, promote safety, and gain a better understanding and management of resources. For almost 50 years, the field of industrial automation (IA) has been the driving force behind the third industrial revolution. Figure 6 depicts the Industrial Development.

The advent of the industry in 1974 marked a significant turning point in how industries generated revenue. The construction of mechanical industrial infrastructures for water and steam-powered machinery in the 1800s resulted in the emergence of Industry 1.0. This era brought substantial benefits to the economy as production capacity increased. In approximately 1870, the invention of electric power and the implementation of assembly line production contributed to the rise of Industry 2.0. This phase primarily focused on task distribution and mass manufacturing, and the integration of electronics, limited automation, and information technology played a crucial role in boosting the productivity of industry organizations. The third revolution, which began in 1969, paved the way for the fourth revolution just 40 years later. It is worth noting that the growth of the three previous revolutions spanned approximately 100 years, while the third revolution led to the fourth revolution in a much shorter time.

Innovative manufacturing practices have advanced into Industry 4.0 since 2011. The primary goal of cutting-edge technologies is to improve productivity and increase production efficiency (4). The future of manufacturing, Industry 5.0, aims to integrate human ingenuity with intelligent machines to enhance production (5). Researchers (6, 7) argue that organizations can benefit from digital technologies by becoming more focused. Similarly, researchers (8, 9) have underscored that the implementation of digital technology can extend a firm's scope by improving coordination among multiple units.

Digital Transformation Experience by the Firm: Researchers have introduced the concepts of "digitalization," "digitization," and "digital transformation" in the broader context of DT as depicted in Figure 7. Although these concepts have distinct meanings, they are often used interchangeably (10). While researchers (11, 12) argue for more precise definitions, digitization is the first phase of transformation, which involves the conversion of analog data to digital format. The next phase is digitalization, which entails the use of digital technology and its impact on business processes (e.g., digitalization of a process) (12). Digitalization is also defined as the innovation of business models and processes that maximize digital opportunities. The broadest concept, digital transformation, encompasses the entire organization and its processes, as well as the indirect and direct effects of digital technologies and processes on firm economic conditions and innovative products and services (13).

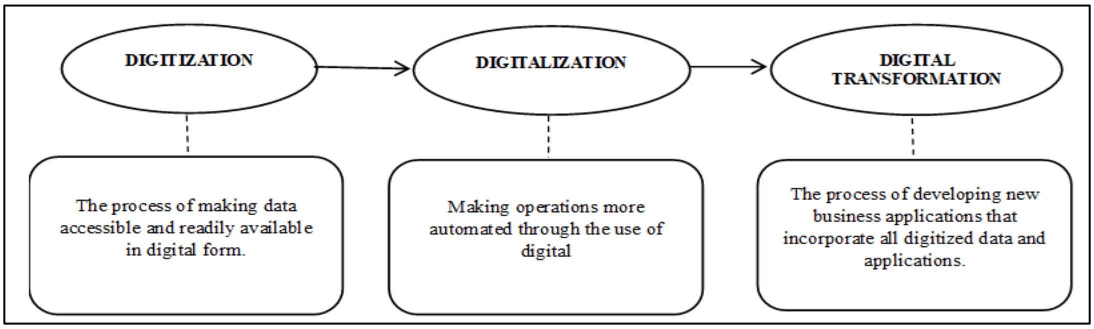

Figure 7: Transformation of Digital Transformation

Digital technology (DT) represents a comprehensive integration of digital technology across various aspects of an organization or industry, fundamentally transforming processes, operations, and value creation (14). DT refers to the suite of tools, systems, and solutions that facilitate this transformation and enable organizations to adopt and utilize technological advancements to create new business models and enhance firm performance. This encompasses technologies like computer engineering, the Internet of Things (IoT), artificial intelligence (AI), and more. In essence, DT serves as the strategic vision, while digital technology operationalizes that vision through practical application.

Cloud Manufacturing (CM): Cloud manufacturing (CM) is an industry concept that employs cloud computing technologies, which offer a range of benefits, including reduced costs, increased flexibility, and scalability. With CM, global collaboration and product innovation are possible. Additionally, it improves resource utilization and supply chain management, enabling data analytics and performance monitoring (15). The adoption of CM can enhance a company's performance by decreasing costs, increasing productivity, shortening the time-to-market, ensuring product quality, supporting innovation, and improving competitiveness and output maximization through measures such as research and development, waste reduction, and employee skill upgrades.

Artificial Intelligence (AI): AI encompasses the utilization of technical devices to imitate human cognitive capabilities, allowing for the accomplishment of tasks independently while simultaneously considering any constraints (16). In the context of manufacturing, AI enables predictive maintenance, thereby facilitating the early detection of equipment failures and reducing downtime. Moreover, it enhances quality control through the utilization of AI-powered vision technologies that accurately and promptly identify errors. The automation of repetitive manufacturing tasks through AI increases efficiency while simultaneously eliminating errors. In addition, AI is instrumental in product development and enhancement, leading to the generation of new ideas for lighter, stronger, and more cost-effective products. Furthermore, manufacturing can leverage AI algorithms to forecast demand and sales.

Internet of Things (IoT): The Internet of Things (IoT) is a network that connects various devices, sensors, and smart technologies to facilitate communication between individuals, objects, and vice versa (17). In the manufacturing sector, IoT offers numerous advantages, such as boosting operational efficiency, conducting predictive maintenance, improving quality control and safety measures, enabling data-driven decision-making, and streamlining integration and automation. Predictive maintenance enables the early detection and rectification of equipment issues, while IoT devices monitor parameters to guarantee product quality, safety, and enhance operational efficiency, ultimately reducing human error. Overall, the implementation of IoT in manufacturing leads to increased productivity, reduced costs, improved customer satisfaction, and a competitive edge.

Improved Firm Performance through Output Maximization: Enhancing corporate performance involves increasing production efficiency by leveraging advanced digital technologies, such as the IoT, AI, and CM, while simultaneously grappling with budgetary constraints. The seamless integration of these technologies enables organizations to optimize production, streamline operations, and reduce disruptions. Table 1 clearly illustrates how (DT) improves firm performance, aligning with the theoretical concepts and principles advanced by academic researchers.

Table 1: Analysis of How DT Improves Firm Performance through Output Maximization

Digital Technology	Improved Firm Performance through Output Maximization				Theory /Concept used	References
	Research & Development(R&D)	**Reduction of waste Resources**	**Scalability**	**Skilled employee upgradation**		
Cloud Manufacturing (CM)	CM facilitates and deepens the connectivity between research and development (R&D) activities in the manufacturing business. It offers a collaborative and virtualized environment in which researchers, designers, and manufacturers may access innovative R&D tools, share data, and efficiently interact. **For example:** in the pharmaceutical business, CM allows researchers to use cloud-based platforms to analyze enormous amounts of information, carry out challenging experiments, and interact with specialists worldwide to discover fresh drugs and optimize manufacturing processes. CM and R&D integration speeds up innovation, reduces development costs, and improves the firm performance.	CM aids in waste reduction in the manufacturing firm. It reduces waste resources like raw materials, energy, and time by enabling real-time collaboration, data exchange, and optimization. **For example:** in the textile industry, CM enables designers, manufacturers, and suppliers to collaborate virtually, improving production schedules, reducing material scrap, and reducing energy consumption, resulting in significant waste reduction and better sustainability.	CM helps to provide scalable and flexible manufacturing operations. It supports scalability by providing on-demand access to computing resources, storage, and services, allowing firms to quickly adapt production capacity to meet demands. **For example:** in the electronics industry, CM enables manufacturers to swiftly scale up or down production quantities based on market conditions. This scalability provides optimal resource utilization, cost-effectiveness, and responsiveness in the manufacturing industry.	Manufacturers may improve the employee's skills and expertise by embracing cloud-based platforms and applications to give training, access to knowledge resources, and collaboration opportunities**. For example:** In the automotive industry, CM enables manufacturers to provide virtual training programs, online workshops, and access to advanced simulation tools, allowing employees to learn new skills, stay up to date on new technologies, and improve their proficiency in areas such as design, production, and quality control. This skill upgrade helps to greater productivity, innovation, and competitiveness in the manufacturing sector.	Theory of Constraints, Total Quality Management. Zero Waste Manufacturing, Zero Waste Economies of scale, Multi-tenancy Social Learning Theory, Cognitive Load Theory	(18,19) (20) (21) (22,23)

Artificial Intelligence (AI)	AI in R&D for the manufacturing industry involves using intelligent algorithms and data-driven models to streamline product development, improve productivity, and support advanced research, ultimately leading to cutting-edge innovations and competitive advantages. **For example:** In R&D, AI is used to speed up design repetitions, mimic accident tests, and improve vehicle performance. AI algorithms can forecast how different car designs would perform by analyzing enormous amounts of data from prior crash testing and real-world events, resulting in safer and more robust vehicles.	AI plays a key role in decreasing waste resources in the manufacturing sector by optimizing processes, increasing resource efficiency, and supporting sustainable practices. **For example:** In manufacturing, AI-powered predictive maintenance solutions analyze real-time data from equipment sensors, allowing organizations to detect and prevent machinery faults. This saves unnecessary downtime, reduces repair-related waste, and increases the lifespan of industrial components, ultimately leading to considerable reductions in resource waste and greater sustainability.	AI helps in growing and expanding the manufacturing industry by providing higher productivity and adaptability to changing demands. **For example**: improve manufacturing scalability by enabling rapid production line reconfiguration to fit different product versions. In addition, AI-driven demand forecasting and inventory management improve resource allocation, allowing firms to scale products efficiently in response to market risk and client needs.	Improving the knowledge and skills of manufacturing workers through the use of intelligent technology and training programs allows them to work effectively with AI-powered tools and systems. **For example**, AI-driven training platforms in the manufacturing industry provide personalized learning experiences, empowering individuals to engage with AI-powered robots and execute unique manufacturing procedures. This skill improvement enhances employee productivity and adaptability, resulting in more efficient and competitive manufacturing employees.	Decision theory, Information theory. Graph theory Process Innovation Augmented intelligence	(23–26) (27) (28) (29)
Internet of Things (IoT)	IoT in manufacturing R&D enables data-driven decisions, predictive maintenance, and supply chain optimization, improving product development and quality control. **For example**: a car manufacturer uses IoT to analyze	The IoT helps to reduce waste in manufacturing by optimizing resource utilization, strengthening process efficiency, and enabling smart waste management. IoT-connected sensors and	In the manufacturing business, by enabling flexible and adaptive operations, easing remote monitoring and management, and improving data-driven decision-making. IoT-connected devices and systems can	IoT-connected devices and augmented reality tools enable employees to learn new skills, stay updated with technology, and expand their knowledge. **For example:** In a smart manufacturing plant, IoT-	Resource-based view, Competitive advantage Total Quality Management	(30) (31) (32) (33) (30)

	production data for design improvements and gathers customer usage data to enhance future car models.	devices measure resource use, detect inefficiencies, and allow real-time monitoring, resulting in less waste and environmental impact. **For example:** IoT sensors in a facility monitor energy and water usage, allowing real-time data analysis to detect areas of waste. By optimizing machine operation and production schedules based on this data, the manufacturing process becomes more efficient, eliminating energy and water waste.	smoothly scale up or down based on demand, resulting in increased efficiency and cost-effectiveness. **For example:** IoT-enabled manufacturing lines may simply grow their operations to meet increased demand by adding more IoT-connected machines and equipment. The sensors in these machines offer real-time data on production rates, quality, and maintenance requirements, allowing managers to optimize workflows and allocate resources more efficiently.	connected machinery and equipment can provide interactive training modules for employees using augmented reality (AR) interfaces. These augmented reality devices provide step-by-step help for complex activities, increasing the workforce's skill level. In addition, IoT sensors capture performance data, allowing managers to measure employee efficiency and identify areas where additional training is required.	Economies of Scale, Cost Management Skill Development	

Table 2: Analysis of how DT improves Firm Performance through Cost Minimization

Digital Technology	Improved Firm Performance through Cost Minimization			Theory/Concept used	References
	Through Change in Operation cost	**Through Low inventory cost**	**Through Enhanced Quality control**		
Cloud Manufacturing (CM)	CM reduces the need for businesses to invest in costly on-premises equipment such as servers, data centres, and software licenses. Instead, they can employ cloud-based infrastructure, paying only for the use. This low-cost strategy saves both initial capital expenditure and corresponding maintenance costs. **For example:** A manufacturing company can move its storage and processing of information processes to cloud	CM systems offer extensive inventory management features that enable firms to monitor inventory levels, track product movements, and automate replenishment procedures. **For example:** Clothing manufacturers can use cloud-based demand planning technologies, including historical sales data, weather forecasts, and social media trend analysis. By exactly forecasting demand for various clothing goods, can optimize production	Enhanced quality control is one of the key benefits provided by CM technology. By utilizing cloud-based platforms and data analytics, manufacturers can monitor and manage various quality aspects throughout the production cycle. **For example:** A manufacturing company that makes electronic devices uses CM technology to streamline its production and increase quality control. They link their manufacturing equipment to a cloud-based platform, including	Virtualization Resource-Based Theory Lean Manufacturing	(34) (35) (36)

	platforms like Amazon Web Services.	planning and reduce excess inventory.	assembly lines and testing stations.		
Artificial Intelligence (AI)	AI technology helps optimize operational costs by automating tasks, increasing efficiency, decreasing waste, or improving decision-making, resulting in cost savings and enhanced profitability. **For example:** In a manufacturing plant that relies significantly on machinery and equipment, AI technology may analyze machine sensor data, such as temperature, vibration, or pressure, and find trends anticipating problems. Early warning indications alert maintenance teams, assisting in the prevention of costly breakdowns and production delays.	AI technology that supports low inventory costs refers to using intelligent algorithms and systems to optimize inventory management processes, resulting in lower inventory levels while maintaining or improving operational efficiency and overall firm performance. **For example:** Demand forecasting is one application of AI in manufacturing business that promotes reduced inventory costs. AI algorithms can accurately predict future demand by analyzing previous sales data, market trends, seasonality, and other relevant aspects.	AI may be used to analyze massive amounts of data, find trends, and make intelligent decisions to improve product quality and overall firm performance. **For example:** In manufacturing companies, AI computer vision systems can inspect products on the assembly line, finding flaws, variances, or anomalies in real time. These systems use machine learning algorithms to analyze images or video streams and compare them to established quality standards. Defective products can be further examined or eliminated from the production line, ensuring that only high-quality items reach the market.	Deep Learning Reinforcement Learning Fault Detection and Diagnosis	(37–39)
Internet of Things (IoT)	IoT technology can be built to create a smart factory environment. Various machinery, equipment, and components can be interconnected using sensors and network connectivity to establish a network of interconnected devices. These devices can collect and exchange real-time data on industrial processes, machine performance, energy consumption, and other variables. **For example:** IoT sensors can monitor machine conditions, which can detect future issues. By analyzing this data, manufacturing can estimate maintenance	Low inventory cost in manufacturing involves using interconnected devices and systems to improve inventory management operations, reduce carrying costs, and increase overall operational efficiency. **For example:** The manufacturing firm that produces electronic devices. They can set up sensors on their manufacturing lines and inventory storage locations by using IoT technology. These sensors can capture real-time data on inventory levels, production rates, and client demand. This data is sent to the IoT	The manufacturing industry refers to the integration of IoT devices, sensors, and connectivity into manufacturing processes to monitor, track, and analyze product quality at various stages. **For Example:** IoT technology can be used to improve quality control in a manufacturing plant that produces electronic parts. Sensors can be integrated into manufacturing equipment, assembly lines, and warehouses to monitor and collect data on variables like temperature, vibration, and humidity. This assists producers in optimizing their manufacturing processes,	Sensor Technologies Just-in-Time Total Quality Management	(40) (41) (42)

	needs and arrange repairs or replacements before equipment failure. This method decreases unplanned downtime, lowers repair costs, and enhances overall firm performance.	platform, which is analysed to generate insight and trigger automated actions.	reducing waste, increasing operational efficiency, and improving firm performance.	

Improved Firm Performance through Cost Minimization: Enhanced manufacturing company performance is achieved through minimizing costs via the adoption of digital technologies like IoT, AI, and CM. These seamlessly integrated solutions enable optimized production processes, streamlined operations, and reduced expenses in Table 2. It shows how technology impacts firm performance with examples and theories or concepts applied by the researchers.

Difficulties or Barriers of DT in manufacturing industries: DT in manufacturing industries can offer numerous benefits, but it's also accompanied by several obstacles and it may differ from one industry to the next. Furthermore, the extent of the same difficulties may vary between sectors (43). The major challenges of the DT process were identified after studying the literature and were divided into four primary areas in Figure 8. Digital skills gap, new technologies adoption, innovation procedures, and policies, and change organizational process.

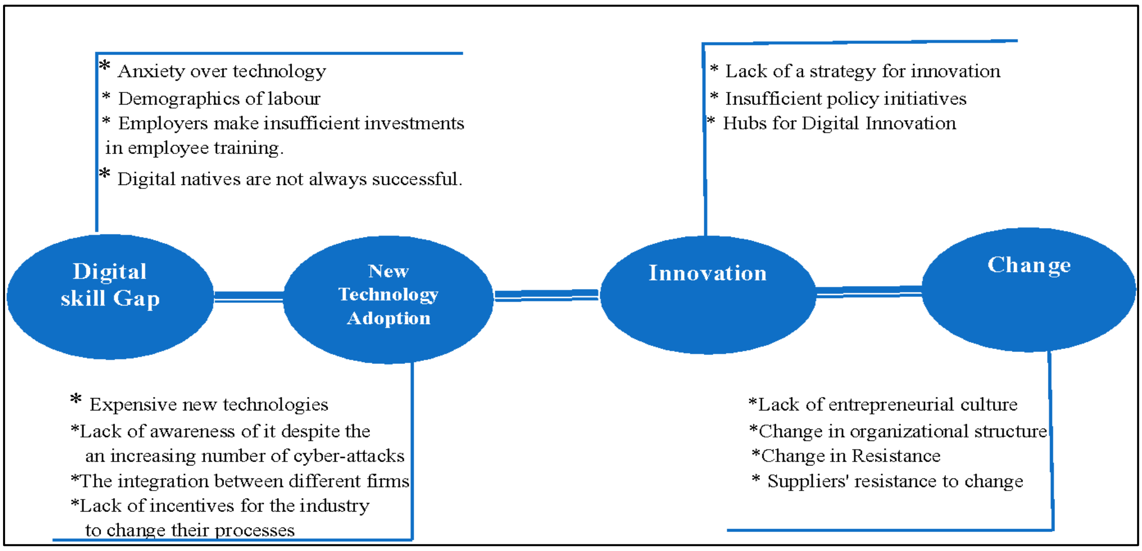

Figure 8: Challenges Faced by Firms in Implementing Digital Transformation

Digital Skills gap: There is an essential digital skills gap between what industries have and what they need to stay competitive in technological innovation (44). According to the SAP (Systems, Applications and Products in Data Processing) analysis, there is a 20%-40% skills gap between what is required and what is obtainable. Digital skills are becoming more important in DT, and the demand for these skills is projected to increase in the years to come (45). On the other hand, employers do not provide appropriate resources for employee training. Fear of technology is another issue in this regard. Workers fear that technology may eliminate their jobs and as a result, they will reject this transformational environment (46). No one wants to lose their career to technology or have a machine replace them.

New Technology Adoption: The adoption of new technology necessitates an organizational risk-taking culture. This risk requires an essential initial investment as well as a long-term return. This has been referred to as entrepreneurial culture (47). This high-return endeavour is unknown to manufacturing firms. Such risk tolerance is evident in the 2017 Made Smarter survey, which found that investment in innovative manufacturing technology is limited, particularly in SMEs (48). Cyber-attacks are a growing risk in the digital era. Organizations invest a lot of money and effort in preventing assaults since every day, the number of attacks grows. The main problem with such attacks is that they constantly change, with new threats being used to exploit the firm (49).

Process of Change Management: The concept of DT refers to a mix of disruption technologies (50). Due to the disruption, they are challenging to apply and use. As a result, research (46) handling the structure of a manufacturing organization is one of the most difficult actions that demand enormous effort and time to overcome challenges (51–53). Employee resistance to change is another issue that arises when people get used to working with old methods and systems and are unwilling to leave their comfort zones (54–56). To make the changes that are needed, such resistance must be handled in the adaptation process and unfreezing the current state quo.

Innovation Initiatives: The effectiveness of DT procedures within the manufacturing sector is dependent on innovation. On a strategic level, most businesses do not have an innovation strategy (57). The absence of effective innovation in manufacturing can result in outdated processes, reduced competitiveness, and missed growth opportunities by this the progress can be delayed by outdated technology, lower production, and disengaged employees. Manufacturers must prioritize innovation, promote a creative culture, and adopt new technology to overcome these drawbacks and stay competitive and adaptive.

Factors Leading to Digital Transformation Success and Failure: The successful implementation of digital transformation within organizations requires addressing various challenges that are presented in Table 3. A lack of understanding and awareness of digital technology limits the potential benefits that can be derived from it. To overcome this, organizations must stay updated on technological changes and analyze opportunities for effective utilization. Ineffective technological resource management such as outdated systems and inadequate cybersecurity measures, hampers DT efforts. Effective leadership and proper resource management are crucial for successful implementation. Clear DT plans are necessary to align organizational efforts with business objectives and redesign processes to capitalize on digital opportunities. Setting clear objectives and goals provides focus and direction for monitoring performance and achieving desired results. A well-defined roadmap guides the organization's digitalization journey. Creating a culture that embraces change. Innovation and collaboration are essential for overcoming resistance and fostering a supportive environment for digital projects building a people management system that identifies digital talent, provides training, and fosters employee success in digital tools and infrastructure effectively. Employee resistance to change can be addressed through effective change management, focusing on communication, involvement, and problem-solving. Overcoming incompatibility issues between existing systems and new technologies requires robust technology management practices. Finally having knowledgeable leaders who recognize the importance of DT and involving employees in the process increases commitment and enables successful digital adoption.

Table 3: Reasons for DT Failure and Success Factors

Reasons for Failure	Success Factors	Opportunities for Future Investigation
Unawareness of digital technologies	Tech Awareness: Improve understanding	Investigate the impact of technology awareness and internal/external analysis on organizations' understanding of digital technologies.
Ineffective technology management	Effective Management: Optimize practices	Explore the role of effective management in ensuring the successful implementation and utilization of digital technologies within organizations.
Uncertain strategy	Clear Strategies: Ensure digital adaptation	Explore the necessity of clear digital business strategies for organizations to adapt and thrive in the digital era.
Uncertain long-term and short-term goals and objectives	Digital Roadmaps: Define clear objectives	Investigate the significance of establishing clear digitalization roadmaps and action plans to achieve both short-term and long-term digital goals.

Unsuitable culture	Digital Culture: Foster innovation	Explore methods to foster a digital-friendly culture within organizations to facilitate digital transformation and innovation.
Personnel knowledge gap	HR Enhancement: Bridge the knowledge gap	Investigate strategies for enhancing human resource management to bridge the knowledge gap and adapt to digital technologies effectively.
Insufficient funding for technology investment	Tech Funding: Support digital initiatives	Explore the importance of adequate funding for technology investment to support successful digital transformation initiatives within organizations.
Change resistance	Acceptance: Promote change	Examine factors influencing resistance to change and strategies to promote acceptance of digital transformation initiatives among stakeholders.
Technology incompatibility	Technology Compatibility: Ensure integration	Investigate the necessity of implementing new technology management systems to address compatibility issues and support digital initiatives effectively.
Ignorant leaders	Leadership Participation: Drive transformation	Explore the role of leadership participation in driving successful digital transformation efforts within organizations and mitigating ignorance towards digital technologies.

Theoretical and Practical Implications

The theoretical implications of integrating digital technology into the manufacturing industry's various aspects are profound. Where digital simulations and virtual prototypes may accelerate innovation, and scalability, where digital platforms offer flexible growth, the promise for increased efficiency and innovation is obvious. Efforts are being made to reduce costs in several ways, from skilled employee upgradation, where digital learning platforms promise continual advancement, to operational efficiency, where digital optimization tools promise streamlined processes. It is also possible to reduce inventory costs and improve quality control throughout the entire production process by using data-driven improvements. Apparent from these theoretical implications that digital technology has the potential to transform manufacturing procedures and performance.

The practical implications of integrating digital technology into the manufacturing industry are tangible and impactful. Virtual simulation speeds up product development and shortens design iterations. Real-time monitoring and optimization result in less material waste, improved energy efficiency, and significant cost savings. Scalability becomes possible, allowing for quick changes in production levels in response to market needs while retaining optimal resource utilization. Furthermore, digital learning systems provide a competent and flexible workforce, while simplified processes powered by digital optimization tools result in lower operating costs and increased efficiency. Excess inventory is reduced by data-driven demand forecasts, and the integration of sensors for quality control assures constant product standards, defect detection, and customer satisfaction. In summary, these practical implications highlight the measurable advantages of digital technology adoption, which promotes improved performance and competitiveness in the manufacturing industry.

Conclusion

This research aims to assess and revise the current state of knowledge on DT. Digital technology and DT have the potential to revolutionize the manufacturing industry by enhancing decision-making, productivity, scalability, and quality assurance. Using digital tools and platforms makes it possible to automate tasks and use modern technologies like robotics and AI, the IoT, and CM. This results in streamlined processes, reduced lead times, lower error rates, efficient inventory management, and enhanced quality control. These advancements lead to improved firm performance, cost reduction, increased customer satisfaction, and a competitive edge in the market. To succeed in a fast-changing environment, manufacturers must maintain flexibility, constantly adapt to new technologies, embrace DT and further address the questions the digital revolution changed how the industry works by using new technology to make things faster and better. Digital transformation helps industries do things like making products quicker and better, which helps them compete with other industries. But sometimes, it's hard for the industry to change because they might not have the right skills or tools. So, they need to plan well to manage changes carefully to succeed.

Limitation and Future Direction

This research focuses on the manufacturing industry, highlighting the critical role of digital transformation in optimizing operations and enhancing firm performance. However, organizations may encounter barriers such as outdated infrastructure, lack of technical expertise, and employee resistance, which can impede successful implementation. Additionally, challenges like cybersecurity threats and data privacy concerns must be addressed for secure technology adoption. The study's exclusion of investigations in other languages may limit the generalizability of findings across different cultural contexts. Future research should explore the impact of digital transformation in other industries, such as retail, finance, and healthcare, which may face unique challenges and opportunities. By extending the scope to these sectors, future studies could provide a comprehensive understanding of digital transformation's effects on business performance, leading to more tailored strategies and examining these effects across different geographical contexts would provide insight into how regional factors influence the success of digital initiatives. Mixed-method studies could further focus on making digital technologies more accessible, user-friendly, and cost-effective in cross-industry collaborations, offering valuable insights for both industry-specific and cross-industry strategies.

Abbreviations

ADO: Antecedents, Decisions, and Outcomes framework, DT: Digital transformation, IoT: Internet of Things, AI: Artificial intelligence, CM: Cloud Manufacturing, RBV: Resource-Based View, CoM: Computerized manufacturing, SEM: Structural Equation Modelling, IA: industrial automation.

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Darathi J: Conceptualization, Methodology, Visualization, Formal analysis and Investigation, Writing – Original Draft Preparation.

Madhumita Das: Methodology, Writing, Review and Editing, Supervision.

Conflict of Interest

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Ethics Approval

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References

1. Lee MH, Yun JHJ, Pyka A, Won DK, Kodama F, Schiuma G, et al. How to Respond to the Fourth Industrial Revolution, or the Second Information Technology Revolution? Dynamic New Combinations between Technology, Market, and Society. Journal of Open Innovation: Technology, Market, and Complexity. 2018;4:21.
2. Shipp SS, Gupta N, Lal B, Scott JA, Weber CL, Finnin MS, et al. Emerging global trends in advanced manufacturing. 2012. https://apps.dtic.mil/sti/citations/ADA558616
3. Paul J, Benito GR. A review of research on outward foreign direct investment from emerging countries, including China: what do we know, how do we know and where should we be heading, Asia Pacific Business Review. 2018 Jan 1;24(1):90-115.
4. Echchakoui S, Barka N. Industry 4.0 and its impact in plastics industry: A literature review. Journal of Industrial Information Integration. 2020 Dec 1;20:100172.
5. ElFar OA, Chang CK, Leong HY, Peter AP, Chew KW, Show PL. Prospects of Industry 5.0 in algae: Customization of production and new advance technology for clean bioenergy generation. Energy Conversion and Management: X. 2021 Jun 1;10:100048.
6. Brews PJ, Tucci CL. Exploring the structural effects of internetworking. Strategic Management Journal. 2004 May;25(5):429-51.
7. Howells J. The geography of knowledge: never so close but never so far apart. Journal of Economic Geography. 2012 Sep 1;12(5):1003-20.
8. Mabey C, Zhao S. Managing five paradoxes of knowledge exchange in networked organizations: new priorities for HRM? Human Resource Management Journal. 2017 Jan 1;27(1):39–57.
9. Newell S, Scarbrough H, Swan J. From Global Knowledge Management to Internal Electronic Fences: Contradictory Outcomes of Intranet Development. British Journal of Management. 2001;12(2):97–111.
10. Vrana J, Singh R. Digitization, Digitalization, and Digital Transformation. Handbook of Nondestructive Evaluation 40. 2021;1–17.
11. Bounfour A. Digital futures, digital transformation. Progress in IS. 2016;10:978-3.
12. Unruh G, Kiron D. MIT Sloan Management Review. Digital Transformation on Purpose. 2017 Nov 06. https://sloanreview.mit.edu/article/digital-transformation-on-purpose/

13. Pousttchi K, Gleiss A, Buzzi B, Kohlhagen M. Technology impact types for digital transformation. Proceedings - 21st IEEE Conference on Business Informatics, CBI 2019. 2019 Jul 1;1:487–94.
14. Butt J. A Conceptual Framework to Support Digital Transformation in Manufacturing Using an Integrated Business Process Management Approach. Designs. 2020;4:17.
15. Wan C, Zheng H, Guo L, Xu X, Zhong RY, Yan F. Cloud manufacturing in China: a review. International Journal of Computer Integrated Manufacturing;33(3):229–51.
16. Haenlein M, Kaplan A. A brief history of artificial intelligence: On the past, present, and future of artificial intelligence. Calif Manage Rev. 2019 Aug 1;61(4):5–14.
17. Uckelmann D, Harrison M, Michahelles F, editors. Architecting the internet of things. Springer Science & Business Media. 2011 Apr 2. https://doi.org/10.1007/978-3-642-19157-2
18. Chesbrough H, Bogers M. Explicating open innovation: Clarifying an emerging paradigm for understanding innovation. New Frontiers in Open Innovation. Oxford: Oxford University Press, Forthcoming. 2014 Apr 15:3-28.
19. Altay N, Gunasekaran A, Dubey R, Childe SJ. Agility and resilience as antecedents of supply chain performance under moderating effects of organizational culture within the humanitarian setting: a dynamic capability view. Production Planning and Control. 2018 Oct 26;29(14):1158–74.
20. Kerdlap P, Low JSC, Ramakrishna S. Zero waste manufacturing: A framework and review of technology, research, and implementation barriers for enabling a circular economy transition in Singapore. Resour Conserv Recycl. 2019 Dec 1;151:104438.
21. Tang B, Sandhu R, Li Q. Multi-tenancy authorization models for collaborative cloud services. Concurrency and Computation: Practice and Experience. 2015 Aug 10;27(11):2851-68.
22. Zhou D, Xue X, Zhou Z. SLE2: The Improved Social Learning Evolution Model of Cloud Manufacturing Service Ecosystem. IEEE Trans Industr Inform. 2022 Dec 1;18(12):9017–26.
23. Carvalho AV, Chouchene A, Lima TM, Charrua-Santos F. Cognitive Manufacturing in Industry 4.0 toward Cognitive Load Reduction: A Conceptual Framework. Applied System Innovation. 2020;3:55.
24. Sjödin D, Parida V, Palmié M, Wincent J. How AI capabilities enable business model innovation: Scaling AI through co-evolutionary processes and feedback loops. J Bus Res. 2021 Sep 1;134:574–87.
25. Soni N, Sharma EK, Singh N, Kapoor A. Impact of artificial intelligence on businesses: from research, innovation, market deployment to future shifts in business models. https://arxiv.org/abs/1905.02092v1
26. Liang J, Al-Walai S. Impact of Artificial Intelligence on Management and Leadership in Research & Development: A Case Study of Thermo Fisher Scientific. 2021. https://www.diva-portal.org/smash/get/diva2:1586193/FULLTEXT01.pdf
27. Ahmed S, Mubarak S, Du JT, Wibowo S. Forecasting the Status of Municipal Waste in Smart Bins Using Deep Learning. International Journal of Environmental Research and Public Health. 2022;19(24): 16798. https://doi.org/10.3390/
28. Sadiku MN, Musa SM. Augmented intelligence. A Primer on Multiple Intelligences. Springer Nature Publ. 2021:191-9.
29. Rai A, Singh LB. Artificial Intelligence-based People Analytics Transforming Human Resource Management Practices. The Adoption and Effect of Artificial Intelligence on Human Resources Management, Part A. 2023 Feb 10;229–44.
30. Zamiri M, Sarraipa J, Ferreira J, Lopes C, Soffer T, Jardim-Goncalves R. A Methodology for Training Toolkits Implementation in Smart Labs. Sensors. 2023 Feb 27;23(5):2626.
31. Botta A, De Donato W, Persico V, Pescapé A. Integration of cloud computing and internet of things: a survey. Future generation computer systems. 2016 Mar 1;56:684-700.
32. Liu X, Pei J, Liu L, Cheng H, Zhou M, Pardalos PM. Total Quality Management of the Product Life Cycle in an IoT Environment. Springer Optimization and Its Applications. 2017;126:163–208.
33. Kaur C. The Cloud Computing and Internet of Things (IoT). Int J Sci Res Sci Eng Technol . 2020;7(1):19–22.
34. Tao F, Zhang L, Venkatesh VC, Luo Y, Cheng Y. Cloud manufacturing: A computing and service-oriented manufacturing model. Proc Inst Mech Eng B J Eng Manuf. 2011 Oct;225(10):1969–76.
35. Gangwar H. Cloud computing usage and its effect on organizational performance. Human systems management. 2017 Jan 1;36(1):13-26.
36. Valamede LS, Akkari AC. Lean 4.0: A new holistic approach for the integration of lean manufacturing tools and digital technologies. International Journal of Mathematical, Engineering and Management Sciences. 2020;5(5):851.
37. Bengio Y, Lecun Y, Hinton G. Deep learning for AI. Communications of the ACM. 2021 Jun 21;64(7):58-65.
38. Maity M. Stochastic optimization in perishable food supply chain: a holistic approach (Doctoral dissertation, Kansas State University). 2018.
39. Venkatasubramanian V, Rengaswamy R, Yin KK, Kavuri SN. A review of process fault detection and diagnosis: Part I: Quantitative model-based methods. Comput Chem Eng. 2003;27:293-311.
40. Kalsoom T, Ramzan N, Ahmed S, Ur-Rehman M. Advances in sensor technologies in the era of smart factory and industry 4.0. Sensors. 2020 Nov 27;20(23):6783.
41. Yi Z, Mi S, Tong T, Li H, Lin Y, Wang W, Li J. Intelligent initial model and case design analysis of smart factory for shipyard in China. Engineering Applications of Artificial Intelligence. 2023 Aug 1;123:106426.
42. Souza FF de, Corsi A, Pagani RN, Balbinotti G, Kovaleski JL. Total quality management 4.0: adapting quality management to Industry 4.0. TQM Journal. 2022 Jun 10;34(4):749–69.
43. Zangiacomi A, Pessot E, Fornasiero R, Bertetti M, Sacco M. Moving towards digitalization: a multiple case study in manufacturing. Production Planning and Control. 2020 Feb 17;31(2–3):143–57.
44. Chryssolouris G, Mavrikios D, Papakostas N, Mourtzis D, Michalos G, Georgoulias K. Digital

manufacturing: history, perspectives, and outlook. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture. 2009 May 1;223(5):451-62.
45. Kokolek N, Jakovic B, Curlin T. Digital Knowledge and Skills–Key Factors for Digital Transformation. Annals of DAAAM & Proceedings. 2019 Jan 1;30(006):0046–0053.
46. Heavin C, Power DJ. Challenges for digital transformation–towards a conceptual decision support guide for managers. J Decis Syst. 2018 May 15;27:38–45.
47. Ananyin VI, Zimin KV, Lugachev MI, Gimranov RD, Skripkin KG. Digital organization: Transformation into the new reality. 2018;(2(44)eng):45-54.
48. Cozmiuc D, Petrisor I. Industrie 4.0 by siemens: Steps made next. Journal of Cases on Information Technology. 2018 Jan 1;20(1):31–45.
49. Heikkilä M, Rättyä A, Pieskä S, Jämsä J. Security challenges in small- and medium-sized manufacturing enterprises. 2016 International Symposium on Small-scale Intelligent Manufacturing Systems (SIMS), Narvik, Norway. 2016:25-30.
50. Hausberg JP, Liere-Netheler K, Packmohr S, Pakura S, Vogelsang K. Research streams on digital transformation from a holistic business perspective: a systematic literature review and citation network analysis. Journal of Business Economics. 2019 Dec 1;89(8–9):931–63.
51. El Hamdi S, Oudani M, Abouabdellah A. Morocco's Readiness to Industry 4.0. Smart Innovation, Systems and Technologies. 2020;146:463–72.
52. Loonam J, Eaves S, Kumar V, Parry G. Towards digital transformation: Lessons learned from traditional organizations. Strategic Change. 2018 Mar 1;27(2):101–9.
53. Paavola R, Hallikainen P, Elbanna AR. Role of Middle Managers in Modular Digital Transformation: the Case of Servu. (pp. 887–903). Association for Information Systems. https://research.aalto.fi/en/publications/role-of-middle-managers-in-modular-digital-transformation-the-cas.
54. Kunii Y, Journal THFS and T, 2019 undefined. Fujitsu's activities to support digital transformation. fujitsu.com];55(1):3–8.
55. Laird K. Understanding the digital transformation called industry 4.0. Plastics Engineering. 2017 Jan 1;73(1):24–8.
56. Rojo Abollado J, Shehab E, Bamforth P. Challenges and Benefits of Digital Workflow Implementation in Aerospace Manufacturing Engineering. Procedia CIRP. 2017;60:80–5.
57. Tokody D. Digitising the European industry - Holonic systems approach. Procedia Manuf. 2018;22:1015–22.