

# Exploring Digital Transformation in the Manufacturing Industry: Challenges, Strategies and Benefits

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**Abstract** – The digitalization of manufacturing processes has a significant impact on the manufacturing industry, a vital part of any economy. Organizational survival and competitiveness depend critically on the results of Digital Transformation (DT). However, the phrase is not without its barriers, especially in the context of manufacturing. There is no agreed-upon definition of DT, but with scholars' views and experiences, defining factors of the term can be established. This article examines the term “Digital Transformation” and how it applies to the manufacturing sector, including its meaning, obstacles, solutions, and possible returns on investment for businesses. Included in the research is a comprehensive literature review focusing on DT's application in manufacturing and the difficulties and solutions that come with it. The results of this study emphasize the need of embracing DT for businesses to maintain competitiveness and longevity in today's dynamic digital environment.

**Keywords** – Digital Transformation, Manufacturing Industry, Digital Technologies, Organizational Culture, Digital Corporate Strategy.

## I. INTRODUCTION

The concept of Industry 4.0 has garnered significant attention from scholars, economic policymakers, and manufacturers. The concept under consideration is founded on a network of interconnected machinery, intelligent systems, and goods, as well as interrelated solutions within an organization. Additionally, it involves the augmentation of human-machine interaction. Industry 4.0 encompasses the integration and deployment of digital technologies, enabling the monitoring and control of physical equipment, sensors, information, and communication technologies, as well as applications related to the Industrial Internet of Things. The Digital Transformation (DT) [1] of a corporation is determined by the application of a set of Industry 4.0 technologies and their corresponding sequence.

Despite the increasing body of studies about Industry 4.0, organizations are encountering difficulties in comprehending the appropriate approach to DT. One potential challenge confronting firm is the possibility of embarking onto an inefficient DT process that lacks alignment with their unique organizational attributes, instead being only motivated by the prevailing enthusiasm surrounding Industry 4.0. The magnitude of this risk is heightened when considering the implementation of governmental efforts aimed at promoting DT in several countries, including Brazil, India, Mexico, and Italy. To avail themselves of the governmental incentives, corporations may engage in haphazard efforts without adequately evaluating their unique qualities and requirements. Lack of clear standards or established patterns creates doubt about the efficacy of companies' DT efforts.

Companies are adjusting their methods considering the growing use of digital technology across all sectors and the quick pace at which technical developments are occurring. There will be repercussions for both customer service and product distribution because of this change, in addition to its effects on the company's internal workings. The manufacturing industry, a cornerstone of every economy, is being profoundly affected by the rise of digitalization in the production process. The development of novel technologies is principally responsible for this effect since they could boost the efficiency of industrial firms' operational operations. To be competitive in the industrial sector, DT is essential. Adopting digital business procedures seems to be the only way to achieve sustainability in the present competitive market situation. To compete with the new breed of digitally native businesses that have sprung up in the past decade or so, existing businesses must adopt DT.

In recent years, DT has been the subject of much study in the academy. Nonetheless, especially in the industrial sector, there is still a lack of clarity around the exact meaning, structure, and issues related with this phrase. There is no one, agreed-upon definition of DT, as proven by the many different points of view offered by different authors. The authors who have tried to define DT have often reflected the author's own biases and experiences, whether they be from the financial sector or the public sector. In addition, only a small number of literature reviews have been done to investigate this idea in the industrial sector. A thorough literature review is required because of the widespread doubt that surrounds this term, especially in the industrial sector. The purpose of this analysis is to get a deeper familiarity with the concept, to identify promising new areas for study, and to consider creative new ways to put these findings to use in industry.

The aim of this paper is to analyze the concept of DT in the manufacturing industry, including its acceptance challenges, implementation strategies, and potential benefits to businesses. This research was conducted with the aim of providing useful information on the effects of DT on manufacturing procedures and customer participation. The rest of the article is organized as follows: Section II presents a discussion of the aims and objectives of the research. Section III reviews the previous literature works of the paper, while the methodological approach is detailed in Section IV. Section V presents a discussion of the results, which involve the definition of digital transformation, advancement of DT concepts, and past, present, and future barriers of the concept, enabling technologies, benefits of DT implementation, and DT within the manufacturing ecosystem. Section VI presents a conclusion to the article.

## II. AIMS AND OBJECTIVES

There are three major aims and objectives for this study:

- a) Conduct a thorough literature review to better understand the challenges and potential benefits of implementing DT in the manufacturing sector. The goal is to learn new things and attempt new things that will eventually lead to the widespread use of DT in this sector. The purpose of this study is to discover optimal practices and strategies that lead to successful implementation.
- b) To assess the advancement and influence of DT inside the manufacturing sector. This study will examine several efforts and indicators, such as the DT Monitor and DT Scoreboard, in order to evaluate the transformative effects of DT.
- c) To ascertain the advantages and obstacles associated with the implementation of DT within the industrial sector. This study will examine the enhancements in productivity, procedures, and human resources that can be attained through DT, along with the challenges and impediments that businesses may encounter when implementing DT effectively.

## III. LITERATURE REVIEW

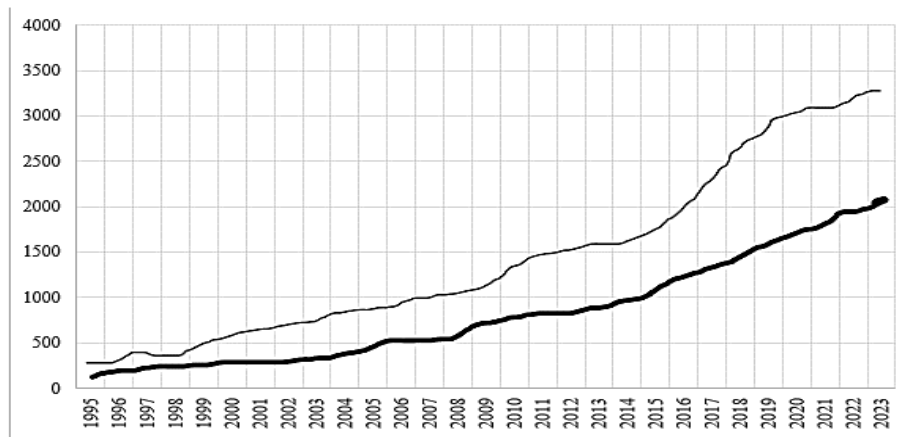
According to Jafari-Sadeghi et al. [2], Digital Transformation (DT) refers to the utilization of digital technologies to either establish novel or modify existing processes of business, culture of the organization, and experiences of the customer in order to effectively adapt to demands of the market and evolving business. DT refers to the conceptualization and implementation of new strategies and practices within the realm of business operations, specifically in response to the advent and proliferation of digital advancements. It surpasses conventional functions such as sales, marketing, and customer service. However, the process of DT commences and concludes with the manner in which one conceptualizes and interacts with customers. The transition from traditional paper-based methods to electronic spreadsheets and advanced digital apps presents an opportunity to redefine our business practices and customer interactions by leveraging the capabilities of digital technology.

According to Pencarelli [3], digital revolutions are having a profound impact on several facets of the manufacturing industry, encompassing not just operational procedures and efficiency but also human resources. The appropriate utilization of technology has the potential to result in enhanced decision-making capabilities, increased possibilities for acquiring new skills, adapting existing skills, and fostering collaboration across different functions. Furthermore, it can contribute to the enhancement of talent acquisition and retention, as well as the improvement of workplace safety and employee happiness. Customers experience several benefits, such as decreased manufacturing lead times, effective launch management resulting in successful initial product launches, and enhanced customer service and complexity management. Moreover, it is important to acknowledge the win-win benefits that arise from the mitigation of environmental effect, which may be achieved by minimizing emissions, waste, and enhancing the efficiency of energy, water, and raw material utilization.

According to Hill, Yates, Jones, and Kogan [4], achieving these enhancements in productivity, process, and personnel poses significant challenges, particularly when considering the complex network of distinct production sites, each with its own site leadership, IT infrastructure, and workplace culture. It is frequently observed that organizations may attain noteworthy outcomes through pilot initiatives conducted at a single plant location, though encounter challenges in reproducing these successful outcomes across their whole network. The aforementioned scenario pertained to a multinational industrial corporation. Faced with a significance increase in demand, wherein the volume of production more than quadrupled within a span of under three years, resulting in the need to manufacture over 50 million more parts, the enterprise undertook an ambitious DT initiative at a specific factory. The objective was to enhance the overall equipment effectiveness (OEE) by a margin of ten percentage points and achieve a reduction in product unit costs exceeding 30 percent. The project successfully achieved its objective as the plant was granted admission to the Global Lighthouse Network (GLN). The World

Economic Forum [5] and McKinsey [6] created this group to recognize outstanding management in the age of 4IR (4<sup>th</sup> Industrial Revolution). The authors commenced the practice of inviting external visitors in order to exhibit its process of transformation. However, for this notable accomplishment, the organization faced a lack of clarity regarding the methodology for extending its triumph at a local level to other locations.

According to Vial [7], the term “digital transformation” has gained significant attention within academic and corporate circles. During the era of the fourth industrial revolution, various industries, including education, business, banking, government, and manufacturing, are undergoing a process commonly referred to as “digital transformation”. The academic discourse over the past two to three decades has extensively explored various aspects of DT, including its constituent elements, the factors that drive and impede its implementation, as well as the value it generates. The request for DT in the Google Scholar database generated a total of three million outcomes. The retrieval of the keywords “digital transformation” from the WoS and SCOPUS databases yielded a substantial number of scholarly articles, with an upward trend in the annual count (refer to **Fig 1**).



**Fig 1.** No. of articles dedicated to the topic of digital transformation, as obtained from the WoS and SCOPUS databases spanning the years 1995 to 2023

The DT of society and business is also a key priority for the EU (European Commission). The EU's governing body has introduced several projects, such as the DT Monitor and DT Scoreboard, with the objective of assessing the advancements made in DT among European Union (EU) member states. The objective of the Organization for Economic Co-operation and Development (OECD) initiative is to enhance policymakers' comprehension of the ongoing digital revolution and establish a policy framework that facilitates societal and economic prosperity in a progressively digital and data-centric society [8]. There is a considerable emphasis placed on the topic of DT.

According to Pappas, Mikalef, Giannakos, Krogstie, and Lekakos [9], digitalization is a fundamental component of the rapid advancement of industry, society, and economy. The contemporary state of human existence is shaped by the interplay between digitalization and globalization. The European Commission predictions indicate that a significant global trend until 2030 will be a disruptive industrial and technology revolution. According to Appio, Lima, and Paroutis [10], technological advancements have the potential to bring about significant transformations in various domains of society, like education, politics, science, science, collective intelligence networks, lifestyles, health like the alteration of human genome, the establishment of open systems.

#### IV. METHODOLOGY

The initiation of a search on internet databases specifically focused on the topic of “Digital Transformation” has been undertaken. This search provided us with a comprehensive overview of how this topic is explored throughout several disciplines, including Manufacturing, Information Systems, Management and Healthcare. The abundance of research results among these resources indicates a significant level of scholarly interest in this issue, particularly in recent years across several academic fields. The major aim of this research is to utilize relevant sources from the manufacturing literature in order to keep a consistent approach towards the specific areas of interest. Additionally, it is crucial to ensure that the sample for the research remains substantial. The research databases selected for filtering the study were WoS (Web of Science), Science Direct, Scopus and Business Source Complete (EBESCO). The Web of Science (WoS) platform features prominent scholarly journals within the field of digital manufacturing. The investigation of Business Source Complete aimed to identify additional journals that encompass discussions on DT from a business perspective, beyond the scope of manufacturing-focused publications.

The utilization of ScienceDirect and Scopus is recommended for the purpose of validation and inclusion of journals that are not included WoS or EBSCO databases, hence assuring comprehensive coverage in the research. The criteria for exclusion encompassed several factors, namely: ongoing activities that were still in process; introductory statements made

during panel discussions; sources that were not accessible in the English language; entire papers that were not available; and papers that were published earlier than 2023. The temporal scope of this research is concentrated on analyzing the phenomenon of DT in both its current state and its anticipated future trajectory. During the preliminary investigation, scholarly articles discussing DT from the 1980s and 1990s were discovered, albeit primarily focused on outdated or obsolete technologies. To enhance the study reliability, papers published within the 15 years ago today were chosen. Furthermore, in order to maintain the focus of this topic, papers unrelated to the manufacturing business have been eliminated. The varying interpretations of DT are contingent upon the specific industry in which it is implemented. The perspective and objective of DT in the banking sector varies from its application in the industrial industry.

The initial search revealed that certain terms, such as Digitalization of Manufacturing or Digital Disruption, have been observed to be used interchangeably with DT. Consequently, it has been identified that these terms, namely Industry 4.0, Digitalization, and Digital disruption, can be associated with DT. The research databases were subsequently queried using a combination of the aforementioned keywords. Subsequently, the list was subjected to a refinement process aimed at eliminating any duplicate entries, while concurrently verifying the titles to ascertain their alignment with the content of the article under review. Subsequently, the abstracts were also examined prior to the selection of the publication for a comprehensive review.

## V. RESULTS AND DISCUSSION

### *Definition of Digital Transformation*

The existing body of literature exhibits a limited number of publications that specifically address the DT, mostly within the contextualization of manufacturing-oriented research. Furthermore, a notable convergence is observed in the definitions of DT and other associated words, such as digital disruption or 4IR. **Table 1** provides a description of the meanings available in the existing literature.

**Table 1.** Definition of digital transformation according to various scholars

No.	Definition	Literature
1	The utilization of emerging modern technologies, like but not limited to mobile devices, social media, embedded systems, and analytics, is employed to facilitate significant advancements in company operations.	Nadkarni Prügl [11]
2	By embracing and integrating new digital technologies like mobile apps, social media sites, cloud storage, big data analytics, a company may undergo a transformation known as “digital transformation.	Kraus et al. [12]
3	The term “digital transformation” has come to mean the widespread adoption and implementation of ICT across industries. It goes beyond mere automation to include the introduction of cutting-edge features in fields as diverse as commerce, government, and people's everyday life.	Mikalef and Parmiggiani [13]
4	Digital transformation is employed in defining the deliberate effort made by businesses to improve their operating procedures by using digital technologies. It also includes researching digital breakthroughs that might significantly impact the company's operations.	Akter, Michael, Uddin, McCarthy, and Rahman [14]
5	Digital Transformation refers to the utilization of technological advancements in order to significantly enhance the efficiency and scope of operations within organizations.	Attaran [15]
6	Typically, when people hear the word “digital transformation,” they think of the use of ICT to create fresh capabilities in areas like business, public administration, and the personal lives of members of society.	Rêgo, Jayantilal, Ferreira, and Carayannis [16]
7	Digital transformation alludes to a business strategy that aims to improve a company by introducing widespread changes to its characteristics through the use of new information, computing, connecting technologies, and communication technologies.	Matt, Heß, and Benlian [17]

These carefully selected definitions provide a range of perspectives on what it means to engage in DT. Authors vary in their descriptions of what it is, with one calling it a strategic approach, another a procedural framework, and still another a disruptive element. Because of the current uncertainty around this sentence, there is room for this variant. Scholars like Authors demonstrate that there is no one, agreed-upon definition of DT. Most academics use the term “Digital Technologies” in their conception, which highlights the significance of technology in the process of DT, mostly in the manufacturing sector. A statement's accuracy and clarity may be compromised by the use of ambiguous language, such as the phrase “social welfare,” or by providing actual examples. Furthermore, it is worth noting that there exists a significance degree of circularity within the meaning, as exemplified by the utilization of the term “transformation” in the given definition.

After conducting a thorough examination of the concept and carefully evaluating the provided meanings, a definition that is conceptual of DT has been established, with a specific emphasis on the industry of manufacturing. DT refers to a customer-centric approach that facilitates ongoing enhancements in manufacturing process productivity through the utilization of developed modern technologies, including IoT, digital win, cloud computing, AI, and big data analytics. These technologies are integrated into all facets of the organization. The suggested definition highlights several key elements, which are depicted in **Table 2** below.

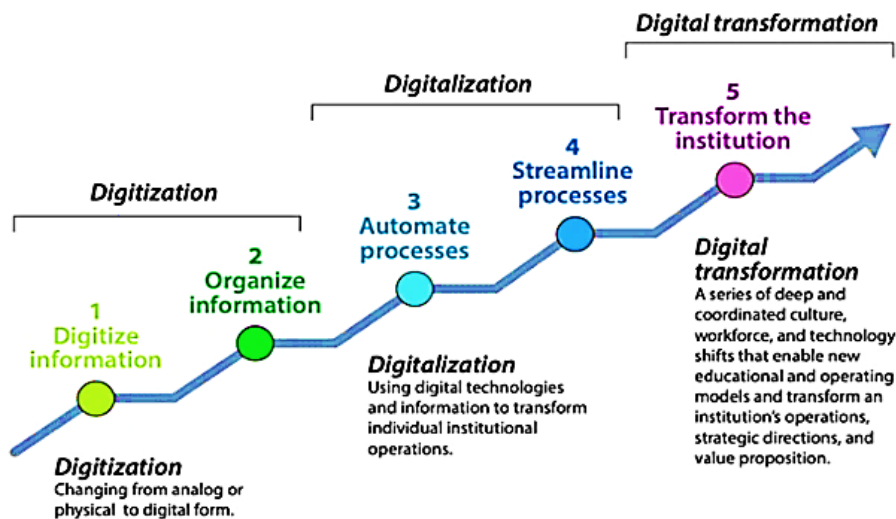
**Table 2.** Key elements of the digital transformation definitions

Critical element of the definitions	Explanation
<b>Customer-centric element</b>	When discussing transformation processes, the customer's perspective has been largely left out of earlier definitions. However, if an organization wants to boost customer happiness and, by extension, profits, it must listen to its customers while it develops its DT process.
<b>Continuity element</b>	The process of DT is ongoing. Manufacturing companies will need to keep updating their operations in order cope up rapid speed of technological change. In order to stay competitive, manufacturing companies must recognize that this is not a one-and-done process.
<b>Digital technologies element</b>	Considering the high price tag and the unpredictability of technology's obsolescence, the technology component of the DT is essential, and choosing the most suitable modern technologies that will adapt to the theme of manufacturing which is very critical to the DT process success.
<b>The organization element</b>	The success of the DT process depends on its incorporation into every facet of the business. In order to maximize the efficiency digital technologies in enhancing the efficiency of production processes, it is necessary to integrate them into all facets of the organization.

*Advancement of the DT concept*

The term “Digital Transformation” has undergone evolution over time. During the decades of the 1970s and 1980s, there was a notable trend towards the incorporation of computing technologies within manufacturing companies. Currently, the term has undergone a shift in meaning, adopting a broader and more inclusive definition. As depicted in **Fig 2**, the evolution of this concept has been delineated in the scholarly literature through three primary stages, which are outlined as follows.

*Digitization*



**Fig 2.** Difference between digitization, digitalization and modern transformation

Digitalization has been recognized as a highly significant technical trend that is impacting both society and industry. Today's businesses are under constant pressure to adapt to the new digital paradigm by adopting new technologies and changing their approaches to doing business. Despite the many benefits of going digital, it's vital to remember that making the switch will need some upfront cash and ongoing costs. With the evident advancements in digital technologies, it is vital to examine how practitioners are utilizing digitalization and to what degree scholars and academics are keeping pace with these developments. Numerous scholarly publications have been published in the existing body of literature pertaining to DT, although the discourse surrounding digitalization remains relatively scarce. One of the initial literature reviews on DT was notably undertaken by Nadkarni and Prügl [18], which was then followed by similar study conducted by Warner and Wäger [19]. According to the scholars, the term “digital transformation” was initially introduced by professionals in the business field.

However, it is significant to consider that there exists a vital disparity in knowledge at the governmental level, with only 1% of global research being attributed to this sector. In light of evolving expectations, governmental entities are presently modifying their operational approaches with the aim of enhancing the provision of public services. Simultaneously, public administrators are actively delineating the concept of DT through their routine professional activities. Therefore, in this context, scholars such as VanDerHorn and Mahadevan [20] are offering empirical definitions of DT derived from expert interviews, as opposed to relying solely on literature studies. In the context of digitalization, a limited number of literature reviews have been identified. One such review conducted by Matt, Heß, and Benlian [21] examines the organizational impacts of digitalization. Another study by Trischler and Li-Ying [22] presents a framework that establishes a connection between digitalization, business model innovation, and sustainability within industrial contexts. This framework serves as a guide for future research scope in this domain. While the terms digitalization, and DT are sometimes used interchangeably, they possess distinct differences.

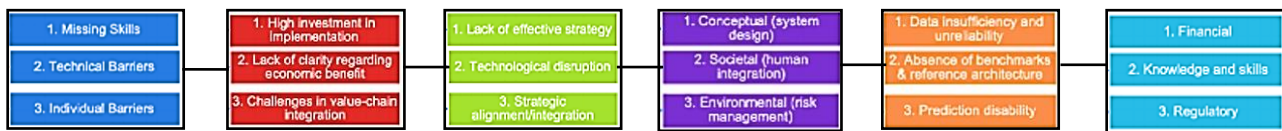
*Digital Transformation*

As mentioned earlier, the current approach diverges from its predecessors by not focusing on technological aspects. The subject matter pertains to corporate strategy, business processes, culture of the organization, management styles, and the crucial aspect of integrating these elements through the utilization of digital technology. The objective of this initiative is to generate significant results for the organization. The various modern projects incorporation, such as the utilization of AR (augmented reality) guided instructions and the integration of 3D printed equipment equipped with IoT-enabled sensors, has the potential to bring about a significant overhaul of the manufacturing process. Both digitization and digitalization contribute to the process of DT.

*Past, present, and future Barriers to adopting DT within the manufacturing industry*

Ulaş [23] highlight a significant insight pertaining to the process of DT in industries that primarily operate in the physical realm. Ladj, Wang, Meski, Belkadi, Ritou, and Da Cunha [24] emphasize the necessity of addressing the inherent tensions that arise when integrating digital and physical components into business models that traditionally operate solely in the physical domain. Therefore, numerous significant obstacles exist in achieving successful DT, particularly considering its intention to substantially alter the features of the organization.

Numerous taxonomies and compilations of obstacles to DT have been put forth, with a significant number stemming from comprehensive literature assessments pertaining to this topic. Barriers are commonly classified based on their relative significance or level of difficulty in being overcome. **Fig 3** illustrates the primary obstacles identified in six prominent scholarly studies about the implementation of DT in the industrial sector. The majority of barriers discussed in the academic literature are mostly focused on technological factors.



**Fig 3.** Major DT barriers

*Enabling technologies of DT*

In their study, Jiang and Katsamakos [25] examine the impact of e-book technology and the Internet on the book industry's DT. The advent of e-book technologies has revolutionized the distribution of books to customers, offering an alternative to traditional methods of purchasing through online or physical retail stores. The industry has been significantly disrupted by the advent of e-book technology, as evidenced by the rise in e-book sales and corresponding decline in sales of traditional paper books. The DT not only brings about changes in the way individuals engage with books, but also introduces novel opportunities for book delivery and market rivalry. According to Margaryan, Littlejohn, and Vojt [26], digital technologies bring either transformative potential or existential risks for organizations that established success prior to the digital era. In relation to this matter, Ruutu, Casey, and Kotovirta [27] propose the inclusion of an operational backbone and a digital service platform as technological assets that might enhance DT plans, particularly during the initial phases. Operational backbones refer to technological systems that promote operational excellence and efficiency, whereas a modern service platform, like PaaS (platform-as-a-service), is seen as a technology that fosters company agility and facilitates quick innovation.

The prevailing body of literature examined primarily focuses on the role of new information technologies (NIT) in facilitating DT. According to Premkumar and Roberts [28], the introduction of novel information technologies, including the Internet, broadband networks, and mobile communications, holds significant potential for reshaping the business landscape. It is crucial to comprehend the appropriate methods and timing for their use. Kukafka, Johnson, Linfante, and Allegrante [29] highlight the significance of effectively implementing new information technologies within a certain industry based on their analysis of 20 prominent companies. A collection of ten drivers of emerging information technologies was discovered. Rather than solely allocating significant resources to new information technologies like websites or broadband networks, firms today emphasize the need of aligning technology investments with their objectives and capabilities to

enhance their competitive advantage. By taking into account the key characteristics of customizability and information content as catalysts for NIT (New Information Technology), organizations can assess the possibility for successful industry change.

According to Chao, Jiang, Hussain, Ma, and Fei [30], the concept of electronic deliverability is identified as a significant factor influencing the adoption of new information technologies (NIT). Bélanger, Hiller, and Smith [31] note that in certain businesses, information may be transmitted electronically, whilst in other industries, this mode of delivery is not feasible. For example, airline firms provide clients the option to conveniently purchase tickets using online platforms, while car manufacturers primarily utilize the Internet to convey preliminary information about their vehicles, emphasizing the importance of test-driving as a prerequisite for making a purchase. The role of information intensity is further influenced by the varying amount of information enabled by new technology for data evaluation. Products and services that possess a greater degree of information intensity necessarily possess a greater potential for deriving benefits. In terms of customizability, NIT provides the opportunity for customers to choose a service that aligns with their value expectations. Additionally, NIT enables the aggregation of services, resulting in combined implications on customer experiences.

Legris, Ingham, and Collette [32] discuss the role of search prices and real-time interfaces in driving the adoption of new information technologies (NIT), with a specific focus on their impact on customer behavior and information processing. The mitigation of contracting risks and the resolution of lacking competencies can be achieved through the implementation of transparent pricing mechanisms and the strategic outsourcing of IT operations. Additional rationales for utilizing emerging information technology include the potential for network effects and the advantages derived from standardization. Gupta and Jha [33] offer an alternative perspective on the utilization of emerging technology. In many instances, the utilization of pre-existing technology for company transformation may present a more straightforward approach compared to the adoption of new or disruptive technologies. Airbnb, as an example, strategically utilized widely adopted networking technology such as mobile phones and applications to enhance profitability by catering to the specific interests of consumers.

#### *Benefits of implementing DT*

The implementation of DT is anticipated to exert a significant influence on both internal and external business operations, as viewed from a business lens. As previously stated, the endeavor at hand is an extensive and challenging undertaking. However, upon successful implementation of DT within the manufacturing processes of the organization, the business will commence the realization of its advantages. The literature extensively discusses the advantages associated with the implementation of DT, as illustrated in **Table 3**.

**Table 3.** Key benefits of DT implementation

<b>Benefit</b>	<b>Explanation</b>
<b>Customer focus</b>	The company that undergoes digital transformation will prioritize consumer feedback in all areas of business.
<b>Increased innovation</b>	Promote a culture of open innovation inside the company.
<b>More profitability</b>	Boosting sales and production output via efficiency improvements.
<b>Productive operations</b>	Manufacturing businesses may benefit from digital transformation if the technology is implemented there.
<b>Competitive advantage</b>	The business-to-business sector is particularly advantageous to technologically advanced companies.
<b>Continuing growth</b>	The company can expand its reach and enter new areas because to its commitment to constant improvement.

The aforementioned benefits are interdependent, forming a cumulative progression of advantages contingent upon the successful implementation of DT. According to the proposed definition of DT, it is characterized as a process that prioritizes the needs and preferences of customers. Hence, the organization undertaking the process of DT will place greater emphasis on incorporating consumer feedback across all dimensions. This communication encompasses the entire product development process, from initial design through manufacturing, ensuring cost-effectiveness and efficient distribution routes for customer convenience, as well as providing comprehensive after-sales services. This form of communication is expected to enhance the organization's profitability and foster greater client loyalty towards its products and services. DT encompasses the ongoing process of constant development. Consequently, the integration of DT into manufacturing procedures has the capacity to enhance the present activities within an organization, resulting in reduced costs and decreased manufacturing time. This is achieved through the utilization of digital technologies that facilitate the efficient and effective implementation of intricate manufacturing processes.

The implementation of DT facilitates the cultivation of an open innovation culture within the organization, particularly within the manufacturing processes that prioritize the utilization of these enabling digital technologies. The aforementioned benefits will result in the acquisition of a distinct competitive edge over the competitors within the organization. According to Cohen and Levinthal [34], if an organization fails to adopt digital technologies, it risks being surpassed by its competitors who have embraced such technology, thereby gaining a competitive advantage. Companies that possess advanced technology frequently have a competitive advantage, particularly within the business-to-business industry. The

implementation of DT has the potential to enhance the strategic position of an organization, regardless of whether it focuses on differentiation, cost reduction, or concentrated market strategies. The primary purpose of corporations is to generate profits for its owners or shareholders. Consequently, all internal processes or strategies implemented within the organization are directed towards fulfilling this core objective. According to Bouwman, Nikou, and De Reuver [35], the implementation of DT strategies can yield greater financial returns for an organization's shareholders. This is achieved through the expansion of sales channels and the enhancement of production processes, which result in reduced operating costs and shorter operational durations.

A. *DT and the manufacturing ecosystem*

Numerous scholarly investigations have been done to determine the impacts of DT on innovation within enterprises. Numerous scholars have undertaken extensive research and engaged in scholarly discourse pertaining to innovation in business technology, product development, company structure, business strategy, new product development processes, and ecosystems for creative problem solving. **Table 4** has presented a discussion of the impact of DT within the industry of the manufacturing economy, supported by literature sources.

**Table 4.** DT impact within the manufacturing economy

<b>Impact of DT in the manufacturing economy</b>	<b>Explanation and Supporting Literature Works</b>
<b>Technological innovation</b>	According to Sui and Yao [36], DT is a key driver of green technology innovation in businesses. The research found that DT greatly aided the innovative use of green technologies inside businesses.
<b>Product innovation</b>	Enterprises can develop products more quickly and cheaply by adopting a digital-platform strategy, as discussed by Scuotto, Del Giudice, Della Peruta, and Tarba [37] through case studies; Ilk, Zhao, Góes, and Hofmann [38] proposed that idea, arguing that enterprise modernization can speed up the innovation ecosystem, strengthen customer contact, and innovation process.
<b>Organizational innovation</b>	Ghezzi and Cavallo [39] used case studies to talk about how well-established businesses are adapting to digital innovation in the face of competition, as well as the changes digital technology has brought about in terms of how businesses are structured. Through a survey questionnaire, Magistretti, Pham, and Dell’Era [40] investigated how DT affected organizational agility and found that companies with digital-transformation leadership were more agile overall.
<b>Business model innovation</b>	King and Levine [41] examined case studies to determine how IoT may be used to spur business-model innovation during DT. Chae used the lens of digital capabilities to assess the impact of modern economy entrepreneurship on the development of sustainable business models for companies.
<b>Innovation ecosystem</b>	In their study, Plata, Aparicio, and Scott [38] discovered that prominent companies like Google and Microsoft establish extensive innovation ecosystems across various platforms due to their robust resource advantages and modern technology capabilities. Additionally, Hekkert, Suurs, Negro, Kuhlmann, and Smits developed a multi-agent model to demonstrate that the impact of enterprise DT on innovation ecosystems varies depending on the size of the market.

The theory of the Resource-based perspective (RBV) posits that a company can achieve sustainable competitiveness when its resources align with the VRIN framework, which entails being valuable, uncommon, imperfectly imitable, and non-substitutable. Based on the based resource theory, it is acknowledged that while the software and hardware systems of a company's modern investment can be replicated and adopted by competitors, the digital-application capability that arises from the integration of business processes, modern technology with enterprise strategy, human resources, marketing, and operations undergoes continuous enhancement during the process of digital technology implementation. Organizations bolster their digital prowess through strategic investments in information technology.

VI. CONCLUSION

This study endeavors to delineate, scrutinize, and revise the existing literature on Digital Transformation (DT), with the objective of presenting six primary discoveries. In essence, DT is a customer-centric approach that facilitates ongoing enhancements in manufacturing process productivity through the utilization of advanced digital technology. Thus far, most contributors have consisted of scholars specializing in the field of information systems. Numerous examples of DT are presented in the literature, each one illustrating how the industrial industry might benefit from adopting this methodology. There are few major roadblocks that must be overcome before DT may be widely used. A lack of training and a skills gap are problems facing the industrial sector. The Internet of Things (IoT) and the Digital Twin are only two examples of the digital technologies that are often used in the process of DT, and they are also briefly discussed in this article. The study's



findings provide credence to the idea that industrial companies might reap substantial benefits by adopting DT solutions. Among these advantages are increased output and more involved customers. This study's results and concerns provide a solid groundwork for further investigation. There is significant potential for DT to impact the manufacturing industry, since it creates opportunities for businesses to scale up the value chain and benefit from value-added activities.

### Data Availability

No data was used to support this study.

### Conflicts of Interests

The author(s) declare(s) that they have no conflicts of interest.

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### Competing Interests

There are no competing interests.

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