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Digital Transformation and Its Influence on Sustainable Manufacturing and Business Practices

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Abstract: The paper focuses on the relationship between businesses and digital transformation, and how digital transformation has changed manufacturing in several ways. Aspects like Cloud Computing, vertical and horizontal integration, data communication, and the internet have contributed to sustainable manufacturing by decentralizing supply chains. In addition, digital transformation inventions such as predictive analysis and big data analytics have helped optimize sustainable manufacturing by reducing overproduction or underproduction through predicting customer demands. It integrates digital technology to enhance business operations, consumer engagement, supply chains, and coordination, the manufacturing process, energy conservation, efficiency, and environmental conservation and culture to satisfy business needs. Businesses' failure to embrace digital transformation in this era contributes to their demise. This research paper will analyze and contrast several businesses and the extent of digital transformation's influence on them during COVID-19. A two-stage study is conducted, the first stage assesses a chosen exemplary business success over three years. The second stage investigates the reasons for success, or otherwise, and the connection to digitalization in the business. Our outcomes suggest that digital transformation strongly influences firms' effectiveness and survival from a technology-centric and business model standpoint. Some essential generic recommendations are suggested based on the results obtained.

Keywords: business practices; digital transformation; industry 4.0; sustainable business; sustainable manufacturing; sustainable organization

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1. Introduction

Traditionally, human civilizations used technology to solve many problems. Since the Industrial Revolution, environmental degradation resulting from wastage and poor manufacturing problems has become a significant issue [1–3]. As a result, the world has begun a global campaign on promoting sustainability in virtually all aspects of civilization. One of the areas that need to embrace sustainability the most is the industrial processes of manufacturing [1,4]. Digital transformation [3,5] not only holds the promise of promoting higher levels of sustainability in manufacturing, but has already begun changing some manufacturing processes to make them more sustainable. Exponential increase to the research output on digital transformation has been observed in recent years, and research scholars have profoundly attempt to examine contribution of digital transformation to private and commercial business sectors [2,4,6,7]. This paper evaluates the role that digital transformation plays in creating opportunities to promote sustainable manufacturing and business practices. It highlights the link between digital transformation opportunities and their impact on sustainable manufacturing and business transformation [8]. A two-stage study is carried out to assess the success, or otherwise, of businesses due to embracing digital transformation. Querying the Scopus database [9] with—TITLE-ABS-KEY ("digital transformation" AND "manufacturing") result in a total document count of 1397. Figure 1 shows the total number of research article types published on digital transformation until the end of 2022, whereas Figure 2 shows the increasing trends in the number of publications since 2015.

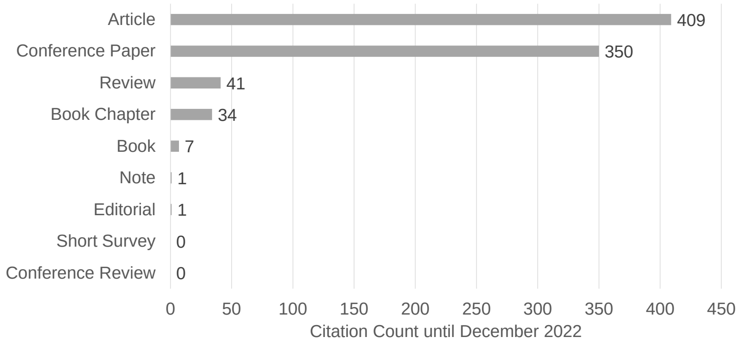

Figure 1. Types of publications on Digital Transformation in the manufacturing sector [10].

Sustainable manufacturing emphasizes aspects such as environmental preservation, energy conservation, reduced waste, and sustainable consumption of natural resources [11]. Evidenced by the consistent elevation in number of research records, data depicted in Figures 1 and 2 drive the motivation of researchers to further explore each technological advancement adopted so far, and to evaluate every contribution made to promote growth of Sustainable Manufacturing. Although not all the developed technologies so far have had positive effects on manufacturing, manufacturers have still adopted Big Data Analytics [12,13], Artificial Intelligence [14] and Machine Learning [15,16], the IoT [15,17,18] and Blockchain [19,20] to streamline operations and promote sustainable production. In the manufacturing sector, research scholars refer to digital transformation as Industry 4.0 since such technologies serve major building blocks to the foundation of fourth Industrial Revolution (IR 4.0) [2,5,17,21].

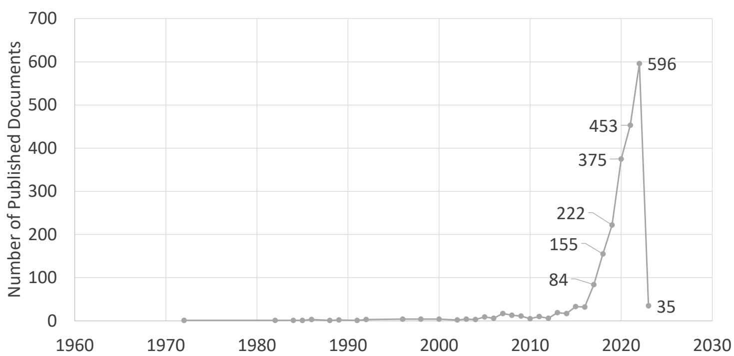

Figure 2. Total number of publications on Digital Transformation in the manufacturing sector [10].

In the current era, increase in the market value of production, demand for sustainability and increase in the number of revenue sales, need businesses to employ processes of digital transformation. However, transformations as such perquisite implementation of digital technologies in traditional manufacturing and operational processes. Target entity, scope and emphasis of digital transformation, delivery and adoption of technologies, and improvements to predicted outcomes, are the four essential evaluation characteristics applicable to access the role of digital transformation [22–24]. A company with a high level of digital transformation maturity may upgrade and change across various situations, including business processes, pricing models, service experience, and culture, while being attentive to market needs and customer expectations [25,26].

2. Research Contribution

The study provides a detailed review of current technologies and their applications in the area of sustainable manufacturing. The primary focus of this study to explore the recent impacts on digital transformation on sustainable manufacturing processes and how digital transformation can contribute to the on going traditional process that still lacking behind many techno-savy businesses. The study also provides two case studies to highlight the benefits of digital transformation. Lastly, the study provides recommendations to the businesses looking forward to incorporate changes enabled by digital transformation.

3. Sustainable Manufacturing

According to Machado, Winroth, and da Silva [27], Sustainable manufacturing is defined as linking systems and processes to generate high-quality services and goods while also being more sustainable in product use and minimizing waste, which leads to environmental degradation. Sustainable manufacturing provides a slew of advantages for producers throughout the world, including cost savings from enhanced efficiency and compliance with existing regulatory rules. Other advantages include increased market access, greater brand perception and reputation, and lower labor turnover due to artificial intelligence's added benefit of reducing effort. Reduced workload encourages a long-term business focus, which helps the company develop and prosper [7,21]. Sustainable manufacturing provides enterprises worldwide with a competitive advantage owing to greater competition, and items produced ethically are mostly purchased by long-term consumers [3]. Sustainable manufacturing is feasible owing to a number of technologies. Autonomous robotics, simulations, systems integration, the IIoT, Cloud Computing, Cybersecurity, augmented reality, and big data and analytics are among the inventions [18,28,29]. In a nutshell, digitizing the production process is the fourth industrial revolution's paradigm, resulting in a situation in which every piece of data acquired is crucial when making any choice [23,30].

Furthermore, by tracking carbon emissions and employing ways to lessen the environmental imprint, big data may play a critical role in understanding the possibilities and difficulties connected with climate change [7,16,31,32]. In China, Huang et al. [16] used big data to quantify self-driving tour carbon emission flow and spatial relationships with beautiful places. Chuai and Feng [7] employed big data to analyze carbon emissions' geographical distribution in China's Nanjing metropolis in order to understand and reduce air pollution in a similar study.There was a lot of other research like this in the literature that used large data. Smart and sustainable manufacturing is gaining popularity in the literature [13,33], and it deals with green, energy-saving, sustainable production, and renewable energy utilization. Manufacturers can meet development goals while decreasing resource usage, deterioration, and pollution by using sustainable manufacturing methods [31]. The IoT, cyber-physical systems, cloud computing, artificial intelligence, big data analytics, and digital twin are examples of digital technologies that have allowed sustainable smart manufacturing [14,34,35].

Policies Promoting Sustainable Manufacturing

International bodies and policymakers such as the United Nations have been at the forefront of advocating for increased sustainability in producing and consuming products. In 2015, the United Nations has outlined 17 sustainability goals known as the Sustainable Development Goals (S.D.Gs). Another policy developed to promote sustainability to avert a political disaster was Agenda 21, which covers all the sustainable goals set out by the United Nations [1,33,36]. The 9th and the 12th sustainable development goals mainly focus on innovation to promote sustainable manufacturing. The 9th goal (Industry, Innovation, and infrastructure) plays a vital role in promoting innovation and advancement in technology in the manufacturing sector, while the 12th goal (Responsible Consumption and Production) is primarily concerned with sustainable production and consumption. The purpose of these S.D.G.s is to reduce waste and prevent a climate disaster that is looming due to the high influx of carbon dioxide released into the air. Despite the high level of incompatibility of manufacturing processes with environmental concerns, these systems play an instrumental role in social structures by promoting people's livelihood by making their lives more accessible and providing them with jobs and employment opportunities that keep the economy afloat. With the understanding of the potential impacts of climate change on the human population, manufacturers have employed a three-dimensional consideration approach. They set out economic, environmental, and social goals that will promote the overall advancement of society [37–39].

Sustainable manufacturing has become a common theme invariably in all industries. Sustainable manufacturing has adopted several dimensions, including manufacturing sustainability by reducing waste, material science, environmental science, and energy science, whose primary goal is to reduce carbon emissions into the atmosphere [7,29,31]. Digital transformation, on the other hand, is a tool that most manufacturers are currently using to reduce emissions and wastage. After understanding the impacts of industrialization, most governments, policymakers, and even private-sectors thought there was no possible way to curb the environmental effects of carbon dioxide without severely affecting the rest of the population [31]. However, digital transformation has indicated the potential benefits of using the technological advances made in communications and information technology to monitor energy use, wastage and promote efficient production methods that reduce pollution.

Furthermore, industry revolution 4.0 mainly focuses on reducing carbon dioxide emissions by the adopting technologies that promote features such low energy consumption and energy harvesting [40]. In addition, industry revolution 4.0 focuses on renewable energy sources, such as solar, wind and coal to drive the demands of increased energy consumption by the industries [31]. As a result of the introduction of these technologies, governments have determined that it is vital to regulate industrial processes in order to guarantee that they support greater levels of environmental sustainability throughout the world. Kaur and Singh [41] contend that inventors developed these technologies to reduce the cost of production in this overly competitive global environment, but have also proven helpful in promoting sustainability. This concept, therefore, illustrates that the digital transformation might have arisen out of need for manufacturers to promote more efficiency and higher profitability, as opposed to the intentional promotion of a sustainable workplace. However, it has also given various policymakers a platform to institute mandatory sustainability measures for all manufacturers. Nevertheless, technologies discussed under the domain of fourth industrial revolution appear to consistently mature and enable improvements to the developmental processes of sustainable manufacturing. As a result, better levels of profitability are achieved while simultaneously lowering the environmental effect that companies have had in the past. Furthermore, future value chain reorganization, changing and developing business models, and other digital technologies will greatly cut carbon emissions and enhance social sustainability.

4. Digital Twin for Smart Designs—Replicating Physical Systems

At present, Industries make use of offline simulation software. Humans typically set up the simulated environments to develop automated programs deployed on real physical systems [14,30,42,43]. Whereas the programs generated using offline simulation are efficient, these lack accuracy when allowed to work on physical systems, and the difference between the results of simulations and the results acquired from actual physical may vary drastically [14,35]. Variation leads to revisions in the created or deployed programs or resolution of simulation or actual program deployment errors. This variation, in turn, leads to time-consuming debugging processes, representing an overhead posed by physical systems when deployed with a model software application. Simulating virtual models online overcomes such a limitation, and in fact, the online simulation offers remote connection to the automated processes that allows control and tuning of generated programs along the desired path, as well as to track real-time simulation on-screen.

Digital twins are the virtual models that allow creation of virtual designs, testing, and evaluation of real manufacturing systems, production processes, or products. A recent trend in Industry 4.0 is the development of virtual models that allow remote monitoring of production processes and manufacturing. Introduced in 2002, the role of Digital twin has gained a lot more interest in the present times. It currently drives the area of systems engineering, wherein model-based system engineering (MBSE) designs are developed to transform physical systems into virtual reality models.

Digital Twin is the concept of creating a digital replica of physical models [30,35]. A virtual instance of a physical system (twin) is generated in the production of a digital twin [24]. Digital Twins can replicate all the characteristics and parameters of real devices digitally, and the developed virtual models receive frequent updates from multiple data sources to learn actively and stay updated [34,44,45]. The current manufacturing systems, production processes, and products embrace full digitalization. However, identifying suitable technologies in digitalization processes is the first step, and digital twin is among the core technologies that enable support to digitalization.

The notion of the digital twin has been extended to smart systems, in particular smart manufacturing processes. The potential and efficiency of digital transformation employing digital twin technology can be envisioned in applications [43,46], and even the realization of smart cities is also driven by this technology [20,34]. Similarly, virtual modules have been applied in online educational processes, such as in architecture, engineering, management, and construction (AEC) [3,47]. In healthcare and well-being, digital twin technology drives the transformation and maintenance of old-style electronic health/medical records (focused on individuals) into readily available digital entities [17,44,45]. Concerning Covid-19, digital twin technology has enabled support to integrate physical and virtual systems and real-time patient flow mapping to develop a sustainable and dynamic vaccination center [44,48,49]. DT generates data and information to provide numerous optimization possibilities for a cyber-physical system. As processes communicate online, digital twin technology offers handy security solutions for data storage and communications. The proposed solutions emerge via different platforms that harvest all the incoming data and ensure reliable operation. For example, DT can be used at power systems' different control and security levels [14,34].

4.1. Blockchain in Smart Manufacturing

Blockchain technology revolutionizes the way of data communications, data security, the mechanisms of fault tolerance, and transparency in data to ensure reliable and efficient communication of data [19,20,34,46]. Blockchain technology builds on a decentralized or distributed directory architecture that works on smart contracts to trace, manage records, automate supply chains, and support payment transfer applications and other business transactions. Blockchain finds its applications in various other areas such as agriculture [20], Internet of things (IoT) [50], health-care [12,13,32,41], Smart manufacturing [33,36,41,51,52], education [19,53], banking [22], transportation [11,54], and supply chains [20]. Due to its numerous benefits that override the existing formulated solutions. Figure 3 shows typical architecture of Blockchain Technology.

Cryptocurrencies are digital currencies based on Blockchain technology since mathematical cryptographic tools serve as the base to these digital forms of currencies. Proposed and implemented by anonymous developers for creating a secure digital currency, Blockchain-based on a distributed ledger technology is the key to this process. Researchers are seen extending this technology to several other areas, and currently, the applications of Blockchain go beyond the cryptocurrency objective. In relation to Smart manufacturing, Blockchain helps to assess assets, quality of production, track logistics and information on transactions. For instance, efficiency and tracking accuracy of a product improves when Blockchain connects to ledgers distributed across a supply chain. Blockchain reduces the time frame drastically to track a product using automation techniques compared to methods or approaches that help suppliers to track products, manually [55]. Various open source standards are coming up from leading tech companies such as Cisco Systems to fully exploit the potential of Blockchain in manufacturing processes. Likewise, smart-contracts are developed to define standard protocols, allowing data communication between heterogeneous Blockchain systems, and supply chain management serves as the primary domain to test the initial application of smart-contracts of Blockchain technology [56,57]. Blockchain technology enables secure distribution of ledger among different stakeholders to ensure transaction updates to each node in the chain. While the IoT sensors collect real-time data from the physical processes and ML modules used to pre-process, filter, and analyze data, Smart contracts in Blockchain characterize the level of intelligence, allow definitions of privacy protection, and drive automation of currently employed systems.

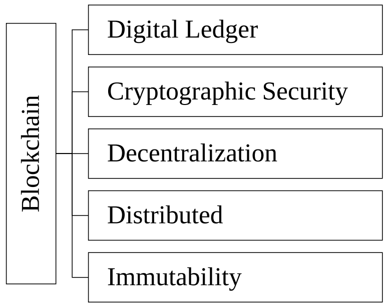

Figure 3. Architecture of Blockchain Technology.

4.2. Decentralization of Smart Manufacturing via Blockchain

Decentralizing information systems is not a new concept, though the boom of Distributed Ledger Technologies (DLTs) has been perceived in late years to drive the role of decentralization [46]. Centralization or decentralization allows integration of resources space [58]. Whereas a decisional center (dc) in a Centralized Decision-Making (CDM) process is privileged to make any decisions and holds all the system information centrally, Decentralized Decision-Making (DDM) system models privilege each distinct independent network entity to take autonomous decisions either to optimize its system resources or to meet any given set of desired objectives [59]. Smart manufacturing requires the decentralization of platforms and resources to deliver and drive massive productions at lower costs, and Blockchain can actively meet such demands with high efficiency. In traditional centralized smart manufacturing units, a trustworthy central server may validate nodes generating data. If the centralized server develops a technical snag, then the whole system drops off. This drop-off leads to delays in communication and an increase in computational costs. Since Blockchain uses peer-to-peer blocks that eliminate the need to engage any third party, Blockchain decentralizes data storage and enables frequent and fast updates via multiple systems. The distributed network configuration permits nodes to execute transactions with the decentralized server and slash the server [21]. Although the terms decentralized and distributed define systems without a central controller and both terms are used interchangeably, these terms are used in different contexts and have a slightly different meaning; decentralized defines a conceptual and logical model of control, whereas the term distributed defines the technical characteristics used for building the infrastructure [18].

4.3. Blockchain-Enabled Immutable Smart Manufacturing

Blockchain systems showcase strong support for the immutability and non-repudiation in economies that realize a lack of trust in third-party service providers. Cryptographic hashes chained via links between blocks enable the execution of immutable historical transactions. While trusted third-party organizations that support rollback have control over the conventional technologies, Blockchain ledgers are less adaptable than conventional technologies due to their Immutable nature. Blockchain-backed immutable transactions serve as the key to decentralized manufacturing processes since non-intervention by third parties is undesired in smart manufacturing systems while the transactions are carried out. Inadequate information among coordinating nodes in a smart manufacturing setup can lead to severe losses. However, with Blockchain limiting frequent changes to the data in the blocks linked by a hash key and replicated in different blocks, and the coordinating nodes tend to remain synchronized during transactions. Any attempts made to change the system configurations at one location are instantly realized or interpreted as an attack on the integrity of other coordinating systems, and thus unwanted transactions to the system are immediately rejected. Transactional data is validated before being accepted by a block, transactional data is validated and the Blockchain then records the transactions permanently.

4.4. Data Acquisition in Smart Manufacturing—Role of IoT

The IoT paradigm is the key enabler of smart environments. The continuing and rapid growth of industrialization and urbanization envision 21.5 billion active connected the IoT worldwide by 2025 [18]. Leveraging the power of intelligence of billions of interconnected tiny smart devices globally, the IoT find applications in a wide range of smart designs, and most importantly, in the plans proposed to develop to smart home [18], smart grids [30], smart cities and transportation [34], automation, and smart healthcare [60]. Despite research advancements over the last decade, the realization of such a vision has never reached an end. Typical sensors used for environmental data collection are the IoT sensors, including temperature, humidity, gyroscope, gas sensor, pressure sensor, and accelerometer. Prolific studies have focused on developing the IoT-based monitoring systems that successfully showcase positive results and recognition by industries. The use of the IoT, ML, big data, and sensors in monitoring systems enables manufacturing units to predict business trends, reduce costs, and improve production and supplies. The key concept to the design of the IoT architecture is the vision to ensure high Quality-of-Service (QoS) based on low-latency resolution. High QoS supports the latency-aware real-time applications employed in the IoT applications, IT services, user tasks, and client events in the ecosystem [34]. Figure 4 describes an overall of different smart technologies in the realm of the IoT.

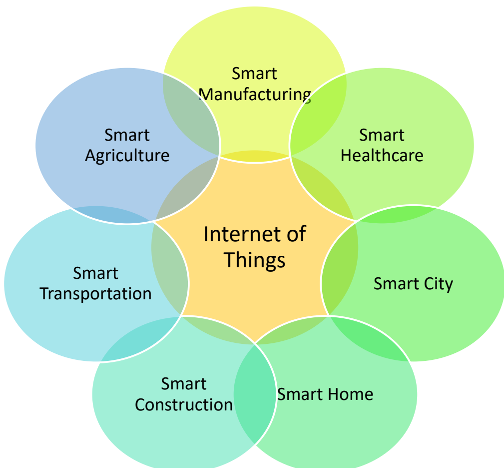

Figure 4. Different smart technologies in the realm of the IoT.

At present, industries implement smart manufacturing technologies to primarily focus on developing intelligent manufacturing infrastructures that employ state-of-the-art technologies, such as machine learning (ML) [37], the IoT [15,61], Blockchain [22,27,37], edge-computing, big data [7,41,55], cyber-physical systems (CPS), cloud computing, and so on [34]. The IoT architectural designs implement devices that typically comprise very low-power microcontrollers and lightweight security protocols. The IoT sensors enable consistent and automated monitoring of manufacturing processes. Intuitive future Internet networking architectures [46,61], such as Information-Centric Networking (ICN) are crucial to deploying the IoT devices employed in smart environments. Demands to develop new lightweight protocols to enable security services such as authentication and data integrity, seek advancements to research. The increase in the size of the IoT networks has triggered security alarms over the confidentiality of data exchanged between the IoT devices and edge devices. Cryptography covers the most attractive and focused area of research, and interest in cryptography is exploding due to elevated demands to guarantee data confidentiality and integrity in secure data communications [43].

The IoT sensor networks generate data streams that are sent to the server for processing over the internet. While the sensor networks deployed in manufacturing industries generate huge amounts of data, monitoring systems serve as a base for manufacturing decision-making and management processes. When deployed and distributed massively into environments, the IoT devices generate huge streams of data, offer distributed computational resources, mutually coordinate with each other to allow processing of some tasks locally, and collaborate with some special nodes called Coordinators to assign them to execute tasks of intensive complexities. Smart environments with complex ecosystems, prerequisite highly scalable management platforms, as these enable such systems to discover, integrate, tune and optimize configuration settings of newly added the IoT devices, dynamically.

Typically, data and communication security in the IoT systems rely on asymmetric cryptography; however, it comes with the drawback of intensive computation and memory requirements. Increased needs to ensure reliable communication of the IoT networks data confidentiality and integrity has led to an explosion of interest in cryptography schemes among researchers. While being deployed to monitor real-time physical processes, the IoT devices starve to meet the demands of low-latency and low-power/energy requirements, and the IoT in this context perquisites hardware acceleration for Elliptic Curve Cryptography (ECC) based algorithms [14]. ECC has been widely adopted in context of the IoT. For instance, ECC enables data security services to exchange encryption and decryption keys and to create a digital signature. When implemented in software, ECC algorithms exhibit high configurability traits compared to their implementation in hardware, wherein it serves as suitable and efficient solutions to the problem emerging out of power/energy and resource-constrained devices or in real-time the IoT applications.

5. Technology Tools of Industry 4.0

5.1. Manufacturing and Digital Transformation

Digital transformation is the use of digital technologies, processes, and competences to effect cultural, organizational, and operational change. In a nutshell, digital transformation is a straightforward process that comprises creating, enhancing, and introducing new technical improvements that may help organizations achieve better levels of productivity optimization. Big data analytics, reorganizing supply chains, smart devices, the IoT communication integration, and other digital advances are examples. In the manufacturing industry, digital transformation has led to the replacement of mechanized industrial plants with digitized and computerized plants, allowing for ubiquitous optimization of production processes, the elimination of inefficiencies, and the creation of a centralized operation that heavily relies on data management [31,32]. Different digital transformation technologies have made a substantial contribution to manufacturing's overall progress and advancement. The majority of digital technologies rely on data collecting and analytics to boost organizational effectiveness (see Figure 5).

5.2. Digitalizing the Supply Chains

Big data has been a key component of the digital revolution, allowing for the development of a variety of additional innovations in this sector. Data analysis and collecting are critical in practically all manufacturing decisions, as well as other areas where organizations leverage similar technologies, such as finance and machine learning. Because of the high degree of digitalization, an intelligent, linked, and decentralized manufacturing process has been developed, lowering the amount of money spent on centralized production methods [11,12,15,18]. Data gathering and analysis have also aided in the development of alternative supply chain models that challenge centralized systems, allowing businesses to lower the amount of petroleum consumed in carrying goods [11,12]. Despite the fact that the manufacturer is an American corporation, companies will create branches in Asian nations to make items for Asian markets. This procedure facilitates the delivery of items produced in these areas to their direct buyers. This kind of decentralization would not have been conceivable without the internet. As a result, decentralizing supply chains and managing logistical problems is a big benefit of data analytics as part of the digital transformation model. The adjustment of supply chains to minimize the distances of transporting commodities would have been impossible without the emergence of the internet and the other technical breakthroughs made possible by the digital transformation period. Despite the benefits of digitization in changing supply chains to encourage sustainable production in numerous industries, a significant digitization process renders many company models useless on a regular basis [11,12,15].

Figure 5. Industry 4.0 technology trends and design principles [25].

5.3. Opportunities in Vertical and Horizontal Integration

The integration of processes within companies' systems determines their performance characteristics. Integration of processes is mainly looked upon from two perspectives: vertical integration and horizontal integration. It is an essential feature that directly drives the creativity, development and manufacturing of the product, including its administration [62].

5.3.1. Vertical Integration

Vertical integration, also described as internal integration mapping is basically defining the underlying processes within systems. It evaluates systems to find out crucial areas driving systems applications in different contexts. Analyzing vertical integration requires identifying two components that underline the separation between purposes of revision, though during analysis such components integrate together due to similar elements to form a single bigger system process. The two key terms used to define systems are:-

- Socio-technical system is a key system for the organizations, whose inclusion relies on the operational successes of organizations. It further requires addition of the following three main elements for monitoring–technological system, organizational system and human operating system [63–65]. Socio-technical systems perceive an organization, either fully or partially, as if is made of a set of interacting sub-systems (see Figure 6)). The model illustrates that business organizations recruit and hire individuals with unique capabilities, who drive themselves to work achieve the set out objectives, follow up with the company processes, make use technology, consistently and efficiently operate within organizations' physical infrastructure, and mutually share unique or common cultural assumptions and ideologies.;

- Value creation modules involve two extra elements to perform and complete the activities, thereby enabling the module to be analyzed rigorously. It helps to analyze in a way wherein each area focused by the value creation modules objectives nearly match to the ones defined by the socio-technical system. Thus, value creation modules offer support to the operations with high output precision. Similar to , social-technical systems, value creation modules require more than the three elements - technological system, organizational system and human operating system, to be included in the system. The three elements are included in the form of the additional products and processes involved. Thus, ensures high synchronization levels in the execution lead by socio-technical systems [64];

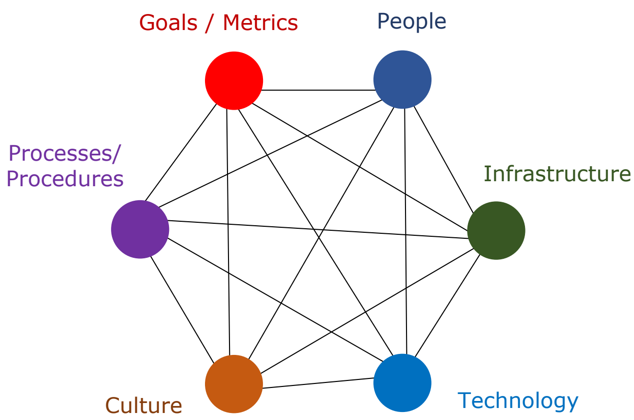

Figure 6. Socio-technical System [66].

5.3.2. Horizontal Integration

Within manufacturing systems, complex relationships that exist between the strategic and operational goals are perceived. Horizontal integration requires organizations participating in the value chain, to play a significant role to meet the customer needs. Within the supply chains, prevail different processes and activities that produce value in the form of products and services targeted to satisfy needs of consumers [67]. Creating value for customers in today's organization necessitates strong ties and collaboration among different heterogeneous organizations constituting a supply chain [68]. The association of organizational groups via the upstream and downstream linkages constitute a supply chain, and digitalizing the entire supply chain shows improved benefits dedicated to organizations, as well as for the customers [69].

Implementation of Industry 4.0 favors development of practically feasible and applicable state-of-the-art business models. Intuitive designed models are subjected to implementation in markets to enable value to the customers and create competitive advantage [70]. The horizontal integration perspective requires that each participant organization must align its goals to meet the value added to customers as a result of collaboration [71]. The goals need to be formulated in light of organizations culture, its processes and people employed, and infrastructure and technology. Moreover, the organizations' goals should be linked to the financial situations that influence the way the supply chain operates.

Though seldom examined, horizontal and vertical integration have made a significant contribution to sustainable production. According to studies [3,15], the progress of sustainable manufacturing is strongly reliant on expanding the connectivity and communication speed of organizations. Vertical integration refers to the ease of communication between top-level management and subordinates in diverse geographical areas, whereas horizontal integration refers to how firms collectively communicate information via various I.C.T. infrastructure advances.

In the current times, manufacturing systems demand integration of intelligent manufacturing systems and exhibit such relationships at different levels of the system. To help identify such relationships, the model developed by Stevens aim to defines each relationship based on the identified characteristics of a manufacturing system considered under the strategic planning phase. However, the model prerequisites standardized techniques and an agile scenario as an operational goal [72].

The smart cross-linking of producers with their suppliers and workforce is a vital component that has aided in the promotion of sustainable manufacturing by enhancing manufacturing costs, lowering worker turnover, and improving product shelf-life through timely production procedures. The incredible speed with which data is exchanged has completely transformed the production process.

5.4. The Promise of BlockChain

Although the industry has made incredible strides in improving this field as it currently is, there are still countless numerous opportunities that digital transformation has for promoting sustainable manufacturing. One of the recent inventions in digital transformation is the Blockchain used in the development of cryptocurrencies. Although the adoption of Blockchain in promoting sustainable workplaces is still in its hype phase, very few companies have wholly embraced the invention to promote sustainable manufacturing [19,20,34,46]. Blockchain refers to a digital ledger or a database in which the files recorded in the database are unchangeable once published. It has become an incredible tool for book-keeping and for managing various supply chains. Notably, Blockchain has proven its usefulness in eliminating many unnecessary processes within the manufacturing process. For instance, aspects such as warehousing, inventory management, the monitoring of goods in transit, and the quantities of products dispatched, can rely on Blockchain to prevent the modification of these figures, thereby promoting transparency. Likewise, Blockchains are admissible in recording all products purchased by the manufacturer and the quantities used in each phase of the production process, thereby allowing the organization to make some radical changes to the production process to make it more effective. Thus, this record-keeping tool is expected to increasingly contribute to promoting sustainable manufacturing altogether in the future.

5.5. Internet of Things and Cloud Computing

The IoT is a web of networked devices containing sensors, software, and electronics that allow data to be exchanged and gathered. The Industrial Internet of Things (IIoT) is a term used in the manufacturing industry to describe a system that allows people, products, and equipment to communicate. Manufacturers are attaching sensors to machines and other physical assets on the manufacturing floor to collect data that influence real-time choices and enhance efficacy and productivity. The massive data captured by the IIoT aids firms in creating defined objectives and better understanding their systems by giving previously unavailable insights [18,28,32]. It can build a digital network that connects the entire organization, boosting collaboration and effectively applying other critical Industry 4.0 technologies [2,5,17,19,22]. The introduction of 5G, with high-speed, low-latency, and large-volume data transfers, has bolstered the IIoT adoption. The interconnection of various gadgets enhances the user experience and aids in effective decision-making. There have also been studies on the IoT technology to measure and control air pollution [5,19]. The impact of air pollution and disaster management has been measured using social media.

Because sustainability is a long-term strategy, monitoring and assessing the organization's progress is crucial to the organization's decision-making in order to achieve the intended results. As explained above, the new agile business environment builds on the cloud [8]. Collecting data throughout the manufacturing processes is crucial to promoting sustainability since it helps to identify areas reflecting the level of an organizations' ineffectiveness and incompetence within the production processes [6]. In addition, when it comes to becoming more sustainable, data collection and storage access strategies are instrumental in monitoring organizational progress, and cloud computing offers incredible support to such strategies, thereby strengthening the role of sustainability in the manufacturing processes. While being a critical facilitator in the digital transformation projects, Cloud provides organizations' size and speed to concentrate on transformation. The ability to provide flexible, on-demand access to the resources that power these new digital business services relies heavily on cloud-based infrastructure, and it is the platform that makes agile application development possible [25,73–75]. Cloud technology extends business infrastructure as needed to meet changing business needs, and also decreases the level of risk of squandered IT resources that previously stifled investments in innovative digital services.

The most important thing to understand in digital transformation is that the cloud is simply necessary, and the cloud's future is transformational. Other technologies may not actually offer efficient solutions to the growing needs arising in the context of transformation and innovation without the cloud. Cloud services can be realized in various contexts such as in the IoT to analytics, systems of insight, edge security, mobile/mobility, and big data [5]. For those who enjoy discussing disruptive services or disruptive entry into established markets, it is worth mentioning that it is rarely the case that such digital markets are predominantly cloud-based [33,73,76,77].

5.6. Predictive Big Data Analysis

Four types of analytics can be performed based on the data. The first is descriptive, which allows for a clear visual representation of the current situation. The second is diagnostic, which aids in determining the source of problems. The third type is predictive, which uses past data and algorithms to forecast future company needs. The final type is prescriptive, in which complex analytical techniques are used to prescribe actions and solutions. Various BDA tools (e.g., Xplenty, Skytree, Talend, Lumify) are commercially available and can give a relevant analysis of a big quantity of data [12,13,27].

The availability of online customers and sales data has made it possible for companies to predict customers' demands prior to receiving an expression of those. Companies commonly respond to customers' demands as those are explicitly expressed. Customers nowadays, on the other hand, want firms to implicitly respond to their expectations before they are even aware of them. Changing consumer needs necessitate predictive models that anticipate enterprises to anticipate changes in consumer preferences and tastes ahead of time and adapt to them before they (customers) respond with demand patterns indicating dramatic change requests [8].

Advances in data collection and analysis methods enable predictive analysis to be applied on the collected data. One brilliant example applied in the real context is [78], where in Target when they started sending coupons for baby products to a household where a teen daughter was pregnant long before disclosing this fact to her parents. The company used the cookie data on the girl's browsing history to predict that she was pregnant. When the parents sued the company for sending them baby product coupons, yet none of the females was known to be pregnant, they soon realized that it was their daughter who had been pregnant [78]. This illustration is a perfect example of how companies use predictive algorithms to predict their customers' needs before explicitly expressing such needs. The amount of data companies collect on customers by building individual profiles for their clients and using data analytics to predict their purchase patterns based on their browser history has been another pivotal component of sustainable manufacturing.

Data collection and analysis in this manner allows businesses to comfortably meet the demand for some of their products as soon as it arises. The concept of predictive analysis of customer needs is a critical component of intelligent manufacturing, allowing companies to be ahead of the demand curve. The digital supply chain, which entails monitoring goods in transit, inventory levels, demand curves, and other similar aspects, has made it possible for manufacturers to focus on producing products and services that meet the demand without having a surplus in the production process. For instance, manufacturers can predict the demand for their products by using the digital supply chain, preventing an overproduction, which is incredibly unsustainable. The ability to make predictive models of the demand of the products promotes sustainability by reducing waste [7,31,79]. Though most people concentrate on complex technologies when evaluating sustainable production, such as robotics and machine learning, few people understand that communication and the collection of digital information such as the demand and supply of products constitute the backbones of sustainable manufacturing

5.7. Smart Manufacturing and the Provisions of Artificial Intelligence

Optimizing a company's production capacity depends extensively on Smart Manufacturing, which heavily relies on artificial intelligence. Artificial intelligence relies on extensive data collection and analysis to make decisions beforehand, which are more effective than human managers' decisions normally based on their intuition [3]. Unlike humans, artificially intelligent manufacturing software makes decisions based on the collected data, thereby improving the accuracy of the decisions that they eventually make. These smart models promote the production process by ensuring that companies have minimal waste resulting from delayed production or overproduction of products that customers do not necessarily need. Likewise, artificial intelligence has also been instrumental in various other areas and predictive analysis of demand and supply trends. Organizations use artificial intelligence to tweak manufacturing processes and increase their efficiency. Sharma and Jabbour [38] contend that companies rely on artificial intelligence software to map areas where organizations waste the most resources. Promoting efficiency depends heavily on the wise use of resources throughout the production model. Companies use simulations to outline the manufacturing inefficiencies in organizations by indicating areas where the process wastes the most resources. For instance, some institutions use artificial intelligence to identify potential materials for recycling, thereby saving the costs of acquiring more material that is not necessary. Such programs have also identified areas that consume the most energy, deeming it necessary for the companies to evaluate ways to save electricity or substitute the electrical sources used in supplying this part of the production process with renewable energy sources (see [38]).

A significant upside of using artificial intelligence in manufacturing is its broad applicability since developers create each artificial intelligence (AI) program to accomplish a specific task. AI software has had a critical impact on reducing redundancy in the organization, thereby streamlining the production process to promote sustainability in the manufacturing process [4,50]. The evolution of artificial intelligence promises more advances in the field that will streamline production processes extensively. The energy industry is at a crossroads. Digital technological advancements have the potential to alter our energy supply, trade, and consumption significantly. AI technology drives the new digitalization model. Smart software will control energy supply, demand, and renewable sources into the power grid autonomously, optimizing decision-making and operations. AI will be crucial to achieving this goal.

Because of its benefits, such as lower defect rates, improved quality, increased reliability, decreased waste, and better floor space utilization, demand for industrial robots in production has been rising for the last several years, making them crucial to manufacturers. As a result, 'cobots,' or collaborative robots, have emerged, interacting closely with humans and complementing their talents [16,25]. The International Federation of Robotics has identified four types of collaborative manufacturing applications: co-existence (no space sharing), sequential collaboration (human and robot work on a part separately but not at the same time), cooperation (human and robot working on a part or machine simultaneously), and responsive collaboration (human and robot working on the same part or machine concurrently where robot responds to the human movements in real-time. Cobots are designed to bridge the gap between traditional robots and human professionals, allowing automation to expand into new areas. Cobots are designed to work in the same way as humans but with the added ability to analyze and communicate data [4].

6. Important Points to Emphasize

6.1. Contributions of Digital Transformation to Sustainable Manufacturing

According to these various definitions, digital transformation is not a single step taken to upgrade particular tasks of organizations, but rather a process that causes profound changes in organizations and results in the creation of additional opportunities for improvement. Digitalization involves automated routines and tasks, such as converting analog information into digital data. Digitalization is the addition of digital components to product or service offerings. In contrast, digital transformation introduces new adaptive business models and digital platforms completely [6,13,19,33]. Furthermore, digital transformation is a phenomenon that causes changes in the industry and society rather than a process within an organization. It is critical to understand the distinction between digital transformation and digitization and digitalization. The use of data has had a tremendous impact on the manufacturing process.

To encourage sustainable manufacturing, management employs a variety of organizational design solutions. To optimize and re-engineer business processes and maximize their total potential, these methods involve modifying the design and engineering of equipment utilized in manufacturing. The IoT equipment operated over the internet, as well as other digital concepts, cleared the way for manufacturers to build digital design and engineering solutions. Robotics and artificial intelligence, which have enhanced the manufacturing of products and services, are also important components that have aided in the promotion of sustainable production. Enterprises currently rely on advanced and clever gear to control and manage the production process [18,21]. Another excellent opportunity for sustainable manufacturing that has arisen as a result of digital transformation is the use of data to improve production management. Production management is keeping track of the best practices utilized in scientific manufacturing process management in order to prevent undesirable outcomes caused by inefficiency. Third, quality management has enhanced sustainability by incorporating data into production.Quality management lowers the number of faulty or malfunctioning items, resulting in less waste and more long-term output. Quality management lowers faults and avoids product recalls by conducting continuous testing, monitoring data in the manufacturing process, and finally altering the viewpoint utilized while developing new goods [12,21,23,80]. Most organizations have dramatically transformed the conventional production process, which was fairly obsolete, via constant testing and review. Fourth, via maintenance management, data integration in industrial processes has improved long-term production. Manufacturers of the IoT devices can use existing data to maintain and upgrade these devices [23,64].

For instance, the auto industry uses the IoT to continually maintain and monitor the quality of their products, allowing these manufacturers to prolong the life cycles of these products and their attractiveness to customers. A perfect example of this case is Tesla Motors, which enables car owners to update their vehicles, improving the speed, performance, and features the car contains. Finally, a meaningful way digital transformation has led to increased sustainability in manufacturing is through logistics management. Logistics management comprises the administration of a company's fleets in order to minimize emissions, reduce incidences of theft in transit, and decentralize the supply chain in order to cut down on the costs and time spent transferring items from one location to another. Furthermore, decentralized supply chains have resulted in the establishment of new factories near areas where items are in high demand, reducing the distance these products must travel to reach their clients. Organizations have improved their sustainability and lowered the amount of money spent on making items while reducing waste and pollution caused by factories by implementing these five changes to the production process.

It is a well-known term in the business world for a reason: everyone is keen on finding out how and why individuals become consumers and how they do so. Because of the proliferation of devices, platforms, and touchpoints, the road to purchase is more convoluted than ever. Developing frameworks to understand consumer behavior requires a thorough attention to data, data mining, data modeling, and honest judgments of why customers do not purchase or become regular customers [25,47,79]. Customers should also have access to the information they require to become more engaged with the company. According to a Gartner survey, in the next five years, 89% of organizations will compete primarily on customer experience. Businesses must keep track of their customers in order to make relevant offers to the appropriate people on the right devices at the right time. Smart organizations take a comprehensive approach to their customers' experiences. Multiple divisions of the organization, such as sales, customer service, public relations, and marketing, must convey information and, more importantly, data in order to create a holistic picture. There is no one-size-fits-all answer for all companies. Collaboration, hard effort, and great attention to detail are required for success.

Every business that treats marketing seriously creates and distributes unique content, both organically and through sponsored means. Consumers continue to reject display advertising in large numbers, forcing businesses to reconsider their expenditures. The growth of mobile technology, along with the spread of social media and what appears to be an insatiable need for content, gives marketers an almost unlimited number of ways to reach out to customers through smart content strategy.Content creation is straightforward. Even the most well-intentioned businesses, on the other hand, confront difficulties in discovering and providing useful information. True informed organizations see content campaigns as de facto editorial activity [25]. They recruit ex-journalists and give them entire autonomy in searching for under-reported, intriguing topics and conducting interviews with key executives. They invest the essential resources in producing high-quality multimedia content. They share mutually beneficial tales with their collaborators and key relationships. Going from a content factory that assigns accountability and quantifiable KPIs to every content asset they generate and post to a dedicated content production plant that assigns accountability and measurable KPIs to every content asset they create and post necessitates some dedication and not a small amount of effort [11,32,41].

Every company that takes marketing seriously generates and distributes original content through both organic and paid channels. Consumers continue to reject display advertising at high rates, prompting firms to reassess their investments. The rise of mobile technology, coupled with the proliferation of social media and the seemingly limitless thirst for material, provides marketers with endless possibilities to contact consumers through smart content strategy. It is simple to create content. However, even the most intentional companies face challenges in identifying and delivering relevant content. Content campaigns are treated as de facto editorial activities by truly educated organizations [25]. They hire ex-journalists and offer them complete freedom to look for under-reported, exciting stories and conduct interviews with key C.E.O.s. They devote the necessary resources to the creation of high-quality multimedia material. They tell mutually beneficial stories with their partners and crucial associations. To go from an organization that periodically shares content they have on hand to an enlightened content factory that assigns accountability and quantifiable KPIs to every content asset they generate and post requires some devotion and not a small effort [11,32,41].

In their engagement with agency partners, smart firms have learned several universal truths. Relationships demand continual assessment. Accountability must be advantageous to both parties. Failed agency relationships cost a lot of money in terms of time, energy, and money. Consumers increasingly regard providers as competitors rather than partners [11,12]. We do know, however, that better connections result in better outcomes. It is vital to maintain open lines of communication with agency partners and to conduct a thorough examination of a company's activities. It is not necessary to employ all of these technologies in a digital transformation project, but it is possible. Data appears to be a recurring subject. The difficulty now is to harness all of the data that has been available in the last decade as a result of fast technological advancements. The digital transformation team works with marketers to solve the difficulties described above and to identify their most pressing needs and pain points

6.2. Current Challenges in the Sustainable Manufacturing

However, not all manufacturers have invested in the industry 4.0 advancements which have been highly effective in promoting sustainable manufacturing [3,17,21,22,81]. Some manufacturers will have little if any interest in sustainable manufacturing if they make a profit. The high cost of investment required to adopt these technologies into all manufacturing units has been a critical determinant that has driven many potential investors to shy away from adopting digital transformation tools or embracing sustainable manufacturing processes in their organizations [6,25]. Other companies shy away from these technological advancements because they need them to completely replace all their traditional manual equipment and replace it with modern plant equipment, which can be extremely expensive. With this understanding, the goal of attaining sustainable manufacturing processes from all producers worldwide seems like a far-fetched dream for most companies. Nevertheless, change is inevitable, and the manufacturers who fail to embrace these changes will be out of business soon. Because all governments are currently working towards sustainability in virtually all sectors, the most probable outcome is that sustainable manufacturing will be mandatory [17,22,61].

Notably, some of the implemented policies entail curbing carbon emissions and the wide use of fossil fuels in various companies [7]. Despite the wide use of digitized information, digital transformation inventions have little impact on the direct reduction of carbon emissions. One of the exceptionally effective strategies is using a digital-focused supply chain to reduce the carbon emissions from supply fleets from the manufacturer by reducing the distance of transporting goods. The rearranging of the supply chain reduces carbon emissions from vehicles but does not limit the carbon produced during manufacturing. Therefore, despite being highly effective in promoting sustainability within the company with a high degree of efficacy, these technologies have impending limitations to offering solutions for environmental sustainability, which is currently the most pressing issue.

Figure 7 shows a simple breakdown of the present and future investments that the various manufacturers worldwide will invest in the future. More companies have started the digital transformation of their plants to promote higher levels of sustainability [54]. In the future, all industries will be fully dependent on digital transformation [32].

It is worth mentioning that COVID-19 has influenced a transformation in the production process for major industries in general. According to a Wall Street Journal report, companies that manufacture various products and machines prioritize higher-priced models due to the global supply chain crisis [15]. The report pointed out that the supply crisis that hinders production and increases shipping costs made companies focus on higher-priced products, which led to the difficulty of finding cheaper alternatives. The shift to more expensive products comes intending to offset costs and maintain profitability. A combination of inflation and scarcity is pushing manufacturers towards producing more expensive goods. Suppose a manufacturer encounters difficulty obtaining enough parts to make all the products it usually manufactures. In that case, a shift is made to more premium products to protect its profitability.

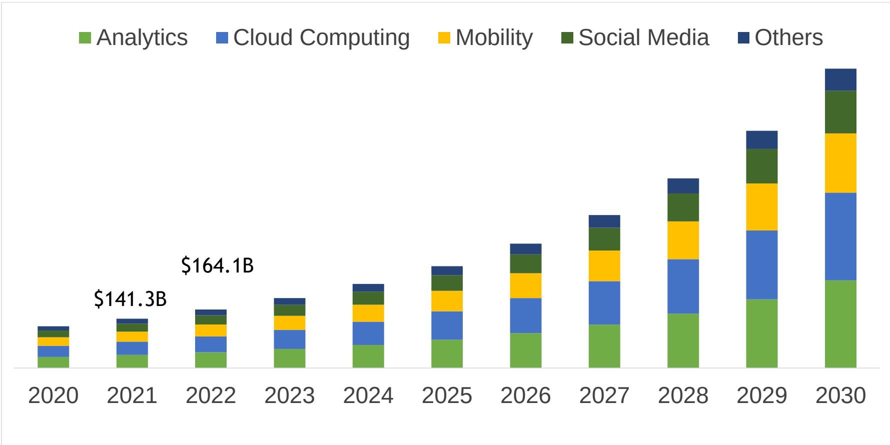

Figure 7. US Digital transformation market (US Billion). Figure shows the investment projections on various digital transformation tools from 2020 to 2030 [82].

7. COVID-19 and Digital Transformation

The COVID-19 pandemic, global health, and socio-economic emergency have posed unique issues for citizens, governments, and organizations. During this time, industries are becoming more complex and uncertain. Empty buildings lie vacant, staff work from home, and customers have less disposable income [41,76,83]. Despite how dismal things may appear, chances do exist. Organizations, on the other hand, will have to change. COVID-19 has left cities vulnerable, but internet-enabled technologies such as AI, the IoT, and 5G have quickly responded and presented a potential for urban growth and disease tolerance [5,27,31,54]. Authorities have repeatedly stressed the supportive role that science and technology can play in the fight against the pandemic's spread. The Japanese government, for example, has attempted to increase funding for scientific research programs and has promoted ethical evaluations for COVID-19-related scientific operations [22,36,41]. It is undeniably true that businesses with weak digital readiness and presence have suffered most during the pandemic. Innovations, systems, and technologies were progressively becoming a crucial element of daily business/manufacturing operations before the end of 2019 and the eruption of the COVID-19. In this new context, technology is not a luxury but a necessary business strategy that should be integrated into every aspect of an organization's structure [50]. As a result of being a member of a digital global society, businesses are able to become more innovative, competitive, and sophisticated. The COVID-19 disaster, on the other hand, has ushered in years of transformation. This shift changed the way firms in every industry function in only a few months. According to the McKinsey Global Survey of CEOs, COVID-19 has forced businesses to accelerate their digitization by three to four years. Businesses have reacted to new needs far more quickly than they expected before the crisis.In order to obtain a degree of efficiency and effectiveness, businesses have wandered towards quickly adopting digital adjustments on their internal and external corporate processes, consumer and supply-chain linkages.

Dell's Digital Transformation Index 2020 surveyed approximately 4000 corporate executives across the world and discovered that eight out of 10 companies had accelerated and increased their digital transformation activities [8,77,84]. Improved client contacts, enhanced worker efficiency and mobility, and solid data discoveries are all benefits of transformation, which enable a company to develop, flourish, and endure post-crisis. The application of digitalization across the whole corporate supply chain is being accelerated by COVID-19. As a result, enterprises' digital supply network, database, analytical applications, software platforms, cognitive automation, networking platforms, and e-commerce are more widely accepted [8,75,85]. McKinsey & Company's study results reflect the fast-growing trend of communicating with clients via digital channels. The study's findings show that adoption rates have changed and expanded since the participants were polled years ago, and that their consumer relationships have become more digital than previously [3].

In July, Whirlpool Corp., a maker of many home appliances, including washing machines, confirmed it would switch to higher-priced products as part of a plan to help cover rising costs. Across all industries, manufacturers of products as diverse as toilet paper to television sets are raising prices, reducing product diversity, and imposing purchasing restrictions on retailers. The global supply chain crisis, which has worsened as the pandemic continues, has led to massive congestion at ports, as well as higher costs for transportation and essential materials for manufacturing. At the same time, manufacturers, retailers, and consumers are affected by high inflation, which is expected to continue for at least the coming two years [3,5]. Automakers in the United States face weak stocks after car factories closed in the spring of 2020 for two months to limit the spread of the emerging Coronavirus.

Presented here is a two-stage study that will uncover if businesses' success during COVID-19 has become parallel with the efficiency of digital transformation. The first stage assesses selected sample businesses' success/failure in the U.K. throughout 2018–2020. Three diverse businesses are chosen for this pilot study that, in our view, indicate the general influence of the pandemic on the sales of businesses given the achieved degree of automation. Then, analysis is conducted to explain the influence that also applies with equal validity to manufacturing. Next, some essential generic enterprise strategies are suggested based on the findings.

7.1. First Stage

This first stage in this research seeks to measure several businesses' success in 2018, 2019, and 2020. For this study and illustration, we have targeted businesses whose financial statements are available online [51,52]. We employ free financial data sets made available online provided by Thomson recuiters Eikon [86]. The country of choice is the United Kingdom (U.K.). Three prominent businesses have been selected for monitoring their performance throughout the prescribed years.

One division of Associated British Foods operates the Primark retail business. Primark is based in Dublin and then expanded to the U.K. and several European countries with over 392 branches. Primark is a store that sells the latest items ranging from homeware to fashion and cosmetics at low costs. Its success over the years was due to its competitive prices, quality products, suitable excellent store locations, and its concentration on specific popular markets. In 2018, Primark's operating profit increased by 15 percent, while its operating profit margin grew by 11.7 percent in 2019 [50]. Time went by as the store witnessed considerable growth and focused on developing its website while promoting digital marketing platforms. However, the website did not cater to online shopping and was more of a storefront display that mainly served a products catalog. As a result, when the COVID-19 arose and spread throughout England, Primark faced A major setback where 188 stores in England temporarily shut down in March 2020 due to the pandemic crisis. The dilemma aggravated since Primark failed to provide an online alternative for its services. A quick look at digitalized online retailers in the late few months of 2020 with enabled online sales functionality shows an apparent increase in sales. This increase is because they had the digital edge and skills earlier than the start of the crisis.

Primark previously asserted that it will not sell online due to the high cost of doing so [50]. These costs would have an impact on their prices, preventing businesses from offering low rates to customers. Primark Turnover-Continuing Operations have suddenly reduced in 2020, as seen in Table 1, which is not coincidental with the entrance of COVID-19. As shown, gross profit, operating profit, and total comprehensive income will all decline in 2020. After a difficult year, profits have dropped by 60%. Similar to Primark, Flying Tiger Copenhagen is a multi-department shop. It faced the same problems with diminishing revenue, gross profit, and income statement throughout the crisis, which hurt the store and risked its sustainability. Primark and Flying Tiger Copenhagen are both facing similar issues and must digitalize their companies in some manner to enhance their statistics.

J.D. Sports, a global athleisure department store, on the other hand, had a modest growth in revenue over the three years (2018–2020) [46]. As indicated in Table 2, J.D. Sports' net income maintained around the same level [51]. Their sales growth has had some ups and downs, but nothing big, and their operating profit has climbed by 2020. They did, however, have a small issue with income growth, although nothing as baffling as Boots. Over the course of three years, revenue at Boots, a pharmaceutical retailer, fell, with sales, operating profit (EBIT), and net income all falling at a fast rate [47]. As a result, something has gone wrong in their company, which must be investigated and corrected. J.D. Sports, on the other hand, must maintain and, if possible, improve their results as they progress. Finally, Tables 1 and 2 show that Primark saw the greatest decrease in 2020, followed by Boots and J.D. Sports, which experienced a minor fall and maintained a relatively constant position [52].

Table 1. Primark Stores Limited [87].

Primark		
		(GBP Thousands)
Turnover-Continuing Operations	Year	Amount
	2018	3,346,702
	2019	3,449,257
	2020	2,540,686
Gross Profit	Year	Amount
	2018	634,742
	2019	638,072
	2020	341,313
Operating Profit	Year	Amount
	2018	336,695
	2019	336,660
	2020	139,435
Total Comprehensive Income for the Period	Year	Amount
	2018	248,410
	2019	259,684
	2020	35,071

7.2. The Second Stage

The second stage of this study focuses on determining the causes of the incline/decline in revenue and how this relates to the extent of digitalization readiness of the business. Compared to Primark and Boots, saw the least drop over the three years, as illustrated in Tables 1 and 2. Primark experienced the greatest drop in sales in 2020, which indicates the significant impact COVID-19 had on them. Like Flying Tiger Copenhagen, Primark did not have an online store to shift to accommodate customers' orders. Not having an online shopping cart played a significant factor in the dropping figures exhibited in their statements. This drop raises the serious question of the degree to which a business's digitization influences its success.

J.D. Sports, on the other hand, stressed customer relations prior to the COVID-19 breakout by completely switching to an online presence, which proved to be a huge success. As a result, the corporation claimed a 510 million pound operational profit, a staggering increase from 2018 to 2019. The corporation posted a net income of 246 million pounds, down from 262 million pounds the previous year, but significantly higher than expected. The revenue during the time period was somewhat higher, at 6111 million pounds. All of this illustrates the company's strength, stability, and market leadership, as well as its significant maintenance of financial statements (revenue, earnings, and sales) during a period of significant instability and store closures across the United Kingdom. Despite the fact that Boots had completed some digital transformation before to the epidemic, the company nonetheless experienced negative consequences.

Table 2. Income Statements—Henry Boot PLC and JD Sports Fashion PLC [51,52].

	Boots		J.D. Sports	
		(GBP Thousands)		*(GBP Millions)*
Revenue	Year	Amount	Year	Amount
	2018	397,052.00	2018	3161
	2019	379,693.00	2019	4718
	2020	222,411.00	2020	6111
Sales Growth	Year	Amount	Year	Amount
	2018	−2.08%	2018	32.90%
	2019	−4.37%	2019	49.24%
	2020	−41.42%	2020	29.53%
Operating Profit (EBIT)	Year	Amount	Year	Amount
	2018	48,158.00	2018	311
	2019	45,925.00	2019	318
	2020	7672.00	2020	510
Net Income	Year	Amount	Year	Amount (Billion)
	2018	37,505.00	2018	232
	2019	37,596	2019	262
	2020	11,921.00	2020	246
Net Income Growth	Year	Amount	Year	Amount
	2018	−11.48%	2018	29.62%
	2019	0.24%	2019	12.89%
	2020	−68.29%	2020	−6.00%

Boots UK has seen a considerable reduction in retail sales compared to the previous year. As a result, Boots UK is surely pursuing a transformation and development plan to mitigate the pandemic's impact on their business. J.D. Sports has invested much in digitization and a thorough grasp of its target market. As a result, J.D. Sports can maintain a positive relationship with their customers, who have increasingly switched to online shopping channels in Covid-19 times. J.D. Sports Warehouse, situated in Rochdale, England, has recently invested more in its online operations, shipping, and packaging. As a consequence, they will be able to handle both online expansion and their customers' desire for speed. At this point, their opponents were either still or moving slowly. Years before the pandemic, the corporation focused on growing its internet presence, which helped them when the United Kingdom closed in 2020. Despite the lockdowns in the United Kingdom, J.D. Sports was able to maintain some control over the situation due to its early digitization and fast improvements to its digital services during the crisis. Furthermore, this demonstrates that the COVID-19's development is the reason of the dip and decline in business statements. As a result, businesses were compelled to radically adapt and adjust their digital strategies, indicating a strong link between sales success and the level of digitalization within a company.

Apparently, applications of digital transformation tools and technologies as discussed in the prior sections, play a vital role in transformation of businesses employing traditional approach business services. Digital technologies include embedded systems and robotics, mobile applications, artificial intelligence and machine learning, blockchain, social media, virtual reality, augmented reality, and cloud computing, among other things. By employing digital transformation tools, technologies enable digital transformation in projects. As observed in the case studies discussed in this study, the step to switch to online platform, eventually led to an increase in the sales figures. However, improvised results could be anticipated if the other types of technologies, such as AI, social media etc., are implement and incorporated in businesses. For instance, AI can help evaluate a lot of data and create predictions based on customer data. AI can aid vendors to make better decisions and provide quality service to their customers. Similarly, smartphone and tablet users can leverage mobile payment apps to make purchases. The use of this kind of payment mechanism is expanding globally. A study by Accenture [10] finds that almost half of people worldwide would prefer to pay with their mobile devices than cash or credit cards.

8. Discussion and Possible Recommendations

According to the findings of our pilot study, businesses will continue to face issues unless they embrace digital transformation, at least for the sake of survival and competitiveness in a world built on a digital foundation. Changes in the market have forced businesses all over the world to restructure their operations. When the crisis struck, adaptation accelerated to three years ahead of plan and expectations. Despite the fact that more than half of firms had started to conduct digital transformation, they were not fully equipped to ensure that COVID-19 will have no impact on their operations. Prior to the epidemic, both Primark and Flying Tiger Copenhagen were profitable. Primark's website lacked an online order processing method to guarantee the sales activities were not disrupted, resulting in a huge outage. To compete in today's market, Primark must digitally alter its business. Not only is Covid-19 forcing them to adapt to the digital trend, but so are all other firms. Flying Tiger Copenhagen also suffered a significant setback. They are now putting out their plans for re-fishing in the near future with new digital transformation methods, targets, and plans to ensure long-term viability. Flying Tiger Copenhagen will be able to stand on its own two feet and grow as a business again thanks to these ideas. Boots was one of the companies who struggled to digitize their operations. However, when the COVID-19 struck, it was not as far along, which had a detrimental impact on the firm. Because J.D. Sports was more advanced in its digitization, the pandemic had less of an impact on them, and they were able to prosper as a business later on while others were struggling.

The findings of a conducted survey (see Figures A1–A7 in the Appendix A) on local firms in Kuwait correlate with digital transformation as more proof of the linkage between company success and digital preparedness, particularly during unforeseen events. Our research study's hypothesis is proven without a shadow of a doubt by the findings. Most local firms in Kuwait were significantly impacted by the epidemic, as indicated by our study findings, because to a lack of digital transformation. One of those companies, however, was unscathed since they were so well advanced in their digital transformation that the epidemic had no impact on them. Kuwait's lockdown limitations in reaction to the crisis had just a little influence on them. Given the issues businesses experience throughout the epidemic, the findings from our study and those from three U.K. organizations indicate a reasonable generalization of the link between companies and digital transformation. We now propose a set of principles for businesses to follow in order to mitigate the consequences of impending issues, such as a pandemic, and transition to a digital corporation.

Businesses must now prioritize and strategy digital acceleration by quickly implementing a future digital technological framework that combines various parts of company operations and workplace management. Additionally, organizations will focus on customer behavior in order to create a client-centric culture within the company. Furthermore, having a consistent digital platform for customers to interact with the company and make purchases is critical for business continuity. This digital venue avoids direct interaction while providing exceptional service and performance to their clients' needs and aspirations. Next, as part of their operations and supply chain, organizations should digitally communicate with their providers.The capacity to undertake data analysis, regardless of the digital platform used, is a must-have function. As a result, the firm will become more stable and adaptive. As a result, they are able to adjust to shifting market conditions and customer expectations. It's critical to understand that digitally enabled firms develop resilience, which means they can overcome difficult situations like surviving the effects of a pandemic and fast recovering.

It is highly recommended that organizations create aggressive business models and digital transformation initiatives that respond to changes in the environment and customer tastes. Once the implementation is executed with caution, the pandemic could be turned into a business opportunity. In addition, businesses should focus on transforming the sustainability strategy from challenges to opportunities instead of prioritizing sustainability in their business models and assessing their long-term resilience. It is also essential that businesses strategize the shift to sustainability through, for instance, increasing the operational and environmental efficiency and providing backup platforms. This shift can be done by performing familiar things in novel ways. Process improvements and investing in efficient technologies are the mainstays of business sustainability improvement. Another piece of advice is to ensure that the adopted digital solutions can interpret the transactional and manufacturing data in all formats and provide appropriate managerial reports in the context of a specific user's function. It is, in most cases, preferable to consider isolating technological applications from one another:

The argument that the vast majority of I.T. solutions include a considerable number of capabilities that are either irrelevant to the customer's needs or too challenging to use effectively. As they have for decades, many firms today continue to use monolithic solutions or platforms to value how they tackle integration difficulties by providing something to address a particular job or workflow. One primary objective for effective business digitalization would be to prioritize visibility centralization. Ninety percent of all data has been created in the past two years, according to some estimates. Manufacturing is no exception, and the challenges it presents might be significant. Knowing what data is relevant, having it readily available and at the right time are all critical. With digital thread initiatives pushing data integration developments, now is an excellent time to look into best-of-breed possibilities and leverage purpose-built solutions for various business functions. Platforms have the benefit of being a bit of a devil's bargain. In exchange for saving money on application integration costs, their rigidity and scope may force a business to become "captive" to that provider, which is a risky situation.

Owing to today's technology, such as web services, accessing information stored in either an on-premises application or some cloud service has never been easier. Despite this, many firms continue to collect data from a range of apps using inefficient laborious manual methods and processes. Finally, an organization should strive to avoid making the mistake of equating activity with progress where rather than progress, activity is frequently monitored. Gaining critical visibility into the commercial impact of digital transformation activities is one of the most challenging challenges manufacturers face. Manufacturing operational executives, like outstanding marketers, must focus on the customer journey and look for tent poles of inefficiency. For efficient management of a digital transformation project, selecting the right metrics, consistently taking measurements, and monitoring progress against goals is critical. It requires time and a solid understanding of the company's objectives to do this.

COVID-19 has created challenges for the supply chain, especially when securing enough supply of raw material and parts needed to manufacture enough to meet consumers' demand [12]. Those challenges are particularly true for the cheaper line of products whose profit margin is rather low in most cases. Digital transformation can be instrumental in improving the management of the supply chain through connecting to alternative suppliers and help in better predicting demand with a safety net of supply material to sustain unexpected circumstances up to a certain margin of certainty. The world post the Covid-19 pandemic will be a very different place. The supply shock that began in China in February and was followed by a demand shock as the global economy collapsed exposed flaws in companies' production methods and supply chains worldwide. Shortages of drugs, crucial medical supplies, and other products, as well as temporary trade restrictions, exposed their flaws. Together with the trade conflict between the United States and China, these trends have fueled an increase in economic nationalism.

To many manufacturing industries and businesses, self-sufficiency has become a strategic goal with a rapid adaptive digital transformation to efficiently manage the supply chain and facilitate the transition to sustainability. The focus should increase operational and environmental efficiency by introducing innovative approaches to traditional business practices. Process improvements and investments inefficient technologies are the mainstays of business sustainability improvement. Industries/businesses ought to actively pursue sustainability as a source of market differentiation and competitive advantage by developing completely new business models.

Impacts of Digital Disruption

Industrial manufacturing spans across different domains with established engineering practices. Digital manufacturing technologies are applicable to different industry sectors, typically showcase an increase in the number of technical tools and products, in the number of adopted strategies to develop and manage end user applications. However, evidence by [81] suggest that digital manufacturing not economically feasible. Businesses experience barriers that deviate them to permit any possible advantages out of digital transformation into their processes and existing systems. Digital Transformation's paced development exhibits constraints that relate to its realization, and there are various challenges that emerge as a result of its adoption. Section next describes typical challenges that digital transformation brings in to the businesses sectors, in general:

Digital transformation requires technologies that generate large vast amounts of data. Data collection in itself poses several challenges, and data security is one of them. Securely managing data is perceived as a critical and complicated task since a simple data breach can comprise huge amounts of public or private information. Criminals, terrorists, competitors in businesses, antagonists, or other malign entities may exploit that data in ways that threaten human lives. Over the last decade, there has been a tremendous increase in the number of illegal activities over the online platforms. Social media has been used by terrorists as a platform and terror organizations have transformed traditional practices of financing terrorism using more advanced methods based on digital technologies, such as cryptocurrency and virtual currencies, crowdfunding, fundraising, social networks and most often telegram channels have been actively used by such organizations to ensure growth of illegal networks [88]. Likewise, dark web has been used by drug dealers, and other places to exploit potential victims, exchange unsolicited photos and videos, and other information.

While employing digital transformation in manufacturing, the physical layer is exposed to many vulnerabilities, wherein the IoT devices are more prone to security incidents than other endpoint devices. The IoT devices perform operations on data, however are limited in data processing, storage and networking capability [89]. This eventually limits their ability to defend against security threats over the open networks. Similar to the aspects of the IoT, authors in [90] have investigated security and trust of social networks, and conclude that both the social and the IoT technologies have various security threats separately, however their integration adds these vulnerabilities in entire value chain.

In relation to cyber security, organizations need to implement smart, innovative and efficient controls to detect and prevent advanced and emerging cyber-attacks. Cyber security incidents heavily leave impacts at different levels, i.e., at individual, institutional, organizational, corporate, national, international level. Instance downtime, inability to implement business processes, data breach, all represent a direct role of cyber security in financial and other critical loss, while legal obligations, lost privacy, stolen identity, regulatory penalties, loss of reputation and bad public image are indirect impacts. Currently, most organizations need enough preparation and knowledge to tackle such challenges [91–93], and cyber risks cannot be avoided since these are key tasks for stakeholders in digital transformation. Apparently, the processes to tackle and manage such challenges seem to be unsuccessful, if end users aren't ready for it, yet. Imperative to organizations would be educating customers or end users, which prerequisites educational investments, basically surface new challenges in itself.

As digital technology evolves and changes over time, technologies used in business too need changes to stay updated. Changes needed to the existing systems mainly correspond to existing hardware or software running the systems, and any updates required by the systems, demand additional costs of upgrades. This additional cost leads to reserving shares for upgrades and training staff to learn new roles, methods, and technologies in businesses. Eventually, significant impacts on the profitability can be observed since businesses may need to pay the cost of the upgrade and the cost of training the existing workforce to accommodate new changes in the system.

Previously, people would work in a physical location. However, the latest trend shows people take up jobs remotely since digitalization and automation empower remote working and management [94]. Task assignment and processing are typically carried out remotely via the internet. However, job insecurity is negatively related to life satisfaction, and this relationship becomes stronger when employees have low job embeddedness [95]. With digital disruption, a Third World worker with a relatively low wage economy now has access to remote workplaces and could be employed to replace the workforce demanding high wages. While computers gradually serve as a fine replacement, the need to employ humans for handling tasks is increasingly diminishing. It appears that low-level employment types, such as driving, laundry, and delivery jobs, would soon vanish as automation keeps ticking the clock on step ahead every time, thereby warning them about the severe effects of disruption posed by the digital transformation.

9. Digital Production Barriers, Implementation Strategy, and Impact

An Organizational Structure (OS) within businesses allows management teams to structure, organize, execute, and coordinate different activities within an organization [96]. Knowing the OS of a business that implements traditional ways to carry out business operations, allows the owners of that business to incorporate new operational methods and advancements to their underlying business model. An insight into the OS helps its stakeholders to identify the processes driving businesses. Getting an overview of an OS, uncovers the process-to-process coordination required within the OS, and the coordination and communication between the work processes of an OS are the key factors that determine the level of efficiency and outcomes established by the businesses. Businesses with well-defined organizational structure, offer support to decision making processes, to events demanding conflict resolution between various stakeholder or teams driving the core business processes, and even provide methods to effectively deal with changes in the ambient [96].

Data is the force driving digital transformation within organizations. Data collection and assessment guide us to explore: (a) sources of data and (b) the platforms that process and communicate data. For the data sources, may cover both the external and internal data sources. While external sources may include data acquired from business consulting agencies, original equipment manufacturers, retailer businesses, and other competing firms in the market, the data originating from internal sources mainly relates to customer interactions with devised business process of the organization. Platforms of data constitute the data and communication media that transfer data within the entire ecosystem of an organization. Data originates within business transfer to customers and everything in between.

9.1. Barriers to the Success of Digital Transformation

Our literature review suggests that there are various barriers that need addressal. Listed are the 5 main barriers, that we observe to hamper the digital transformation projects' success rate among organizations:

9.1.1. Non-Readiness to Frequent Experimentation in Businesses

While in operation, experimenting with underlying business processes could lead to disasters and companies may incur huge losses. As per the survey conducted by [97], 53% of senior executives realize that the inability to experiment frequently with businesses, represents the major barrier to the success of business projects. Although worth consideration, the result as such are insignificant compared to the pace with which the digital innovations advance in the current times. A business needs to respond and acclimatize quickly to the changing needs of customers and markets. It is most likely to perceive an innovation as old, by the time the implementation of a new idea is realized for a change in the system.

9.1.2. Non-Readiness in Adapting Changes to Current ICT SYSTEMS

Digital transformation requires replacing legacy IT systems with state-of-the-art in order to adapt to the new system and technologies for manufacturing. Legacy systems deployed, serve as essential building blocks of infrastructure, however depict maintenance needs most relatively at very high costs. Being highly complex in nature, legacy systems lack interfaces that allow them to work and communicate with other technologies. As a result, a number of enterprises showcase multilayered middleware architecture. To provide solutions on top of core technologies, enterprises also implement connectors to solve a different set of challenges within intra and inter operational systems. However, not all systems may incorporate such changes. Apparently, constraints limiting updates or changes to the already implemented legacy systems are a significant barrier to the digital transformation projects' success.

9.1.3. Diversity of Participating Teams

Though communicating occasionally, teams formulated to run businesses typically compete against each other to gain access to resources, funding, and may share some common objectives, as well as accomplishments. Nonetheless, these diverse range of participating communities are non-conducive to digital transformation, as the transformations envision and seek changes across the entire end-to-end business. Diversity as such reflects a barrier to the application of digital transformational processes within organizations since these need to ensure teams can collaborate to enact changes to the overall system.

9.1.4. Disconnection between Organizational Units and I.T

As per [97], 49% of respondents perceive collaboration as an obstacle, hampering the path to digital transformation. Technology drives the business processes in every organization these days, and the role of Information Technology (IT) forms the core unit driving in organizations' IT needs. IT units, therefore, need to have a clear perception of current business processes and must ensure strong connections or ties with other units in every aspect that effects overall success of a business. Businesses that are looking to implement digital changes to ensure sustainability in manufacturing may have problems as a result of a severe gap between leaders and IT. Eventually, this workflow blockage may occur within these businesses.

9.1.5. Inabilities to Respond to Risk Factors

As per [97], 47% of respondents reveal intermediate disliking of a culture that exhibits risk factors. Respondents perceive risk prone culture as a real blocker to their digital transformation opportunities. Digital transformation necessitates risks, towards which organizations' culture resistance has to overcome. For businesses adaptive to exploration and experimentation, perceive risks as source of distraction that organizations must dissect, while considering cultural perceptions, existing within their employees.

9.2. Implementation Strategy

Digitalization needs technological advancements that mostly rely on tools, methods and techniques of ICT. Growth of digital technologies, and data originating by the processes of digitalization, profoundly drive to transform architectures of businesses to create added values and satisfy the needs of end users [98]. Digital transformation seeks to incorporate structural changes within organizations to include new operations in existing systems [99], and changes as such mostly rely on the organizations' internal mechanism that guides : how new intuitive activities are added to existing structure? To craft strategies for the future, businesses need assessments of current work environments. In other words, adapting to the role of digital transformation would need detailed responses to the following tasks, listed in phases:

9.2.1. Phase(1): Reviewing Current System

The first task requires an organization to review its current manufacturing environment, and then the required digital manufacturing strategy. Ideally, it requires organizations to:

- Explore the methods and approaches currently employed to accomplish given business objectives.
- Explore the existing management system used in the manufacturing operations.

- Track the ways, how data is collected and managed during the process of product manufacturing.
- Track and identify the process automation techniques that rectify errors.
- Monitor the employees' satisfaction levels within the existing system.
- Set up a list of Key Performance Indicators (KPIs). to monitor efficiency of allocated work processes and check the level of tasks carried out by the employees within the organization.
- Track the KPIs of processes in real time, including the level of work needed for data collection.
- Track routes that determine how sensitive information flows in and out of the enterprise.

9.2.2. Phase(2): Identifying Prevailing Deficiencies

Not all the business organizations operate in a similar fashion, and varied differences may exist between operational processes. Analyzing weaknesses exhibited by every organization is a daunting task, and devising a universal solution may not suffice for all. Therefore, presented here are the most common tasks, which when addressed shed light on the existential flaws and weaknesses encountered by the manufacturing systems.The second task (Task(2)) is to explore flaws and weakness prevailing in the existing workflow and manufacturing strategies adopted. Exploration and identification task of discovering and highlighting weaknesses or flaws in existing businesses of manufacturing require to:

- Explore the short-term flexibility if it is possible by incorporating an initial change in the system.
- Explore options for improvements subject to low investment costs.
- Spot weak and scalable processes driving the manufacturing processes.
- Track and find routes accountable for extended delivery times of manufactured products.
- Identify the existing intra and inter processes ecosystems, underlying the business processes that are mainly responsible to communicate and coordinate within and outside of business organization.
- Localize complex processes and reduce complexity using functional integration.
- Measure the current performance of automated systems and search spots eligible for retro-fitting the new technologies.
- Identify pioneers in the current markets to trace success factors.

9.2.3. Phase(3): Preparing for Digital Transformation

Digital transformation needs preparing a road map, which requires different phases. Each phase here requires individual testing of formulated responses to the list of tasks in phase(2), and each idea needs updates or revision on a smaller scale prior to implementation at a large-scale rollout. Additionally, as new technologies are incorporated, employees training needs should be met since exposure to new technology always recommends training sessions, particularly when it comes to implementing ICT for enabling digital transformation in the prevailing and operative systems. Task to be completed in this phase are, to:

- Explore current tools and software applications for automation.
- Identify and explore success factors provided by currently prevailing digital business models.
- Underpin technology and underline gaps in resources.
- Compare and assess efforts and costs needed for digitalization of the Past or Present system.
- Localize processes for upgrade by evaluating performance characteristics.
- Develop and describe your new business model
- Determine applicable realistic,achievable and measurable goals.
- Formulate teams and encourage collaborative efforts enabling digital transformation.
- Formulate strategies with staff members enabling tracking competitors and analyzing market trends.

- Apply estimation and prediction techniques enabling analysis of customers' needs and the reasons for staying away from adoption of the currently manufactured products.

9.2.4. Phase(4): Implementing Plan of Change

Even if successfully implemented, digital transformation never stops and presents an ongoing process since technologies are subject to frequent upgrades. Dynamic business processes underlying manufacturing, prerequisite usability maintenance and sustained productivity. Eventually, it requires businesses to track solutions based on recent technologies and shifts prevailing in current markets. Implementing the proposed and planned activities of Phase(3) requires the organizations, in general, to:

- Identify actors responsible to enable digitalisation in the organization.
- Sort and assign priorities to the tasks planned in phase(3).
- Set out a criteria to prioritise the process of transformation.
- Access to determine the level of urgency for each of the planned activities.
- Devise a plan to track down consequence reflecting effects of planned activities for change.
- Track availability of resources needed to incorporate the changes to the system.
- Plan to prepare for start up, execution and reviewing the implementation of developed model and associated technologies enabling change.
- Track implementation progress with timely report and documentation.
- For every milestone, review the progress of prior accomplishments and check if progression conforms to established financial needs of the organization.

9.3. Impacts of Digital Manufacturing

Impacts of digital transformation underline complexity and diverse range of influential results on the competitiveness of a business. Impacts as such are hard to tackle and difficult to schematize since businesses may not have proper data interpretation and organization techniques. The framework proposed by [100] defines that the "digital forces are reshaping five key domains of strategy: customers, competition, data, innovation and value". Table 3 presents five strategic domains and some of the corresponding critical concerns in addition to the key areas.

Table 3. Five strategic domains and respective critical concerns [100].

Strategic Domains	Central Concerns	Key Topics
Customer	harness customer networks	reinvented marketing funnel path to purchase core behaviors of customer networks
Competition	Build Platforms, not just products	platform business models (in)direct network effects (dis)intermediation competitive value trains
Data	Turn data into assets	templates of data value drivers of big data data-driven decision making
Innovation	Innovate by rapid experimentations	divergent/convergent experimentation minimum viable products paths to scaling up
Value	Adapt your value proposition	concepts of market value paths out of a declining market steps to value proposal evolution

Since from the early beginning of ideation phase to the phase when the products are delivered to the customers, digital transformation guides the whole design and development process. Product models are developed virtually by implementing the concepts mediated through the ideation phase. Virtual models can be tested to ensure that the requirements follow up in-line with the specifications proposed to deliver the end products. Creation of digital threads enable virtual testing that starts right from product design phase until the production. In addition, the developed virtual models of products enable support to data generation, data aggregation, analysis, frequent modelling of parameters, characterization, and testing of each sub unit at an individual level.

Virtually modeling processes allow iterative testing to ensure results explored with a test-bed, can be reproduced at other sustainable units of manufacturing with high accuracy and efficiency. Apart from that, the simulation and modeling software can help track down the errors or bugs in the software, which perhaps in some cases could be the most difficult phase of the design engineering process. Modeling also gives room for experimentation during ideation phase since models can be tested before and without the need of any physical resources. The data generated during the virtual modeling phase can be shared and analyzed across all the supply chain and also in the development life-cycle stages to the phase of final delivery of the product. While being inexpensive and consuming low level of effort and human labor, manufacturing processes can be improved at pace by digitalizing the processes of development. Also, processes can be tested and tuned before the manufacturing processes start or even before the products are delivered to markets. Thus, the processes underlying manufacturing can inevitably ensure sustainability in production processes.

Developing production lines being reconfigurable in architecture, seeks the role of digital twin, which in itself accesses open information sources enabled by Cloud based manufacturing systems. Likewise, automation is driven by processes empowered by AI and automation technologies that allow capturing patters and trends in data with precise detailed measurements. The IoT abridges the gap of physical data sensation to processing layer. Numerous sensors accountable for monitoring real time processes and data collection form the core backbone of the IoT networks, can be realized as indispensable elements in the event of sustainable manufacturing.

10. Conclusions

The digital transformation which has resulted from the increase and improvement of data management technologies has led to the radical modification of the manufacturing process and the methods of conducting business. The goals that digital transformation help achieve are reducing waste and promoting environmental sustainability. Sustainable manufacturing/business encompasses social, environmental, and economic sustainability. The manufacturing process will reduce environmental degradation, improve the lives of communities, and simultaneously promote the economic progress of the manufacturers through improved efficiency. Digital technologies have promoted sustainable manufacturing in a variety of ways. Technologies such as machine learning, cloud computing, artificial intelligence, the IoT, Big Data analysis, and logistical management have brought about radical changes to the manufacturing process while simultaneously improving the overall financial standing of the existing companies by improving efficiency. Digital transformation contributes to saving labor costs. Companies have also used these digital technologies to reduce energy consumption by decentralizing their supply chains and using renewable energy sources to power most plants.

In summary, digital transformation has increased the sustainability of businesses in various ways but still has a long way to go promote the overall sustainability of the environment and existing communities. Furthermore, the high costs of installing industry 4.0 plants that can encourage more sustainability are still critical challenges that deter many manufacturers from adopting sustainable manufacturing plants [15,42,81]. Nevertheless, the involvement of government bodies in advocating for sustainability has made it necessary for various manufacturers throughout the world to embrace this new manufacturing model for their overall success and compliance with existing regulatory policies.

The purpose of digital transformation in business, in general, is to improve its performance, raise its revenue, and ensure its survival in the current age of technological development. There is a powerful bond between businesses and digital transformation.

Without digital transformation, it would be difficult for a business to ultimately achieve its goals and vision and thrive in today's market. A business needs to focus on the aspects that must be digitized and make the necessary modifications to transform the organization into a competitive advantage. To this effect, some recommendations have been made to help businesses and industries better strategize their strive towards sustainability and digitalization.

Future research needs to focus on how businesses can become agile organizations that can react to the dynamic business environment as clients want more and more innovative services and tools as digital media and other forms of media converge.

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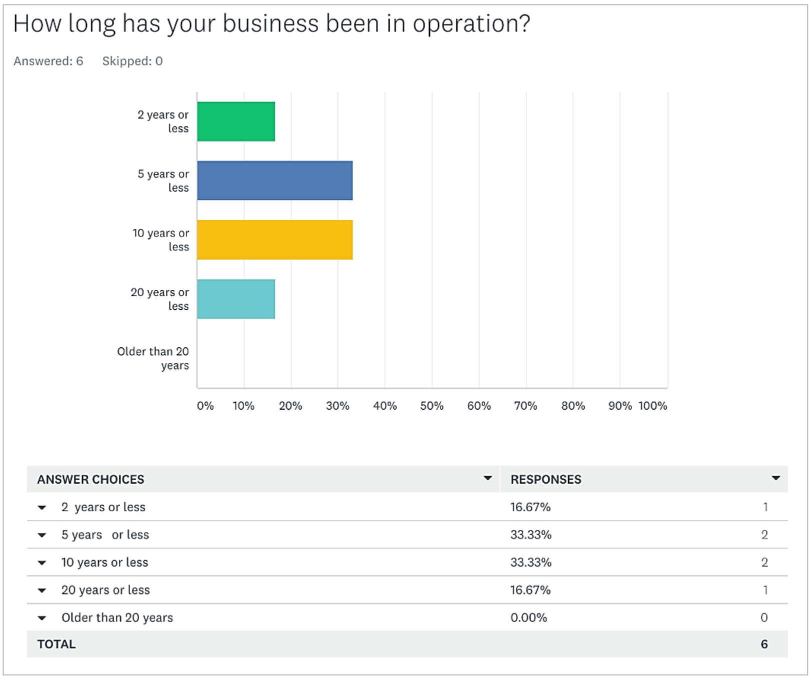
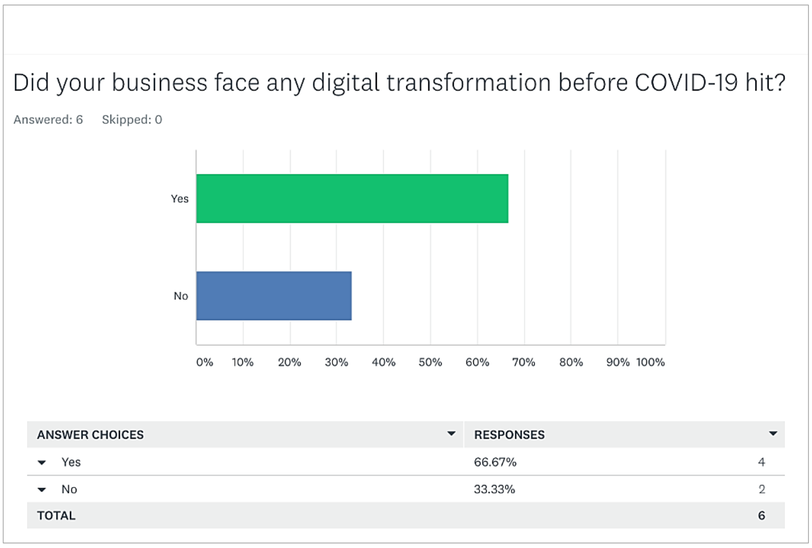
Appendix A. Survey Results



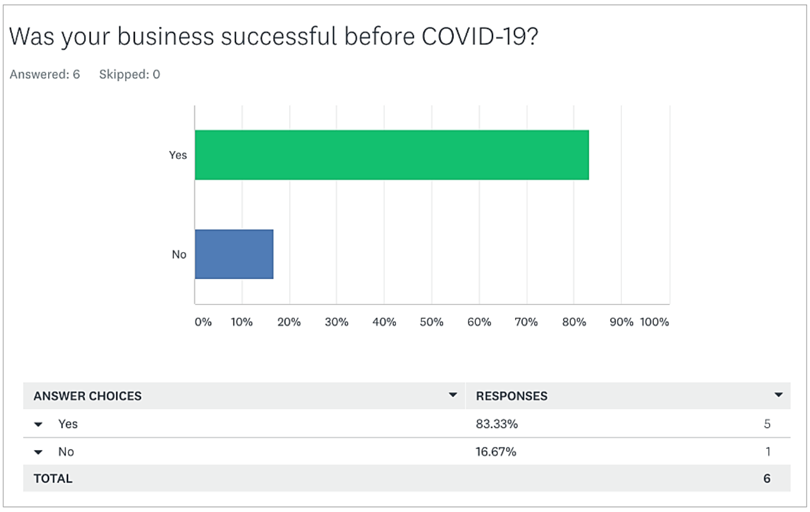
ANSWER CHOICES	RESPONSES	
2 years or less	16.67%	1
5 years or less	33.33%	2
10 years or less	33.33%	2
20 years or less	16.67%	1
Older than 20 years	0.00%	0
TOTAL		6

Figure A1. Survey question and responses (Q1).



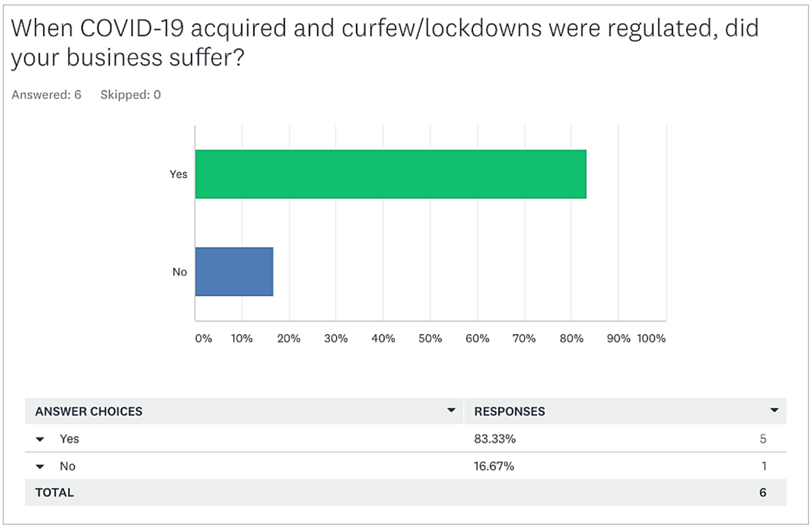
ANSWER CHOICES	RESPONSES	
Yes	66.67%	4
No	33.33%	2
TOTAL		6

Figure A2. Survey question and responses (Q2).



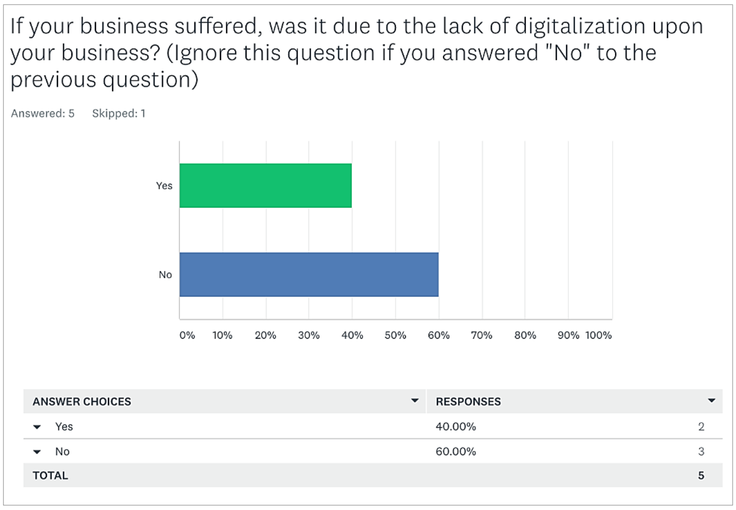
ANSWER CHOICES	RESPONSES	
Yes	83.33%	5
No	16.67%	1
TOTAL		6

Figure A3. Survey question and responses (Q3).



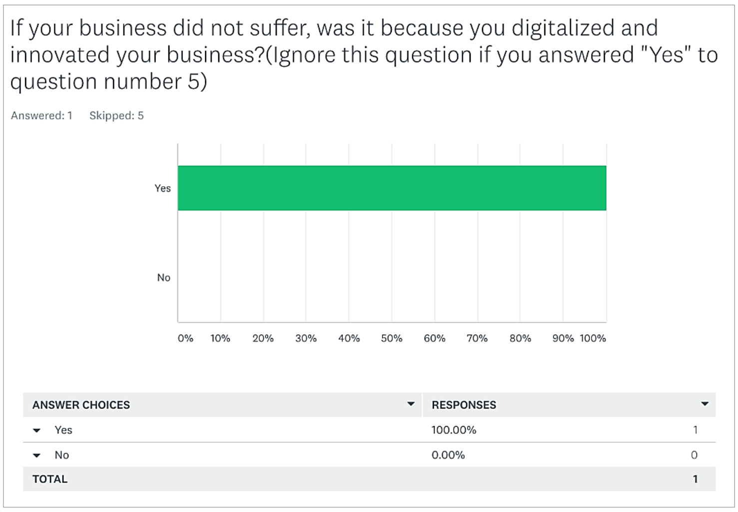
ANSWER CHOICES	RESPONSES	
Yes	83.33%	5
No	16.67%	1
TOTAL		6

Figure A4. Survey question and responses (Q4).



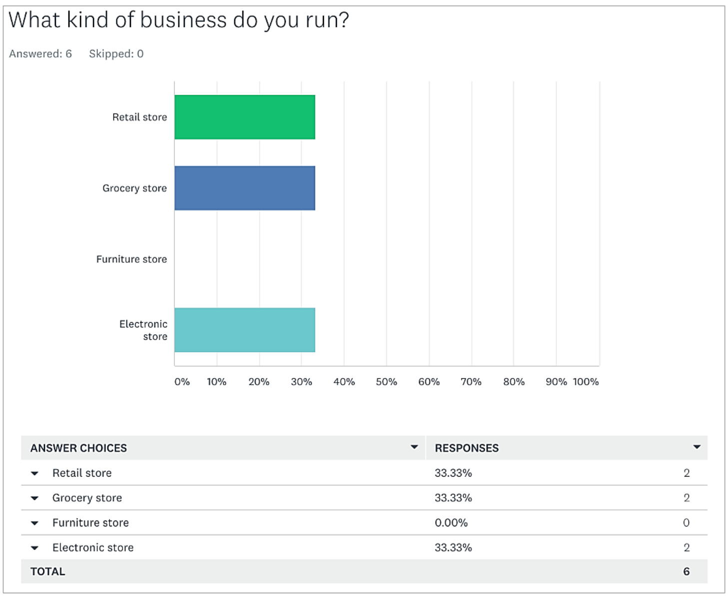
ANSWER CHOICES	RESPONSES	
Yes	40.00%	2
No	60.00%	3
TOTAL		5

Figure A5. Survey question and responses (Q5).



ANSWER CHOICES	RESPONSES	
Yes	100.00%	1
No	0.00%	0
TOTAL		1

Figure A6. Survey question and responses (Q6).



ANSWER CHOICES	RESPONSES	
Retail store	33.33%	2
Grocery store	33.33%	2
Furniture store	0.00%	0
Electronic store	33.33%	2
TOTAL		6

Figure A7. Survey question and responses (Q7).

References

1. Albukhitan, S. Developing digital transformation strategy for manufacturing. *Procedia Comput. Sci.* **2020**, *170*, 664–671. [CrossRef]
2. Blunck, E.; Werthmann, H. Industry 4.0—An opportunity to realize sustainable manufacturing and its potential for a circular economy. In Proceedings of the DIEM: Dubrovnik International Economic Meeting, Sveučilište u Dubrovniku, Dubrovnik, Croatia, 12–14 October 2017; Volume 3, pp. 644–666.
3. De Carolis, A.; Macchi, M.; Negri, E.; Terzi, S. A maturity model for assessing the digital readiness of manufacturing companies. In *Proceedings of the IFIP International Conference on Advances in Production Management Systems*; Springer: Berlin/Heidelberg, Germany, 2017; pp. 13–20.
4. Ahmad, T.; Zhang, D.; Huang, C.; Zhang, H.; Dai, N.; Song, Y.; Chen, H. Artificial intelligence in sustainable energy industry: Status Quo, challenges and opportunities. *J. Clean. Prod.* **2021**, *289*, 125834. [CrossRef]
5. Dutta, G.; Kumar, R.; Sindhwani, R.; Singh, R.K. Digital transformation priorities of India's discrete manufacturing SMEs—A conceptual study in perspective of Industry 4.0. *Compet. Rev. Int. Bus. J.* **2020**, *30*, 289–314. [CrossRef]
6. Brodeur, J.; Pellerin, R.; Deschamps, I. Collaborative approach to digital transformation (CADT) model for manufacturing SMEs. *J. Manuf. Technol. Manag.* **2021**, *33*, 61–83. [CrossRef]
7. Chuai, X.; Feng, J. High resolution carbon emissions simulation and spatial heterogeneity analysis based on big data in Nanjing City, China. *Sci. Total Environ.* **2019**, *686*, 828–837. [CrossRef]
8. Borangiu, T.; Trentesaux, D.; Thomas, A.; Leitão, P.; Barata, J. Digital transformation of manufacturing through cloud services and resource virtualization. *Comput. Ind.* **2019**, *108*, 150–162. [CrossRef]
9. Scopus Database, Elsevier. Start Exploring. 2023. Accessible online: https://www.scopus.com/ (accessed on 10 January 2023).
10. What Are the 4 Main Areas of Digital Transformation? 2022. Available online: https://www.digital-adoption.com/what-are-the-4-main-areas-of-digital-transformation (accessed on 10 January 2023).
11. Pflaum, A.; Prockl, G.; Bodendorf, F.; Chen, H. The Digital Supply Chain of the Future: Technologies, Applications and Business Models. In Proceedings of the 52nd Hawaii International Conference on System Sciences, Maui, HI, USA, 8–11 January 2019; pp. 5153–5154.
12. Kaur, H.; Singh, S.P. Heuristic modeling for sustainable procurement and logistics in a supply chain using big data. *Comput. Oper. Res.* **2018**, *98*, 301–321. [CrossRef]
13. Kumar, A.; Shankar, R.; Thakur, L.S. A big data driven sustainable manufacturing framework for condition-based maintenance prediction. *J. Comput. Sci.* **2018**, *27*, 428–439. [CrossRef]
14. Yar, H.; Imran, A.S.; Khan, Z.A.; Sajjad, M.; Kastrati, Z. Towards smart home automation using IoT-enabled edge-computing paradigm. *Sensors* **2021**, *21*, 4932. [CrossRef]
15. Garrido-Hidalgo, C.; Ramirez, F.J.; Olivares, T.; Roda-Sanchez, L. The adoption of internet of things in a circular supply chain framework for the recovery of WEEE: The case of lithium-ion electric vehicle battery packs. *Waste Manag.* **2020**, *103*, 32–44. [CrossRef]
16. Huang, Y.L.; Fan, L.T. Artificial intelligence for waste minimization in the process industry. *Comput. Ind.* **1993**, *22*, 117–128. [CrossRef]
17. Ghobakhloo, M.; Iranmanesh, M. Digital transformation success under Industry 4.0: A strategic guideline for manufacturing SMEs. *J. Manuf. Technol. Manag.* **2021**, *32*, 1533–1556. [CrossRef]
18. Manavalan, E.; Jayakrishna, K. A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements. *Comput. Ind. Eng.* **2019**, *127*, 925–953. [CrossRef]
19. Leng, J.; Ruan, G.; Jiang, P.; Xu, K.; Liu, Q.; Zhou, X.; Liu, C. Blockchain-empowered sustainable manufacturing and product lifecycle management in industry 4.0: A survey. *Renew. Sustain. Energy Rev.* **2020**, *132*, 110112. [CrossRef]
20. Lin, Y.P.; Petway, J.R.; Anthony, J.; Mukhtar, H.; Liao, S.W.; Chou, C.F.; Ho, Y.F. Blockchain: The evolutionary next step for ICT e-agriculture. *Environments* **2017**, *4*, 50. [CrossRef]
21. Machado, C.G.; Winroth, M.P.; Ribeiro da Silva, E.H.D. Sustainable manufacturing in Industry 4.0: An emerging research agenda. *Int. J. Prod. Res.* **2020**, *58*, 1462–1484. [CrossRef]
22. Lepore, D.; Micozzi, A.; Spigarelli, F. Industry 4.0 Accelerating Sustainable Manufacturing in the COVID-19 Era: Assessing the Readiness and Responsiveness of Italian Regions. *Sustainability* **2021**, *13*, 2670. [CrossRef]
23. Sartal, A.; Bellas, R.; Mejías, A.M.; García-Collado, A. The sustainable manufacturing concept, evolution and opportunities within Industry 4.0: A literature review. *Adv. Mech. Eng.* **2020**, *12*, 1687814020925232. [CrossRef]
24. Vogelsang, K.; Liere-Netheler, K.; Packmohr, S.; Hoppe, U. Success factors for fostering a digital transformation in manufacturing companies. *J. Enterp. Transform.* **2018**, *8*, 121–142. [CrossRef]
25. Butt, J. A conceptual framework to support digital transformation in manufacturing using an integrated business process management approach. *Designs* **2020**, *4*, 17. [CrossRef]
26. Hausberg, J.P.; 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. *J. Bus. Econ.* **2019**, *89*, 931–963. [CrossRef]
27. Lu, W.; Chen, X.; Ho, D.C.W.; Wang, H. Analysis of the construction waste management performance in Hong Kong: The public and private sectors compared using big data. *J. Clean. Prod.* **2016**, *112*, 521–531. [CrossRef]

28. Ferrari, F.; Striani, R.; Minosi, S.; De Fazio, R.; Visconti, P.; Patrono, L.; Catarinucci, L.; Corcione, C.E.; Greco, A. An innovative IoT-oriented prototype platform for the management and valorisation of the organic fraction of municipal solid waste. *J. Clean. Prod.* **2020**, *247*, 119618. [CrossRef]
29. Kanabkaew, T.; Mekbungwan, P.; Raksakietisak, S.; Kanchanasut, K. Detection of PM2. 5 plume movement from IoT ground level monitoring data. *Environ. Pollut.* **2019**, *252*, 543–552. [CrossRef] [PubMed]
30. Saad, A.; Faddel, S.; Mohammed, O. IoT-based digital twin for energy cyber-physical systems: Design and implementation. *Energies* **2020**, *13*, 4762. [CrossRef]
31. Feroz, A.K.; Zo, H.; Chiravuri, A. Digital transformation and environmental sustainability: A review and research agenda. *Sustainability* **2021**, *13*, 1530. [CrossRef]
32. Müge Klein. Digital Transformation in businesses and its Drivers. *J. Bus. Digit. Age* **2020**, *20*, 24–35.
33. Lee, H.T.; Song, J.H.; Min, S.H.; Lee, H.S.; Song, K.Y.; Chu, C.N.; Ahn, S.H. Research trends in sustainable manufacturing: A review and future perspective based on research databases. *Int. J. Precis. Eng. Manuf.-Green Technol.* **2019**, *6*, 809–819. [CrossRef]
34. Shahbazi, Z.; Byun, Y.C. Integration of Blockchain, IoT and Machine Learning for Multistage Quality Control and Enhancing Security in Smart Manufacturing. *Sensors* **2021**, *21*, 1467. [CrossRef]
35. Warke, V.; Kumar, S.; Bongale, A.; Kotecha, K. Sustainable development of smart manufacturing driven by the digital twin framework: A statistical analysis. *Sustainability* **2021**, *13*, 10139. [CrossRef]
36. Lee, C.H.; Wang, D.; Desouza, K.; Evans, R. Digital Transformation and the New Normal in China: How Can Enterprises Use Digital Technologies to Respond to COVID-19? *Sustainability* **2021**, *13*, 10195. [CrossRef]
37. Shahat, E.; Hyun, C.T.; Yeom, C. City digital twin potentials: A review and research agenda. *Sustainability* **2021**, *13*, 3386. [CrossRef]
38. Sharma, R.; Jabbour, C.J.C.; de Sousa Jabbour, A.B.L. Sustainable manufacturing and industry 4.0: What we know and what we don't. *J. Enterp. Inf. Manag.* **2020**, *34*, 230–266. [CrossRef]
39. Singh, S.; Sharma, M.; Dhir, S. Modeling the effects of digital transformation in Indian manufacturing industry. *Technol. Soc.* **2021**, *67*, 101763. [CrossRef]
40. Davidson, H. China on Track To Lead in Renewables as US Retreats, Report Says. 2018. Available online: https://www.theguardian.com/environment/2018/jan/10/china-on-track-to-lead-in-renewables-as-us-retreats-report-says (accessed on 21 January 2023).
41. Laura, L.; Clayton, O.; Jeremy, S.; Kate, S. How COVID-19 Has Pushed Companies over the Technology Tipping Point and Transformed Business Forever. 2020. Available online: https://www.mckinsey.com/capabilities/strategy-and-corporate-finance/our-insights/how-covid-19-has-pushed-companies-over-the-technology-tipping-point-and-transformed-business-forever (accessed on 21 January 2023).
42. Sanchis, R.; Garcia-Perales, O.; Fraile, F.; Poler, R. Low-code as enabler of digital transformation in manufacturing industry. *Appl. Sci.* **2020**, *10*, 12. [CrossRef]
43. Židek, K.; Pitel', J.; Adámek, M.; Lazorík, P.; Hošovsky, A. Digital twin of experimental smart manufacturing assembly system for industry 4.0 concept. *Sustainability* **2020**, *12*, 3658. [CrossRef]
44. Cichocki, M.; Landschützer, C.; Hick, H. Development of a Sharing Concept for Industrial Compost Turners Using Model-Based Systems Engineering, under Consideration of Technical and Logistical Aspects. *Sustainability* **2022**, *14*, 10694. [CrossRef]
45. Corrado, C.R.; DeLong, S.M.; Holt, E.G.; Hua, E.Y.; Tolk, A. Combining Green Metrics and Digital Twins for Sustainability Planning and Governance of Smart Buildings and Cities. *Sustainability* **2022**, *14*, 12988. [CrossRef]
46. Zuo, Y. Making smart manufacturing smarter—A survey on blockchain technology in Industry 4.0. *Enterp. Inf. Syst.* **2020**, *15*, 1–31. [CrossRef]
47. Cordes, M.; Hintze, W. Offline simulation of path deviation due to joint compliance and hysteresis for robot machining. *Int. J. Adv. Manuf. Technol.* **2017**, *90*, 1075–1083. [CrossRef]
48. Jones, M.D.; Hutcheson, S.; Camba, J.D. Past, present, and future barriers to digital transformation in manufacturing: A review. *J. Manuf. Syst.* **2021**, *60*, 936–948. [CrossRef]
49. Khan, A.A.; Abonyi, J. Simulation of Sustainable Manufacturing Solutions: Tools for Enabling Circular Economy. *Sustainability* **2022**, *14*, 9796. [CrossRef]
50. Jahshan, E. Primark Profits Plunge 60 after a Difficult Year with Covid. Retail Gazette. 2021. Accessible online: https://www.retailgazette.co.uk/blog/2020/11/primark-profits-plunge-60-after-a-difficult-year-with-covid/ (accessed on 10 January 2023).
51. JD Sports Fashion PLC. Annual Income Statement. 2021. Accessible online: https://www.wsj.com/market-data/quotes/UK/XLON/JD/financials/annual/income-statement (accessed on 10 January 2023).
52. Henry Boot PLC. Annual Income Statement. 2021. Accessible online: https://www.wsj.com/market-data/quotes/UK/XLON/BOOT/financials/annual/income-statement (accessed on 10 January 2023).
53. von Leipzig, T.; Gamp, M.; Manz, D.; Schöttle, K.; Ohlhausen, P.; Oosthuizen, G.; Palm, D.; von Leipzig, K. Initialising customer-orientated digital transformation in enterprises. *Procedia Manuf.* **2017**, *8*, 517–524. [CrossRef]
54. Li, H.; Yang, C. Digital Transformation of Manufacturing Enterprises. *Procedia Comput. Sci.* **2021**, *187*, 24–29. [CrossRef]
55. Honarvar, A.R.; Sami, A. Towards sustainable smart city by particulate matter prediction using urban big data, excluding expensive air pollution infrastructures. *Big Data Res.* **2019**, *17*, 56–65. [CrossRef]
56. Dolgui, A.; Ivanov, D.; Potryasaev, S.; Sokolov, B.; Ivanova, M.; Werner, F. Blockchain-oriented dynamic modelling of smart contract design and execution in the supply chain. *Int. J. Prod. Res.* **2020**, *58*, 2184–2199. [CrossRef]

57. Hamledari, H.; Fischer, M. Measuring the Impact of Blockchain and Smart Contract on Construction Supply Chain Visibility. *Adv. Eng. Inf.* **2021**, *50*, 101444. [CrossRef]
58. Zhang, X.; Xiu, G.; Shahzad, F.; Duan, Y. Optimal Financing Strategy in a Capital-Constrained Supply Chain with Retailer Green Marketing Efforts. *Sustainability* **2021**, *13*, 1357. [CrossRef]
59. Marques, M.; Agostinho, C.; Zacharewicz, G.; Jardim-Gonçalves, R. Decentralized decision support for intelligent manufacturing in Industry 4.0. *J. Ambient Intell. Smart Environ.* **2017**, *9*, 299–313. [CrossRef]
60. Venkatesan, G.; Mithuna, R.; Gandhimathi, S. IOT-Based monitoring of lab scale constitutive landfill model of food waste. *Mater. Today Proc.* **2020**, *33*, 2729–2734. [CrossRef]
61. Närvänen, E.; Mesiranta, N.; Sutinen, U.M.; Mattila, M. Creativity, aesthetics and ethics of food waste in social media campaigns. *J. Clean. Prod.* **2018**, *195*, 102–110. [CrossRef]
62. Joyce, A.; Paquin, R.L. The triple layered business model canvas: A tool to design more sustainable business models. *J. Clean. Prod.* **2016**, *135*, 1474–1486. [CrossRef]
63. Dombrowski, U.; Wagner, T. Mental Strain as Field of Action in the 4th Industrial Revolution. *Procedia CIRP* **2014**, *17*, 100–105. [CrossRef]
64. Stock, T.; Seliger, G. Opportunities of sustainable manufacturing in industry 4.0. *Procedia CIRP* **2016**, *40*, 536–541. [CrossRef]
65. Wainstein, M.E.; Bumpus, A.G. Business models as drivers of the low carbon power system transition: A multi-level perspective. *J. Clean. Prod.* **2016**, *126*, 572–585. [CrossRef]
66. Matthew, D.; Rose, C.; Dharshana N.W., J; Chris W., C. Advancing socio-technical systems thinking: A call for bravery. *Appl. Ergon.* **2014**, *45*, 171–180.
67. Shamim, S.; Cang, S.; Yu, H.; Li, Y. Management approaches for Industry 4.0: A human resource management perspective. In Proceedings of the 2016 IEEE Congress on Evolutionary Computation (CEC), Vancouver, BC, Canada, 24–29 July 2016; pp. 5309–5316.
68. Albino, V.; Carbonara, N.; Giannoccaro, I. Supply chain cooperation in industrial districts: A simulation analysis. *Eur. J. Oper. Res.* **2007**, *177*, 261–280. [CrossRef]
69. Auramo, J.; Kauremaa, J.; Tanskanen, K. Benefits of IT in supply chain management: An explorative study of progressive companies. *Int. J. Phys. Distrib. Logist. Manag.* **2005**, *35*, 82–100. [CrossRef]
70. Ivanov, D.; Dolgui, A.; Sokolov, B.; Werner, F.; Ivanova, M. A dynamic model and an algorithm for short-term supply chain scheduling in the smart factory industry 4.0. *Int. J. Prod. Res.* **2016**, *54*, 386–402. [CrossRef]
71. Bae, H.s. The Relationships between Orientation, Collaboration and Performance for Supply Chain Management of Korean FDI Firms for Sustainable Growth. *Sustainability* **2020**, *12*, 10311. [CrossRef]
72. Barreto, L.; Amaral, A.; Pereira, T. Industry 4.0 implications in logistics: An overview. *Procedia Manuf.* **2017**, *13*, 1245–1252. [CrossRef]
73. Stalmachova, K.; Chinoracky, R.; Strenitzerova, M. Changes in Business Models Caused by Digital Transformation and the COVID-19 Pandemic and Possibilities of Their Measurement—Case Study. *Sustainability* **2022**, *14*, 127. [CrossRef]
74. Yin, W.; Ran, W. Supply Chain Diversification, Digital Transformation, and Supply Chain Resilience: Configuration Analysis Based on fsQCA. *Sustainability* **2022**, *14*, 7690. [CrossRef]
75. Raghavan, A.; Demircioglu, M.A.; Orazgaliyev, S. COVID-19 and the New Normal of Organizations and Employees: An Overview. *Sustainability* **2021**, *13*, 11942. [CrossRef]
76. DebarghaBanerjee.; Das, D.D.; Pal, S.; Paul, S.R.; Debnath, A.; Reza, M. Effect of covid-19 on digital transformations in teaching learning methodology and its consequences in society: A review. *J. Phys. Conf. Ser.* **2021**, *1797*, 012066.
77. Ragazou, K.; Passas, I.; Sklavos, G. Investigating the Strategic Role of Digital Transformation Path of SMEs in the Era of COVID-19: A Bibliometric Analysis Using R. *Sustainability* **2022**, *14*, 11295. [CrossRef]
78. Hill, K. How Target Figured Out A Teen Girl Was Pregnant Before Her Father Did. 2012. Available online: https://www.forbes.com/sites/kashmirhill/2012/02/16/how-target-figured-out-a-teen-girl-was-pregnant-before-her-father-did (accessed on 20 January 2023).
79. Cooper, Z. Five Reasons Why Digital Transformation Is Essential for Business Growth. 2022. Available online: https://www.itpro.co.uk/strategy/29899/three-reasons-why-digital-transformation-is-essential-for-business-growth (accessed on 20 January 2023).
80. Ngu, H.J.; Lee, M.D.; Osman, M.S.B. Review on current challenges and future opportunities in Malaysia sustainable manufacturing: Remanufacturing industries. *J. Clean. Prod.* **2020**, *273*, 123071. [CrossRef]
81. Savastano, M.; Amendola, C.; Bellini, F.; D'Ascenzo, F. Contextual impacts on industrial processes brought by the digital transformation of manufacturing: A systematic review. *Sustainability* **2019**, *11*, 891. [CrossRef]
82. Research, G.V. *Digital Transformation Market Size, Share & Trends Analysis Report, 2023–2030*; Technical report; Grand View Research, 2021. Available online: https://www.grandviewresearch.com/industry-analysis/digital-transformation-market (accessed on 20 January 2023).
83. Subramaniam, R.; Singh, S.P.; Padmanabhan, P.; Gulyás, B.; Palakkeel, P.; Sreedharan, R. Positive and Negative Impacts of COVID-19 in Digital Transformation. *Sustainability* **2021**, *13*, 9470. [CrossRef]
84. Dash, G.; Chakraborty, D. Digital Transformation of Marketing Strategies during a Pandemic: Evidence from an Emerging Economy during COVID-19. *Sustainability* **2021**, *13*, 6735. [CrossRef]
85. García-Peñalvo, F.J. Avoiding the Dark Side of Digital Transformation in Teaching. An Institutional Reference Framework for eLearning in Higher Education. *Sustainability* **2021**, *13*, 2023. [CrossRef]

86. Refinitiv. Refinitiv Eikon, London Stock Exchange Group. 2021. Available online: https://www.refinitiv.com/en (accessed on 10 June 2019).
87. Primark Stores Limited. Full Accounts Made Up to 12 September 2020. 2020. Accessible online: https://find-and-update.company-information.service.gov.uk/company/00453448/filing-history (accessed on 10 January 2023).
88. Andrianova, A. Countering the financing of terrorism in the conditions of digital economy. In *Digital Transformation of the Economy: Challenges, Trends and New Opportunities*; Springer: Cham, Switzerland, 2020; pp. 20–31.
89. Mendhurwar, S.; Mishra, R. Integration of social and IoT technologies: Architectural framework for digital transformation and cyber security challenges. *Enterp. Inf. Syst.* **2021**, *15*, 565–584. [CrossRef]
90. Zhang, Z.; Gupta, B.B. Social media security and trustworthiness: Overview and new direction. *Future Gener. Comput. Syst.* **2018**, *86*, 914–925. [CrossRef]
91. Dunn Cavelty, M.; Wenger, A. Cyber security meets security politics: Complex technology, fragmented politics, and networked science. *Contemp. Secur. Policy* **2020**, *41*, 5–32. [CrossRef]
92. Information, G.; Survey, S. The Path to Health Care Insight : EY 20th Global Information Security Survey 2017 Cybersecurity Health Sector Results Global Findings; Technical Report; 2017. Available online: https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/health/ey-20-global-information-security-survey-2017.pdf (accessed on 10 January 2023).
93. Wiggen, J. The impact of COVID-19 on Cyber Crime and State-Sponsored Cyber Activities; Konrad-Adenauer-Stiftung e.V.: Berlin, Germany, 2020; p. 11. Available online: https://www.kas.de/en/analysen-und-argumente/detail/-/content/die-auswirkungen-von-covid-19-auf-cyberkriminalitaet-und-staatliche-cyberaktivitaeten (accessed on 10 January 2023).
94. Lingmont, D.N.J.; Alexiou, A. The contingent effect of job automating technology awareness on perceived job insecurity: Exploring the moderating role of organizational culture. *Technol. Forecast. Soc. Chang.* **2020**, *161*, 120302. [CrossRef]
95. Rafiq, M.; Chin, T. Three-Way Interaction Effect of Job Insecurity, Job Embeddedness and Career Stage on Life Satisfaction in A Digital Era. *Int. J. Environ. Res. Public Health* **2019**, *16*, 1580. [CrossRef] [PubMed]
96. Ahmady, G.A.; Mehrpour, M.; Nikooravesh, A. Organizational Structure. *Procedia - Soc. Behav. Sci.* **2016**, *230*, 455–462. [CrossRef]
97. A Harvard Business Review Analytic Services Report. High-Performance Sourcing and Procurement Driving Value through Collaboration. 2017. Available online: https://info.workday.com/rs/078-WHZ-188/images/ScoutRFP-HBR-HighPerformanceSourcingandProcurement.pdf (accessed on 10 October 2021).
98. Correani, A.; Massis, A.D.; Frattini, F.; Petruzzelli, A.M.; Natalicchio, A. Implementing a Digital Strategy: Learning from the Experience of Three Digital Transformation Projects. *Calif. Manag. Rev.* **2020**, *62*, 37–56. [CrossRef]
99. Matt, C.; Hess, T.; Benlian, A. Digital transformation strategies. *Bus. Inf. Syst. Eng.* **2015**, *57*, 339–343. [CrossRef]
100. Rogers, D. *The Digital Transformation Playbook*; Columbia University Press: New York, NY, USA, 2016.