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Smart Factory and Industrial 4.0 Business Models for Enhancing A Firm's Competitiveness in the Modern Digital Era

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ABSTRACT

As the industrial 4.0 digital technologies are becoming increasingly essential for bolstering a firm's competitiveness, this seminal paper offers a critical analysis of a combination of strategies that businesses can utilize to create not only smart factories, but also the industrial 4.0 digital business models that can be used to bolster their overall competitiveness in the increasingly more complex digital era of today. The study used integrative review as the qualitative research method to evaluate and review a combination of different theories and literature on creating smart factories and industrial 4.0 digital business models. Thematic analysis of the gathered theories and literature indicated that to create a smart factory based on value-creating industrial 4.0 digital business models, the critical technologies that must be adopted encompass Internet of Things, Cyber-Physical System, 3D Printing, Artificial Intelligence, Robotics, Cloud Computing, and 5G technologies. Since most of the manufacturing entities are increasingly grappling with how to improve their performance in the increasingly more competitive digital world, this study offers insights that seek to enrich knowledge on how to lower costs while also improving operational efficiency to bolster the business' overall competitiveness.

INTRODUCTION

Smart factory is a highly digitized manufacturing plant that uses a combination of automated manufacturing machineries and production systems that are seamlessly connected to different electronic devices to aid accurate real-time gathering, analysis, organizing, and sharing of different manufacturing data and information (Weber, 2021). This enables management to make the appropriate proactive interventions to mitigate incidents or operational glitches that can undermine the efficiency of manufacturing operations. Smart factory uses manufacturing machineries, equipment, and assets that are integrated with artificial intelligence, robotics, machine learning, cloud computing, big data analytics, and industrial Internet of Things to leverage the overall efficiency of the manufacturing processes. This minimizes wastes, reduces costs, and creates quality products that surpass customer expectations. It connects the physical and digital worlds of the manufacturing enterprise to bolster the overall efficiency of the activities' flow along the manufacturing enterprise's value chain system.

Creation of a smart factory does not, therefore, just improve the efficiency of the internal manufacturing processes (Mohsen et al., 2024). Instead, it also provides predictive analysis that aids thorough diagnosis and response to the emerging disruptive ecosystem trends. Creation of a smart factory does not only require the integration of industrial 4.0 technologies in the typical manufacturing process, but also in the entire value chain system. It necessitates the integration of technologies like AI, IoT, cloud computing, and smart devices in the procurement processes for inputs, storage, manufacturing, storage of finished inventories, and distribution of the final products to the final consumers.

Smart factory improves the seamless linkage and integration of the manufacturing entity with the major players in its digital ecosystem to bolster the manufacturing enterprise's capabilities to sense and respond to more emerging disruptive trends (Weber, 2021). However, the notion of a smart factory is not just about the integration of the use of smart technologies like sensors, actuators, algorithms, computer processing, and connected devices.

Instead, it also requires the creation of a more complex manufacturing system. In that process, smart factory ideology moves away from the conventional notion of industrial automation to create a fully digitally connected and flexible manufacturing plant that uses a stream of data from connected operations and production systems to learn and adapt to new demands. The creation of such a system enables the manufacturing system to use a mass production system while also using aspects of a customized production system (Gustavo, 2014).

Unfortunately, even if that is the case, the use of smart factory concept as well as the ideas of the combination of technologies that are used for creating a smart factory are still challenges that most of the contemporary manufacturing executives are grappling with. It is in that context that this study uses integrative review to analyze the existing theories and offer insights on the smart factory and industrial 4.0 business models for enhancing a firm's competitiveness in this digital era.

METHODOLOGY

Methodology for accomplishing the study entailed the use of integrative review as one of the qualitative content analysis methodologies (Kutcher & LeBaron, 2022). Integrative review was used to analyze the existing studies on how to create and develop a more effective and competitive smart factory as well as the industrial 4.0 digital business models that can be adopted for a business to thrive in the increasingly competitive contemporary digital era.

Integrative review is a qualitative research technique that emphasizes the analysis of all kinds of information published on the concept being investigated (Souza et al., 2010). It differs from systematic review as well as a meta-synthesis that often focus on extracting and evaluating only peer-reviewed qualitative or quantitative studies published in the accredited academic journals. Since limiting the study to the analysis of only the information published in peer-reviewed journals can lead to the exclusion of valuable information and new insights that can change the entire academic thinking, this study opted for the use of integrative review.

As integrative review extracts and analyzes all kinds of information, it improved the extraction of a comprehensive perspective on the technologies that are essential for creating an effective smart factory. To accomplish that, the process of integrative review was structured according to four steps encompassing literature search, extraction, quality analysis, and data analysis and interpretation (Kutcher & LeBaron, 2022).

The literature search process was guided by the integrative review question that sought to assess the kinds of technologies and industrial 4.0 business models for creating and improving the competitiveness of a smart factory. This was accompanied by the use of the research question that focused on examining the case studies of successful smart factory models that can be extracted and used as part of the analogy of the good practices that the manufacturing entities can emulate when seeking to create a more successful smart factory.

After defining the integrative review questions, the study used keywords like "digital technologies for improving manufacturing efficiency," "industrial 4.0 business models," "manufacturing digital technologies and a firm's competitiveness," and "improving competitiveness of the manufacturing firms in the contemporary digital era." Though these key terms were used, it was only the articles published in English and in the period between 2020 and 2024 that were used in the study. This led to the extraction of thirty articles. Each article included in the study was assessed for quality issues to ensure that it was only the articles that offered detailed and logical accounts of the importance of creating a smart factory and industrial 4.0 digital business models that were included in the study. Completion of the extraction of the required articles was accompanied by the analysis of the collected articles.

Data analysis and synthesis were accomplished using thematic and narrative analysis (Kutcher & LeBaron, 2022). Each of the thirty articles was read and re-read to improve familiarization with the thinking in each article. This was followed by the identification of the commonly occurring themes and the extraction of the subthemes and the accompanying narratives or chunks of texts explaining the subthemes on smart factory and industrial 4.0 business models for enhancing a firm's competitiveness in the modern digital era. Based on such analysis, the details of the findings are as presented below.

FINDINGS

Findings imply that a smart factory is a highly automated digital manufacturing system that aids real-time learning to bolster self-organizing, self-optimization, self-reorganizing, and self-adaptation in the context of the unfolding internal or external trends of the production systems. This improves manufacturing assets' efficiency and optimization, quality, cost-savings, safety, reliability, and sustainability that impact on improved financial bottom-lines. Of course, there are several businesses in different sectors that are increasingly embracing industrial 4.0 technologies. But some of the most outstanding cases are exhibited in the case of Schneider Electric. Schneider Electric's Smart Factory

For sixty years, Schneider Electric has been engaging in the mass production of electrical equipment with tremendous achievements and successes (Weber, 2021). However, as competition heat increases and new entrants come in, Schneider Electric, which is regarded as a low-mix, high-volume assembly plant, has not been hesitant to engage in self-disruption to counter potential disruptors (Schneider Electric, 2024). Its self-disruption initiatives have entailed the introduction of an array of industrial

4.0 technologies to bolster its manufacturing efficiency and quality commitment to counter potential disruptors. At its Lexington, Kentucky, Schneider Electric has transformed its previously mechanical and analog drive manufacturing facility into a model smart factory that most of the contemporary manufacturers aspire to emulate (AVEVA, 2023).

To improve its operational efficiency to remain competitive, Schneider Electric Smart Factory has seamlessly integrated the use of Internet of Things' connectivity and predictive analytics to reduce energy consumption by 26%, carbon dioxide emissions by 30%, and water consumption by 20% (Weber, 2021).

Even after receiving the award from the ASSEMBLY's 2007 Award as the Assembly Plant of the Year, Schneider Electric's quests to create a more efficient smart factory still extended to the investment in the establishment of digital technologies like augmented reality, remote monitoring, and predictive maintenance to improve not only energy efficiency but also to lower costs and drive improved business sustainability (Schneider Electric, 2024).

Schneider Electric introduced load centers and safety switches and transformed its Brownfield facility into a complete smart factory by manufacturing processes aided and monitored by smart devices, collaborative robots, cordless screwdrivers, cloud computing, and paperless work instructions. It also introduced RFID (Radio Frequency Identification) tags, torque sensors, and other industrial 4.0 technologies that were unheard of sixty years ago.

Through the introduction of industrial 4.0 technologies in its manufacturing operations, Schneider Electric got vertically integrated to adopt a lean manufacturing process (Schneider Electric, 2024). This improved its cost-savings by streamlining all fabrications and assembly to eliminate 113 minutes of process lead time.

Combined with improved quality, this has driven Schneider Electric's improved growth by 20% since 2007 (AVEVA, 2023). The introduction of industrial 4.0 has also significantly improved Schneider Electric's operational efficiency as it is able to produce 10,000 units of electric equipment per day, assemble 2.8 million load centers, and 800,000 safety switches.

Schneider Electric acknowledges that the usage of industrial 4.0 technologies drives improved flexibility and agility to respond to the changes in market trends. It also improves asset management and performance by eliminating downtimes through the application of predictive analytics in maintenance-related activities (AVEVA, 2023).

Besides empowering operators with the required data and information, industrial 4.0 also improves the efficiency of energy utilization (Weber, 2021). However, integrative review indicated that the achievement of such positive outcomes would require the creation of the smart factory that integrates all its key technological components.

Technological Components of a Smart Factory

Integrative review of different studies indicated the essential technological components of a smart factory to encompass: Internet of Things Cyber-Physical System 3D Printing Artificial Intelligence and Robotics Cloud Computing and 5G

In the subsections below, we shall evaluate each of these components.

Internet of Things

Internet of Things explain the virtual and physical interconnections of the manufacturing facilities, devices, automated guided vehicles, robots, machineries, and equipment as supported by Internet technology. In the smart factory operational business model, every manufacturing equipment, machinery, devices, and other portable devices are ingrained with electronic software, sensors, and actuators that seamlessly connect with the entire Internet networks (Mohsen et al., 2024).

The connection of the actual production assets or equipment is accompanied by the connection of the equipment, vehicles, machineries, and devices used for purchasing, transportation, maintenance, and inventory management during storage (Gustavo, 2014). It also requires linkage of the smart factory with the Internet customer networks using different forms of mobile devices and smartphones (Vasanthraj et al., 2023).

Evidence of how the Internet of Things drives improved operational efficiency of the smart factory is reflected in Bosch Connected Factory's use of the Internet of Things and other industrial 4.0 digital and automation technologies (Bosch, 2024c). Bosch Connected Factory is one of the leading manufacturers of automotive components and parts which is based in Blaichach-Germany. Bosch specializes in the manufacturing of automotive safety parts and components like electronic stability programs (ESP) and anti-lock braking systems.

To leverage its manufacturing efficiency to bolster its competitiveness in the industrial 4.0 age, Bosch created a Connected smart Factory that uses the Internet of Things like Internet-connected tablets and devices to check and monitor parts' compliance with the design and quality specifications (Bosch, 2024a). It also uses the tablets to track, evaluate, and perform maintenance analytics for different manufacturing machineries and equipment.

In that process, quality data is gathered and analyzed to discern the areas requiring immediate corrections and improvements. Besides its IoT using performance tracking system that aids evaluation, identification, and correction of cycle time deviations, Bosch Connected Factory also has an Internet-based operator support system that identifies and suggests solutions for the spotted errors (Bosch, 2024b). In the event that the errors are fixed, it also indicates that the errors have been adequately addressed. This bolsters the overall improved manufacturing efficiency to improve quality and throughput that impact positively on the manufacturing entity's financial bottom-line (Dutta et al., 2024).

Since Bosch works with several manufacturing partners and clients, it introduced a software suit that reads the required essential data from over 60,000 sensors to accurately convey the required information to the designated right clients or manufacturing partners (Bosch, 2024c). For remote maintenance teams, this improves their efficacy to intervene and execute the required maintenance activities before it interferes with the production processes.

To improve the overall productivity of the manufacturing venture as well as energy waste, Bosch also monitors its energy consumption via the embedded software device to spot and eliminate areas of energy wastage (Bosch, 2024a; Bosch, 2024b; Bosch, 2024c).

Bosch Connected Factory is not just an isolated case of how the Internet of Things is one of the critical components of a smart factory. Instead, other empirical evidences are also reflected in Johnson & Johnson's DePuy Synthes in Ireland. Johnson & Johnson's DePuy Synthes is a medical facility that was established in 1997 in Ireland. It specializes in sports medicine, spinal surgery, joint reconstruction, trauma, and craniomaxillofacial (Johnson & Johnson, 2020). However, to improve its operational efficiency and competitiveness, it engaged in some forms of architectural and modular innovations to introduce digital processes and industry 4.0 technologies.

Johnson & Johnson used the Internet of Things and its associated smart devices to create digital twins highlighting the digital reflection of its intended or actual real-world physical product, system, or processes that it intended to create (Johnson & Johnson, 2020; de Leeuw, 2020). This reduced operational costs, lowered downtimes, and lead time to bolster Johnson & Johnson's overall manufacturing efficiency and improved competitiveness in the global sports medicine arena. Besides the Internet of Things, the Cyber-Physical System is the other critical component of a smart factory (Weber, 2021).

Cyber-Physical System

Cyber-physical system refers to the technology that integrates the physical and virtual worlds of the manufacturing enterprise using the Internet of Things, sensors, cloud computing, and computation control and network technologies that link the physical infrastructure and objects with the wider virtual space created by the Internet. Cyber-physical system integrates the electronic computations with the physical processes (Dutta et al., 2024).

In the cyber-physical system, the integrated computers and networks monitor and control physical processes, systems, and infrastructure to offer feedback loops that require the physical system to effect the required computations and vice versa.

This high level of synchronization between the shop floor manufacturing components like machines, equipment, vehicles, and robots and the wider virtual space aids self-evaluation and corrections of the physical systems in the event of emerging deviations (Gustavo, 2014). This improves the understanding of the overall changes in market dynamics for the manufacturing executives to make the necessary modifications of their production schedules to respond to either a sudden increment or decrease in market demand.

High level of synchronization also improves the efficiency of inventory management to avoid overstocking that can cause costly wastes or under-stocking that can undermine customer satisfaction due to failure to respond with adequate quantities during peak seasons.

Of course, the traditional manufacturing systems had the mechanisms for inventory management. But the advantage of the cyber-physical system linkage is that it offers real-time information for the manufacturing executives to make the required changes. Evidence of how the cyber-physical system leverages manufacturing efficiency to drive improved performance is reflected in the case of Infineon's Smart Factory in Dresden-Germany (Pelé, 2023).

After adopting a combination of digital and industrial 4.0 technologies, Infineon has emerged as one of the most intelligent network-driven smart factories of the world. Infineon specializes in the manufacturing of semiconductors, comfort electronics, shock absorbers, and safety systems like airbags and ESP (Pelé, 2023). To bolster its manufacturing efficiency, Infineon invested in the introduction of 200 robots to improve the efficiency of human involvement in manufacturing, reduce costs, and bolster the overall fastness and efficiency of the manufacturing processes (Dutta et al., 2024).

Infineon introduced the cyber-physical system in which all production management, equipment, machineries, control systems, and water transport and usage are interlinked with each other using IT systems supported using the aid of Internet technology. Such a system not only communicates with each interlinked component but also with the external ecosystem partners and other actors (IoTaddA, 2023).

This enables Infineon to gain from self-evaluation and correction advantages often offered by the cyber-physical system. Infineon uses digital twins to discern its representation of the intended or actual real-world physical products, system, or processes and improve its overall flexibility to respond to the changes in customer/clients' needs (Mohsen et al., 2024).

Through evaluation of the unfolding industry information, Infineon has been able to introduce artificial intelligence to bolster its manufacturing efficiency whilst also introducing new solutions for the electronics and automotive industries to leverage its overall competitiveness. Besides Infineon, BCJ Healthcare is another organization that uses the cyber-physical system to improve its overall operational efficiency (Pelé, 2023; IoTaddA, 2023).

BJC Healthcare is a non-profit-making healthcare organization based in St. Louis-Missouri in the United States. BJC Healthcare is the operator of about 15 large hospitals in the US. To leverage its operational efficiency and cost savings, it introduced industrial 4.0 technologies like smart manufacturing (Haque et al., 2014; Verma, 2022).

Internet of Things and Internet-supported inventory management solution to analyze and track the efficiency of the medical inventory flows along the value chain. This enabled management to take interventions that eliminated costly areas of wastes.

In that process, BJC Healthcare also uses Radio Frequency Identification (RFID) to track the flow of medical supplies from the suppliers through the internal storage and processing and final transportation to different designated hospitals. This has enabled BJC Healthcare to reduce costs, improve its operational efficiency, and effective functioning as the healthcare service provider. In addition to the cyber-physical system, 3D Printing is also the other critical technological component of a smart factory (Javed et al., 2023; Hashemi & Shams-Aliee, 2019).

3D Printing

3D printing is another important component of the smart factory. 3D printing refers to the technology or additive manufacturing technology that creates a three-dimensional object layer-by-layer using computer-generated designs. While starting from scratch, 3D printing uses digital design to build up layers of materials to create a 3D part (Vasanthraj et al., 2023). This minimizes material wastage. 3D printing contrasts the conventional subtractive manufacturing processes where the final design is cut from a larger block of materials. This causes a lot of material wastage.

Since it improves the manufacturing efficiency, 3D printing is often used for on-demand production strategy and JIT (Just-in-Time) production system (Weber, 2021). 3D is also used for prototyping to aid the creation of accurate product development, small batch manufacturing as well as customer order-based production system.

3D printing uses processes, techniques, and materials that include stereolithography, multi-jet fusion, fused deposition modeling (FDM), POLYJET, direct metal laser sintering, selective laser sintering, and vacuum casting which are used for efficiently building a range of plastic and metal products (Vasanthraj et al., 2023).

The importance of 3D printing in manufacturing is reflected in Adidas Speed Factory in Ansbach-Germany that has adopted 3D printing as part of the modern technologies used in its different smart factories around the world (Job, 2017). To speed up the production of its sneakers (shoes), Adidas uses 3D printing to create digital mock-ups and replicas of the sneakers.

Combined with the use of robotics and artificial intelligence, the prototypes of the sneakers are quickly printed to respond to the constantly changing customer needs and preferences within days or even just a few weeks. 3D printing improves the manufacturing speed, quality control, and production efficiency (Bourzac, 2017).

Due to these values, 3D printing as combined with computerized knitting, robotic arms, and laser-cutting robots has been widely adopted in different footwear manufacturing plants in Asia, Indonesia, and Vietnam (Vasanthraj et al., 2023). The use of 3D printing is often accompanied by digital twins that integrate production facilities with simulation models to aid the detection of problems as they arise.

Simulations for digital twins enable manufacturers to evaluate each physical asset to discern the ideal workflows and extract data that can enable management to make faster decisions (Weiss, 2017; Pandolph, 2017).

Digital twin reflects the highly complex virtual models that act as the counterpart of the physical manufacturing set-up. In such a system, it has sensors that are connected to the physical assets to collect and map data onto the virtual model.

Through this digital twin, the virtual platform reflects the information on how the physical assets are operating and performing during the manufacturing process (Dutta et al., 2024). This enables immediate interventions to be undertaken in the event of a problem. It enables managers to not only evaluate the current state of the assets' performance but also their likely future state of performance.

Besides 3D printing and digital twins, artificial intelligence and robotics are another important component of the smart factory (Vasanthraj et al., 2023).

Artificial Intelligence and Robotics

The concept of artificial intelligence and robots are integrated and interrelated. However, robots are systems programmed to perform repetitive tasks without much advanced artificial intelligence. Artificial intelligence technologies mimic human brains and can therefore be scaled to accomplish other multiple tasks (Mohsen et al., 2024). As part of artificial intelligence and robotics, collaborative robots are used in smart factories to aid the automation of sorting materials, assembling, and packaging products.

Working alongside humans, robots do not only maintain a user-friendly interface but can also be reprogrammed to execute the required new tasks. This improves the accuracy and efficiency of the manufacturing processes to lower costs and time used in the production of different items (Gustavo, 2014).

Due to these advantages, robots are being widely embraced and integrated into different manufacturing facilities around the world. Robots leverage production flexibility since they can easily be shifted around the factory to accomplish different production activities (Weber, 2021).

Robots can also be linked with 3D printing to bolster the overall speed and efficiency of the manufacturing process. With robots integrated into the manufacturing processes, the humans are shifted to the accomplishment of more essential core activities to minimize cost and time required for accomplishing non-core and core activities (Gustavo, 2014).

Quite often robots are integrated with the use of artificial intelligence to aid the effectiveness and efficiency of material handling, quality control, and predictive analysis and maintenance. Artificial intelligence uses sensors for gathering and analyzing data from different production functions. This enables accurate analysis and discerning where interventions must be made to bolster production efficiency and effectiveness. To improve its production efficiency, Siemens Elektronikwerk Plant in Germany adopted a variety of industry 4.0 technology solutions (Siemens, 2020).

In that process, robots, people, and machines were programmed to seamlessly work together in a way that bolsters the overall production efficiency and effectiveness. Supported by artificial intelligence and robotics, Siemens introduced the dashboards that reflect the performance of different machines and processes in the value chain system (Siemens, 2020).

Such a system has proved quite effective for improving the effectiveness of quality control systems as well as scheduling production and maintenance. In that process, Siemens has integrated the use of industrial 4.0 technologies like AGVs, 3D printing, and lightweight robots. It also introduced MindSphere IoT platform to execute predictive maintenance as well as technologies like Industrial Edge Computing, AI, and cloud computing. Cloud computing and 5G technology have now become important components of the modern smart factory.

Cloud Computing and 5G

Cloud computing is an internet-based process of delivering computing services like servers, data storage, networking, databases, intelligence, software, and analytics to multitudes of users to enhance faster innovation, economies of scale, and flexible resources (Shailaja, 2024). It is the Internet-based process of providing computing services to different users without the actual involvement or management by users.

Cloud computing is characterized by on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service (Gustavo, 2014). Through on-demand self-service, a consumer can automatically request the use of server time, network storage, and analytics without any human interaction with the service provider.

Broad network access offers capabilities that are available and accessible over the network using certain standard mechanisms that encourage the use of thin or thick heterogeneous client platforms like workstations, mobile phones, laptops, and tablets (Iacopino et al., 2020).

Resource pooling aspect of cloud computing offers pooled computing resources to use a multi-tenant model that serves multiple consumers with different physical and virtual resources that are assigned to different customers on demand. Rapid elasticity refers to the capabilities of cloud computing to respond and deliver a range of computing services on an increment or decrease of demand (Gustavo, 2014).

Measured service of cloud computing aids in control and resource optimization by metering, monitoring, controlling, and reporting the nature of the utilization of computing services like bandwidth usage, storage, processing, and active user accounts (Iacopino et al., 2020).

For a smart factory, cloud computing offers the desired scalability and flexibility that enable the smart factory to respond to different changes in consumer demands. Through its pay-as-you-go model, cloud computing eliminates the hefty costs for establishing onsite hardware and software as well as maintenance of different computing devices.

By storing and delivering servers, storage, databases, networking, software, analytics, and intelligence over the Internet (clouds), smart factory executives eliminate the onsite risks like fire and theft that can damage the entire business data and important information. Evidence of the application of cloud computing and 5G in a smart factory setting is reflected in the case of Haier Group Corporation. Haier Group Corporation is a smart factory situated in Qingdao, Shandong in China. It specializes in the production of consumer electronics and home appliances like microwaves, washing machines, fridges, wine coolers, and ovens (Dutta et al., 2024).

However, to bolster its manufacturing efficiency, Haier Group Corporation introduced artificial intelligence and robotics in its different manufacturing processes (Huawei, 2019). It also established a service cloud platform and mass customization platform that enables operators to detect and correct any emerging problems before they can interfere with the product or industrial performance.

In collaboration and partnership with China Mobile, Huawei, and M-Star, Haier Group Corporation also established the 5G Smart Factory to improve the efficiency of quality detection and control, energy management, materials transportation, maintenance, security, and machine collaboration (Huawei, 2024). Besides leveraging a firm's flexibility and agility, cloud computing lowers operational costs while also minimizing operational risks to bolster a business' overall sustainability (Gustavo, 2014).

In that process, 5G, which is the next generation of wireless technology, becomes important for providing high-speed and low-latency connections required to quickly and efficiently move a large amount of cloud-based data from and to any location that the smart factory executives require (Shailaja, 2024).

5G not only provides the required data for new product development and for manufacturing scalability to demand changes but also offers the seamless connection of the smart factory with its customers, business partners, and competitors. This enables the business to constantly stay abreast of the trends unfolding in the market and to discern whether trend changes favor or will disadvantage the business.

5G is ten times faster and built with the speed of one gigabit per second to deliver better user experiences, empower new deployment models, and new services (Dutta et al., 2024). This has improved the efficiency of the Enterprise Resource Planning System. It has also improved the efficacy of big data analytics to accomplish analytics associated with descriptive, diagnostic, predictive, and prescriptive analysis.

Descriptive analytics gather and analyze data that just offers insights on what is unfolding in the organization. Diagnostic analytics evaluate the reasons why such events are unfolding (Iacopino et al., 2020). Predictive analytics evaluate the existing data to discern the possible future scenarios that may arise if the situation is not addressed or the efficacy of the improvement strategies that can be adopted to address the current undesired situation (Vasanthraj et al., 2023).

Prescriptive analytics that relies on the information generated by descriptive, diagnostic, and predictive analytics evaluate the causes of the undesirable situation to offer insights on the best solutions that must be adopted.

CONCLUSION

Generally, this study implies that digital technologies like the Internet of Things, cyber-physical system, 3D printing, artificial intelligence, robotics, cloud computing, and 5G technology are critical components for creating effective smart factory and industrial 4.0 business models for enhancing a firm's competitiveness in the increasingly competitive contemporary digital era.

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