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Industrial Revolution 4.0 in the Construction Industry: Challenges and Opportunities

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ABSTRACT:
Industry 4.0 has been a common concept recently to characterize the movement toward digitization and automation in the industrial world. When comparing the innovations of other industries, the building industry is slow to integrate these revolutionary developments into its standard procedures, considering the rapid advancements used in other industry sectors and covid-19 which undoubtedly brought more urgency to this task. Despite a number of advantages and opportunities, there are many barriers that prohibit the construction sector from adopting IR 4.0 due to a variety of factors. Therefore, the paper aims to determine the key issues that are preventing the introduction of IR 4.0-related technology in the construction industry, as well as the long-term opportunities. The paper concludes, despite the challenges, the implementation of IR 4.0 within the Construction Industry would drive the industry's performance to match with their industry counterparts such as the manufacturing, and automotive industry. Industry 4.0 is indeed the way of the future and must be embraced. There is no alternative to digitization, even on the building site Construction needs to catch up.

Keywords: *Construction 4.0, Digital transformation, PESTEL framework, Enablers, Barriers*

INTRODUCTION

Construction is among the biggest global sectors, and the foundation it produces is the pillar of economic growth and competitiveness. The construction industry accounts for 6% of global GDP and more than 8% of GDP in developing nations, according to the World Economic Forum (WEF, 2016). According to (McKinsey, 2018), global building investment was $11 trillion in 2017 and is predicted to grow to $14 trillion by 2025. The construction sector sits at a crossroads; it is both economically important to a country's growth and a central actor in our daily lives. That being said, the industry is dominated by low efficiency, minimal mechanization/ computerization, and robotic use, among other things. Digitization, automation, and convergence allow for increased efficiency as well as higher design and development output (Global Industry 4.0 Survey 2016). Nonetheless, the construction industry is reluctant to adopt emerging technology and automation. In general, the construction industry faces a range of major obstacles, including opposition to reform, barriers to growth, low competitiveness, predictability, and income, and professional worker recruiting and retention problems, which are compounded by the industry's negative image (Farmer, 2016; Gerbert et al., 2017; Global Industry Council, 2018; Sawhney et al., 2014; The Business Roundtable, 1983; Witthoeft, Kosta, WEF, and BCG, 2017). Because of its potential to improve organizational efficiency and bring a new element

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to the conventional way of operating, digitalization has become a commonly accepted paradigm globally. Digital technology (DT) has had a major effect on many conventional companies' day-to-day operations. Most expertise sectors, like the construction industry, have been transformed by easy access to information and faster communication speeds (wong et al., 2018). As a result, the successful introduction of emerging innovations will have a significant effect on economic growth. However, when it comes to technical advancements, the construction sector falls short compared to major industries (Nasseredddine et al., 2020). Yet it is expected that many digital innovations, such as BIM, Machine Learning, 3D printing, and robotics, will be integrated into its business processes during the upcoming three to ten years.

In contrast to other sectors, the construction sector has become digitally lagging (Agarwal et al., 2016; Friedrich, Le Merle, Grone, and Koster, 2011). Both academics and practitioners have recognized the demand for faster digitalization of the AEC industry. Furthermore, the COVID-19 pandemic this year altered the way the building industry conducts business, from project scheduling to recruiting employees to consult with customers. The pandemic's aftermath will have an impact on several business developments in the future Construction sites are evolving as digital technologies, enhancing the opportunity to win contracts and raises profit margins. The positions of business experts and frontline staff are shifting as a result of changes and revolutions (Bigrentz, 2021). While most other sectors have seen major transitions in recent years, the construction sector has been slow to completely accept newly evolving technology adoption. The lack of digital transformation in the construction sector can be traced to a lack of on-site engagement, a workforce with a limited preference for modern technologies, and fractured relations (Friedrich et al., 2011; Leviäkangas et al., 2017). Furthermore, Besides, construction companies had to deal with the manifold PESTEL (political, economic, social, technological, environmental, and legal) challenges. As a result, it is our inherent duty to promote its digitalization to prepare it for the dawn of the twentieth century, especially, as stated following the Covid 19 pandemic, the construction sector is aware that it needs to reconsider its work processes to operate smarter and more effectively. The main objective of this paper is to recognize the obstacles of introducing emerging technology in the construction industry, as well as the long-term opportunities, while also correlating the key factors (PESTEL) that affect the successful adoption of IR 4.0 in the construction industry. The approach established to resolve these issues would be significant if the existing practices and experiences of the construction industry are understood, and propose a strategic roadmap for the implementation of industry 4.0 in the construction industry. The paper will be divided into 4 sections: The 1st section presents a wide-ranging overview of digital transformation, digital strategy, industry 4.0, construction 4.0 and technology in construction 4.0. The 2nd section present enablers to the adoption of IR4.0 and barriers for adoption 4.0. In section 3 PESTEL frameworks' analysis will be presented, what are the (opportunities and challenges) offered, what are the factors which influence implementations of industry 4.0. And, finally, the strategic roadmap for implementing Industry 4.0 technologies and concepts in the construction industry which is consist of five phases will be proposed in section 4. The paper concluded, despite the challenges, implementation of IR 4.0 within the Construction Industry would drive the industry's performance to match with their industry counterparts such as the manufacturing and automotive industry. Industry 4.0 is indeed the way of the future, and must be embraced. There is no alternative to digitization, even on the building site Construction needs to catch up.

Significance of This Paper

This paper paves the way for future studies that want to conduct research on neglected technologies and propose implementation frameworks for these least-known technologies but extremely essential to increase efficiency in the construction value chain. This paper can contribute to several ways for the construction companies that want to remain competitive in the national and international market, and embracing new era technologies is one of their missions. Firstly, companies can access a general idea of Industry 4.0 and its main technologies in the construction industry. Being familiar with the latest technologies empowers companies with a great management vision. Secondly, this paper can provide a vision for companies to assess their process digitization level. Finally, they can come to the idea that combining one of these technologies can provide more extensive benefits in different dimensions.

Digital Transformation

Over time, studies ranging from academic research to applied for works have focused on exploring the digital transformation process. Alongside the development of the digital transformation process, the scope or capacity to investigate its dynamics expands respectively (Kabakchieva and Stefanova, 2019). From the time when the digital transformation theory was first initiated in 2000 by Patel and Mcarthy, the term's definition has progressively changed. Digital transformation was listed by (Truex, 2010) as using digital technology to influence or change in any facet of human life. On the other hand, DT was defined by (Boardman et al., 2018) as the utilization of technology within a company to progress, expand, or develop its performance or reach. Moreover, DT is defined by (Merriam-Webster, 2018) as the state, action, or procedure of transforming or being transformed. Transformation in the aforementioned definition means changing composition or structure. DT is further defined by other sources as the involvement or relation of computer technology in the changing of the marked, in form, nature, or appearance.

However, the defining of DT needs to be further modified to be applied in the construction industry. In the construction domain, the definition of DT refers to the process of using computer technology to alter various phases and processes during construction. This definition pertains to the construction site processes as well as varying business procedures resulting from augmented usage of digital tools in processes as well as the end-users. Digital transformation brings along the implementation of four factors including (1) warrantying maintenance of business competitiveness (2) increasing business processes efficiency (3) growing customer satisfaction (4) facilitating strategic decision-making for business workers. Digital transformation should allow strategies to be altered quickly and strategically alongside the changes in demands, thus the business operations need to be digitalized along with the extension of supply chain relationships. Moreover, the DT process necessitates purposeful internet usage within design, manufacturing, marketing, procurement, sales, and presentation yielding a data-centralized management model (Boardman et al., 2018).

The process also includes the incorporation of digital technology in security, simulation, internet, cybersecurity, and blockchain (Ferreira et al., 2018). Moreover, DT powers business acceleration via the use of technology tools and focuses on prospects that aid business processes to augment the target market.

Digital Strategy

What sets digital leaders apart from other competitors is a well-thought-out digital strategy, as well as a philosophy and leadership that prevail at pushing digital transformation (Kane et al., 2015). They also learned that the main roadblocks to an effective digital transition are an absence of a clear digital plan and competing priorities. A regulated digital transformation necessitates a substantial investment in developing the necessary operational skills to sustain the company's digitalization efforts, in addition to a consistent and well-communicated digital strategy (Lenka et al., 2017). Unlike conventional methods that rely on operational skills, a digital strategy should define a potential roadmap, rethink business and commerce, and work backwards in terms of capabilities needed, among other aspects (Kane et al., 2015). It's typical for effective digital transformations to concentrate on the "how" of transformation rather than the actual substance of the update (Westerman et al., 2011). The majority of contemporary management and strategy literature believes that an effective digital transition is a result of developing a digital strategy that encourages the enterprise to take advantage of the opportunities that novel digital technology offer (Westerman et al., 2011; Kane et al., 2015; Matt et al., 2015). With the absence of a coherent digital strategy being the biggest obstacle in a digital transformation, a cohesive digital approach backed by management is critical in a world where market strategies have shorter life spans and operating models must be continually reconsidered. Market leaders must remain ahead of the curve with the changing business model (Kane et al., 2015) and reimagine the customer experience, organizational procedures, and emerging business models regularly (Westerman et al., 2011). As a result, the foundation of a successful digital approach isn't a path map to an ideal future state or a checklist of best organizational practices. An effective digital strategy should prioritize fostering the organization's and the market environment's continuous growth in form of products and operational creativity, as well as business and value creation models. According to (Westerman et al., 2011), tactical digital transition happens from the top down instead of the bottom-up. A solid, cohesive, and systematic vision is essential to a successful digital plan when it comes to fully transform an industry. The organization's vision conveys the importance of digital transformation both within the company and to external networks. The importance of top-management vision as a catalyst of digital change and the foundation of most effective digital initiatives is confirmed by the field of strategic management literature (Fitzgerald et al., 2013; Kane et al., 2015). (Fitzgerald et al., 2013) found that 93 per cent of staff focused on the value of digital transition in organizations where the upper executives each expressed their vision. According to (Westerman et al., 2011), the revolutionary vision, in combination with commitment, governance, and KPIs, enables individuals around the organization to find and pursue resources that align with the vision. Employees who have a shared interest and a sense of value in the topic have a more cohesive understanding of digital vision within the organization, which improves teamwork practices within the workplace. For example, (Kane et al., 2015) believe that these collaborative experiences are extremely helpful for businesses seeking to benefit from digital transformation because cross-functional and cross-field cooperation enhances the likelihood of transformational developments. Along with organizational vision and collaboration, the digital approach should strive to identify the strengths, expertise, and resources that the organization lacks, and to either externally attract (Westerman et al., 2011) or internally build these skills (Kane et al., 2015). Minimizing the possibility of losing relevant expertise is the third aspect of maintaining corporate skills that a digital approach should recognize (Kane et al., 2015). The digital strategy must also manage the interaction among emerging digital companies and conventional business divisions, as there may be synergies that need teamwork, but there may also be clear conflicting interests, as new digital businesses pose a challenge to conventional businesses (Westerman et al., 2011). Following the assessment and evaluation of new projects, the digital approach should guarantee that those digital initiatives deemed promising are given the support they need in terms of time and money initiatives (Westerman et al., 2011; Fitzgerald et al., 2013). Furthermore, the technology approach should take into account maintaining adequate IT and information systems, as these aspects impact the organization's capacity to both build and capture value from digital initiatives (Drnevic and Croson, 2013). This investment in IT technology is frequently ignored, according to (Drnevic and Croson,2013), because numerical returns can rarely be strictly attributed to IT infrastructure and information services. Due to the need for continuous innovation and the rapidity with which new opportunities emerge, the emphasis of digital strategies must be on creating a continuous digital innovation process (Fitzgerald et al., 2013). Experimentation and reaction, rather than meticulous estimation and planning, are the methods of production in this rapidly evolving world (Downes and Mui, 1998). Instead of trying to dictate which data and knowledge resources to be using and how to use them, digital strategy and corporate culture would promote the use of data and analytics in decision-making (Kane et al., 2015; Westerman et al., 2011, Reeves and Deimler, 2011; Kreutzer, 2014).

Fourth Industry Revolution 4.0

Digital technology has evolved in four main phases as studied by (Hamelink, 1997): First, Industry 1.0 (mechanical phase) first presented mechanical approaches with the introduction of water-powered mechanical equipment within the agriculture sector, augmenting its economic structure. Second, Industry 2.0 (electrification phase) took place in the 1870s when it presented electric energy. Electric energy allowed the development of a procedure recognized as mass production, relying on human capability to enhance achievement. The 1970s brought along the third industrial revolution titled Industry 3.0 (digital computers and telecommunication phase). This phase took place with the introduction and prevailing of electronical devices. Nonetheless, the digital revolution compasses electronic technology innovations from early devices to today's modern technology. Fourth, Industry 4.0 (Ger. Industry revolution) also known as the industrial revolution is the phase when production processes and information technology and techniques were integrated. There are other terms used to refer to the industrial revolution including Internet of Services, Industrial Internet, Advanced Manufacturing, and Smart Factory. It has also been referred to as the industrial age or second machine age, yet there is no unanimous definition of the terms (Mario Hermann, 2018). However, the European Commissioner's seminar, published in September 2015, articulates that the expression origins from Germany's manufacturing industry (Davies, 2015). Germany's federal government generated the expression in 2011. The word was created by the German federal government in 2011 to promote its high-tech approach, it encompasses a wide range of interdisciplinary concepts with no discernible distinction (Lasi et al., 2014; Oesterreich and Teuteberg, 2016), and to develop a consistent policy framework to conserve Germany's industrial competitiveness in the global market. Industry 4.0, as specified by German Chancellor Angela Merkel, is the systematic transition of the entire field of industrial manufacturing through the convergence of digital technology and the internet with traditional industry (Davies, 2015).

Angela Merkel's statement implies that the entire industry (designers, manufacturers, products, and end-users) should be digitally linked. Industry 4.0 allows for a more comprehensive, synchronized, and integrated manufacturing approach. It connects the physical and digital worlds, allowing for better collaboration and communication between departments, vendors, goods, and employees. It allows the corporation's administrators to accurately track and understand each aspect of their activities, as well as to incorporate hard data to improve efficiency, improve processes, and stimulate growth (Epicore, 2018). With physical and digital technology, Industry 4.0 enhances manufacturing enterprises, business practices, and manufacturing processes (Xu, and Li, 2018). The sustainable construction market, with the emergence of Industry 4.0, can overtake towards more productive production powered by efficient business strategies and market structures (Bartolod et al., 2019). The integration of current and new technology that are part of that same Industry 4.0 model allows for such a transition (Oesterreich and Teuteberg, 2016). Automation, connectivity, digital data, and digital access are the four essential keys for the digital transformation of the European construction industry based on (Berger, 2016) research. In this paper, the revolutionary paradigm is referred to as the Construction 4.0 framework.

Construction 4.0

The Construction 4.0 system focuses on the physical-to-digital transition and then the digital-to-physical transition to help coordinate, design, and execute built environment infrastructure more effectively and efficiently (Dallasega et al., 2018). As former scholars have stated, the idea of construction 4.0 is still evolving, and it is informed by its predecessors' conception of industry 4.0. Construction 4.0 is focused on a convergence of patterns and innovations, similar to the definition of industry 4.0. (both digital and physical technologies). As per the European Industry Construction Federation (FIEC), "Construction 4.0" relates to the construction sector's digital transformation within the Architecture, Engineering & Construction (AEC) industry (Agusti-Juan et al., 2019).

Presently there are no agreed-upon meanings of Construction 4.0 in the literary works (Ali et al., 2019), except that most research relates to it as Industry 4.0's equivalent or counterpart (August-Juan, 2019). The researchers propose the subsequently employed description of Construction 4.0, which was developed dependent on a systematic literature review: Construction 4.0 is a model that integrates organizations, procedures, and information to effectively plan, build, and operate assets using cyber-physical structures, the Internet of Things, Data, and Services to associate the digital layer, comprising of BIM and CDE, with the physical layer, comprising of the asset, over its entire existence to establish an integrated environment incorporating organizations, processes, and information. According to Rastogi, the primary objective of construction 4.0 is to build a digital construction site that uses various techniques to track progression during a project's life cycle. Construction 4.0 implementation would transform not just the construction process, but also the company and project frameworks, transforming the fragmented construction industry into an integrated one (Rastogi, 2017). Although becoming one of the most profitable industries, the construction industry has among the poorest R&D intensity levels. Likewise, employment growth in the AEC has decreased over time, although it has nearly doubled in other sectors (Oesterreich and Teuteberg, 2016). The function of human resources in an Industry 4.0 world is shifting from machine operator to strategic decision creator (Hermann et al., 2016). Robots support humans in dangerous, stressful, and time-consuming tasks, for which humans must be adequately prepared for successful human-machine partnership (Awais and Henrich, 2013). Since it is a labour-intensive sector, the construction industry has a significant opportunity to increase productivity through technical advancement (e.g., robot use), particularly for potentially hazardous and dangerous human labour. Robots are used in restricted ways in the digital building platform, such as 3D printing, structuring walls, placing rebar, welding, drones, and so on. Moreover, all of the aforementioned robots are having only one application (Chen et al., 2018; Garca de Soto et al., 2018; Keating et al., 2017; Zhang et al., 2018). Due to the complex site environments in building sites, multi-functional and multi-purpose robots should be examined.

Construction 4.0 Technologies

Construction 4.0 is described by (Irizarry et al., 2020) as a revolutionary paradigm in which three transitions occur: industrial production and construction, cyber-physical system, and digital technologies. BIM (building information system), CDE (common data environment), cloud-based systems engineering, AR/VR (augmented reality/virtual reality), big data and analytics, blockchain, and laser scanners are all instances of emerging innovations. Robotics and automation, sensors, the internet of things, industrial manufacturing, off-site and on-site construction, employees using wearable sensors, and devices fitted with sensors all fall into the category of cyber-physical systems. As a result, it's crucial to comprehend the developments that make this transition possible. Whereas the current study library addresses several Construction 4.0 technologies, this work aims to focus on eight of the most commonly cited Construction 4.0 technologies. Below is a short overview of each of these technologies:

Drones: Drones are mostly used in the construction industry for observation and tracking purposes during survey work, construction, and facilities operations (Borremans et al., 2019). In the past, they were primarily used for military purposes (Nisser and Westin, 2006). Using drones in building and other industries have risen steadily over the years (Irizarry and Costa, 2016).

Augmented Reality is a data platform and publishing program that enables users to (1) passively see viewed material, (2) remain engaged and communicate with published material, and (3) interact in real-time with people from different areas (Bou Hatoum et al., 2020). AR is defined as a combination of reality and virtual reality (Dolenc et al, 2014; Truijens et al., 2014). AR is growing in popularity in the construction sector, with a range of use-cases been studied and tested during the project lifecycle, including supporting AR-enabled manufacturing process (Hanna et al., 2019) and facilitating remote expert systems (Gerger et al., 2019).

VR: is a step further than AR on the spectrum of virtuality. VR creates a virtual and an immersive experience for the user through headsets with 360-degree visions, allowing the user to experience a completely different environment. Since 1990, it has experienced remarkable growth, undergone development, and been applied in areas such as education and training (Gavish et al., 2015). When using VR in training related to the construction industry, it reduces the risks people may be exposed to, optimizes procedures, and makes it possible to identify danger zones (Atherinis et al., 2018).

3D Printing: The method of making a dynamic, physical 3D structure from a CAD model is known as 3D printing or additive manufacturing. 3D printing has been the focus of 25 years of research and development, and it is now used in several fields, including aerospace, vehicles, and medicine (Chua and Leong, 2014). The construction industry is still looking at 3D printing, but mostly for small to medium-sized projects right now. These technologies have recently ignited attention in the Construction 4.0 sector, particularly with cement, lending to its potential to substitute human workers with automated manufacturing, enabling substantial saving of time as well as personalized and scalable construction manufacturing (Wang et al., 2016) The final result is heavily influenced by the printing quality, material behavior, speed, and printing duration between layers (Paul et al., 2018).

BIM: is a computer program that allows all stakeholders in the construction process to generate, transfer, exchange, and communicate data (Aouad et al., 2008). BIM has been critical in the building industry's digitalization. Overall, BIM – specifically 5D planning and budget integration – is supposed to result in substantial cost savings (direct costs, efficiency, delays, protection, and image) across the entire construction value chain (design, construction, operations and destruction). In other words, BIM (Building Knowledge Modeling) can enhance operating processes over the lifespan of a construction project (Oliver Wyman, 2018). Today, Building Information Modeling (BIM) is considered to be the central technology for the digitization of the construction manufacturing environment (Li and Yang, 2017).

Robotics: This technology is widely used in the construction industry, particularly in the assembling of high-rise buildings. For example, the SMART machine built by SHIMIZU in Japan was also used to create a 30-story office tower. Furthermore, robots can execute various building operations like painting, brick overlaying, and earthwork.

AI: is a concept that refers to a computer that mimics human cognition (Rao, 2020). Throughout the construction industry, 4.0 AI can be used in adaptive vision systems to distinguish different aspects on a construction site, as well as voice and recognize patter to track the progress of construction workers in full detail (Bryson et al., 2017). It's still being analyzed to see how it can forecast several anomalies involved in building architecture, construction, and service. Furthermore, intelligent manufacturing is a viable technique (Hou et al., 2017).

IoT: Using built-in sensors and wireless technology, the Internet of Things allows for the fast storage, processing, and sharing of data. It's generally acknowledged as one of the most critical fields of future technology, and it's gaining a lot of interest from sectors (Lee and Lee, 2015). In the context of construction 4.0, the Internet of Things (IoT) is being used to incorporate goods (Wireless sensor networks, middleware, cloud computing and IoT application software).

Many of these advancements in technology today present new opportunities for businesses who wish to enhance their competition, operations quality, project delivery punctuality, as well as new services delivered to customers (Beddiar et al., 2019).

Also, several of these technologies, such as BIM, sensors, and the Internet of things, have proved to be useful in accomplishing the objectives for a prosperous future (Apanaviciene et al., 2020). Along with the enormous potential and promise of sustainable decision-making in the field of construction technology. In other words, investing in new technology contributes to improved efficiency, and that's what companies like construction are looking for (Adeli et al., 2017) (Figure 1).

Enablers and Barriers to Industry 4.0 Adoption

Enablers for IR 4.0 Adoption

Industry 4.0 enablers, or conditions that aid adoption, are many and varied (Table 1). On the one side, technological advancements force humans to move over and no longer make certain decisions, allowing machinery to work quickly and more effectively. Furthermore, increased communication between networks within a manufacturing or other process allows for easier access to data, allowing for better decision-making. Also, the evolving results contribute to improved supplier competition as well as a greater added benefit for the consumer. This is important in the context of the realistic distribution of results to clients, since it makes for greater output and/or quicker delivery, thus altering client company value-for-mone perceptions.

This is what eventually drives the implementation of industry 4.0 on economic grounds across every manufacturing field, including construction. Although construction management is not a particular context of research, factors such as Big Data IoT, Artificial Intelligence (Fisher et al., 2018), Robotics, Cloud Computing, and Cybersecurity (Pereira et al., 2017) are all being analyzed through a multitude of conditions. While construction management is not a common scope of research, the results can be informative and relevant to the construction industry (Chris et al., 2017).

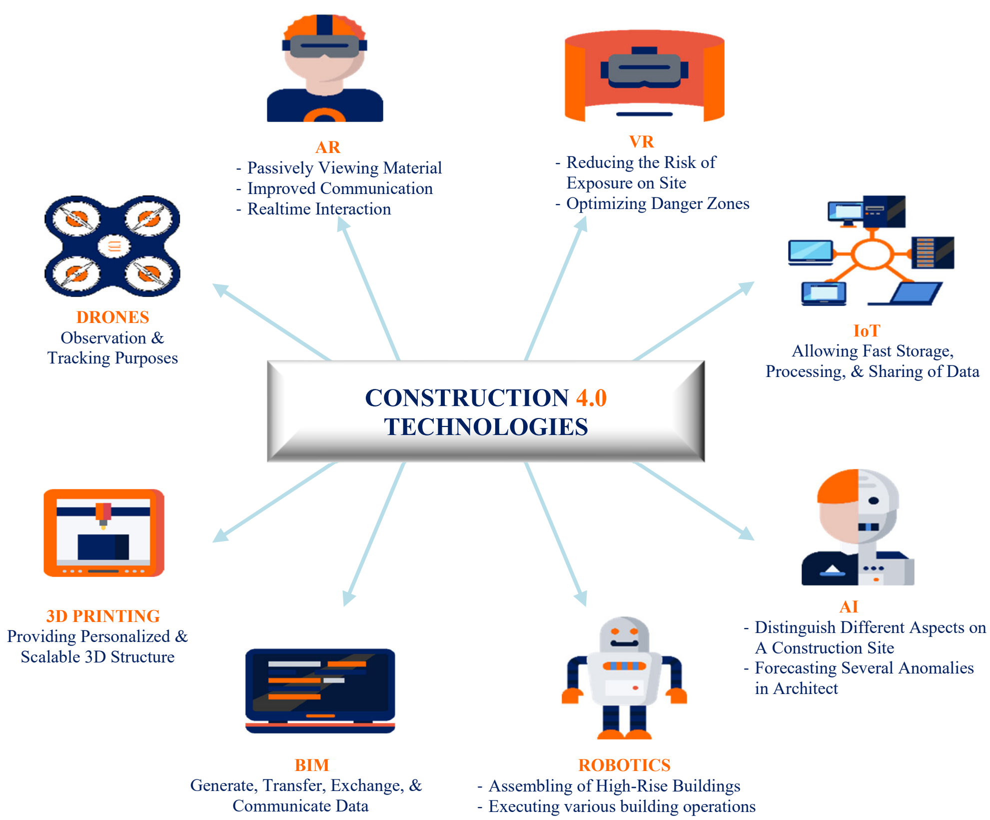


Figure 1: Construction 4.0 technologies

Table 1: Enablers for industry 4.0 adoption

ENABLERS	FEATURES	REFERENCES
Productivity Improvement	Technology permits businesses to improve the productivity of their manufacturing operations. Businesses could examine how employees invest time and implement procedures that improve the efficiency of systems. Task scheduling software helps a business keep on top of obligations, so nothing is forgotten.	(Griffin et al., 2019)
Flexibility Enhancements	Over the past 20 years, communication with colleagues has improved significantly, due to various technological advances that have allowed remote working. Users can also communicate with their peers at any time and from any place, enhancing the company's ability to respond to inquiries rapidly and effectively.	(Oesterreich and Teuteberg, 2016)
Technologies Keep Business Safe	Manual record maintenance and storage posed many company issues. Companies should use digital technologies to keep information secure and enforce processes that only the right individuals could navigate internally. Encrypted passwords have a higher degree of protection, making it more difficult for computer hackers to obtain access to data and avoiding the leaking of sensitive details. When new technologies are launched, technology will begin to transform every part of the workplace, and companies will continue to reap the benefits.	(Fisher et al., 2018)
Butter Customer Services	Customers are essential to a company's survival, but leveraging technology to better their interactions with it will pay off lucratively. Interactive sites, online chat support, and 24/7 customer care via social media will help you stand out from the crowd and boost profits.	(Pereira et al., 2017) (Syberfeldt et al., 2015)
Cybersecurity	Across all industries, communication strategies have greatly increased. Fellow teammates from all around the world will likely collaborate on the same tasks. Currently, networks such as Microsoft Teams, SharePoint, and remote access automated computing mechanisms are on the rise. Digital encryption is another important issue that needs to be discussed in the industry. Hackers and hackers are now using more sophisticated techniques to obtain access to confidential data; as a result, less tech-savvy employees can fail to avoid data loss or theft due to a lack of familiarity with new systems.	(Trappey et al., 2017)
Artificial Intelligence & Robotics	Virtual assistants, expert systems, and automated tools are examples of machine intelligence that has changed the production process. Because of a lack of expertise, advancements in artificial intelligence and robotics have disrupted the construction sector. These improved technologies can harm staff. Adopting AI and Robotics in the construction sector would almost definitely improve efficiency, as the bulk of the work will be performed by automation.	(Sony and Naik, 2019)
Cloud Computing & Big Data	Cloud computing and big data are used in industrial systems. Big data can be turned into usable insights using predictive analytics to help companies accomplish their goals. The real meaning of big data can be analyzed, sought, and analyzed by organizations. Cloud storage, on the other hand, provides businesses with cost-effective and scalable ways to finance activities.	(Sony and Naik, 2019) (Craveiroa et al., 2019)
The Internet of Things	The Internet of Things (IoT) has expanded beyond internet-wired appliances. The convergence of innovations such as embedded systems, artificial learning, and wireless in the digital world. The Internet of Things (IoT) is crucial to the creation and launch of IR4.0 Sensor sensors that are physically connected capture data in real-time. This has the potential to be very useful in the construction sector.	(Chris et al., 2020)

Source: (Chris et al., 2020).

Barriers for IR 4.0 Adoption

IR4.0 has a lot of enablers, but it still has a lot of obstacles. In general, the literature review reported that some of the barriers to be a mixture of high development costs and low human intelligence. Further challenges remain, such as organizational fit with existing activities accompanied by a serious lack of required long-term planning. Both of these disadvantages are extremely pronounced in the construction sector, implying that barriers are exceptionally high in this market. The study reveals that the following obstacles exist: technical adoption (Sony and Naik, 2019), development costs, high process and infrastructure standards (Xu and Duan, 2019), individual hesitancy (Craveiroa et al., 2019), and a shortage of knowledge, (Table, 2).

Table 2: Barriers for industry 4.0 adoption

BARRIERS	FEATURES	REFERENCES
Implementation Cost	According to (Slowey, 2015), IR4.0 technology deployment has a high cost of ownership and operation. It should be remembered that some technology is still in its early stages of development and is subject to continuous development or evolution. It's essential to bear in mind that technical equipment training fees will add up quickly. Such training can necessitate the hiring of an outside consultant to coach the existing workforce, spending time and resources. Will the use of IR4 technologies replace the need for manpower, for example, be another worry for workers? If work cuts or redundancy are a concern, trainees will be hesitant to implement such technologies.	(Griffin et al., 2019)
Technology acceptance	According to the findings, this confusion could affect the adoption of emerging technologies. This has resulted in populism, restricting workers' ability to respond to emerging technology. Technology, once again, comes down to economic and organizational risk, which corporations are trying to prevent. One might argue that validated I4 technology is the sector to venture in and that the gamble has already been taken by another investor.	(Sony and Naik, 2019)
High Requirements	To transition and progress with modern IR4.0 technologies, a knowledgeable or qualified operator is required to either retain or use the technology. The introduction of IR4 technologies necessitates the recruitment and preparation of employees, as well as the acquisition of integration skills. Amazon, for example, also has production machine-only delivery centers in the United States, reducing the need for professional warehouse employees. Although this could seem to be a financially feasible choice, trained operators and maintenance personnel would also be needed.	(Fisher et al., 2018)
Lack of knowledge	The adoption of IR4.0 technology, as per (Neugebauer, 2016), can affect how manufacturing and operations are carried out. This can cause problems with work culture, management structure, and productivity. Although many skilled workers in the industry are ready to implement emerging technology, others may be unwilling due to a lack of expertise or desire to learn new processes. It can be inferred from the above hurdles that construction firms are reluctant to incorporate new technologies into their operations.	(Trotta and Garengo, 2018)
Poor Long-Term Planning	An IR4.0 technology introduction does not guarantee continuous improvement in any company, particularly if it is not closely monitored. Long-term results and risk analyses should be considered when designing a project. In a perfect future, a team will be delegated to monitor not just the entire deployment operation, but also the continued use until the rollout period is finished.	(Pereira et al., 2017) (Syberfeldt et al., 2015)
Insufficient Support	Users should anticipate a platform for discussing their concerns and questions until the technology is implemented. Users should be able to get immediate assistance if they need it, or else they would be hesitant to understand and adopt the technology.	(Oesterreich and Teuteberg, 2016

Source: (Chris et al., 2020).

PESTEL Analysis

In the construction industry, PESTLE analysis is regarded amongst the most significant commercial analysis methods. As a chartered accountant or construction specialist, it's crucial to be aware of this instrument to determine the status of the market daily. The PESTEL framework is used for analyzing the macro business environment external to a firm (Rothaermel, 2014). In this paper, we will discuss the work of (Alaloul et al., 2020).

Opportunities of Industry 4.0 for the Construction Industry in the Context of the PESTEL Framework's Perspective

Table 3: Opportunities of IR 4.0.

FACTOR	DETAILS	EXPLANATIONS
Political (P)	Global Competitiveness	Regional construction firms can boost their international standing by leveraging cutting-edge technology to produce the best product efficiency and performance.
Economical (E)	Product Demand & Supply	Both production and order fulfilment times are shortened due to creative innovations and ideas. The innovations will also save money on items like labour and supplies.
Social (S)	Image Enhancements	Instead of typical workplace environments, the digital transition in the sector will foster a more creative working climate, while simultaneously strengthening partner partnerships and customer relations.
Technological (T)	Reliable Productivity	The improved method would guarantee that there are few or no defects, thus improving quality control. With enough detail, accurate decisions may be taken to produce more successful outcomes.
Environmental (E)	Promotes Sustainability	Using these innovations, a variety of strategies for reducing energy consumption may be applied. It is, therefore, possible to monitor the amount of waste generated, thus avoiding contamination of the atmosphere.
Legal (L)	Established Framework	A large-scale introduction of this scheme would compel the system to have a well-established legislative framework, eliminating uncertainty.
Security (S)	Safety Enhancement	Industry 4.0 was thought to improve protection because various approaches to completing a particular job could be used, and the technology allows people to get instruction or reduce risks.

Source: (Alaloul et al., 2020).

Challenges of Industry 4.0 for the Construction Industry in the Context of the PESTEL Framework's Perspective

Table 4: Challenges of IR 4.0.

FACTOR	DETAILS	EXPLANATIONS
Political (P)	Governance	The building service industry is mostly made up of small to medium-sized businesses, which limits their ability to invest in technology with ambiguous benefits. Construction businesses will have to focus on regulatory bodies and authorities to help them execute these plans by financing schemes and strategic collaborations.
Economical (E)	Financial Transparency	Innovative technology is expensive to introduce. The ambiguity of a payoff makes it even harder. Such charges, such as preparation and infrastructure maintenance, will be added to the list, making it more difficult to incorporate.
Social (S)	Cultural Habits	The incorporation will have a significant impact on various stakeholders involved in construction processes.
Technological (T)	Technical Challenges	To fit the construction environment, equipment must be redefined and strengthened. The need for improved expertise to operate these advanced systems, as well as the need for sturdy equipment elsewhere, will add to the difficulties of integrating it into standard everyday activities.
Environmental (E)	Organizational Processes	Changes in operational structures (horizontal, vertical, and end-to-end) would cause traditional implementation procedures to be distorted in some way. To effectively respond to the new changes and improve development, common practices will need to be revamped.
Legal (L)	Uncertain Regulatory	Lack of consistency in the division of roles held by each stakeholder, as well as legal issues posed by flaws compounds the complexity.
Security (S)	Threat Risk	Information and data sharing will be vulnerable to attacks and placed in vulnerable circumstances, creating a slew of IT security issues regarding data privacy and security.

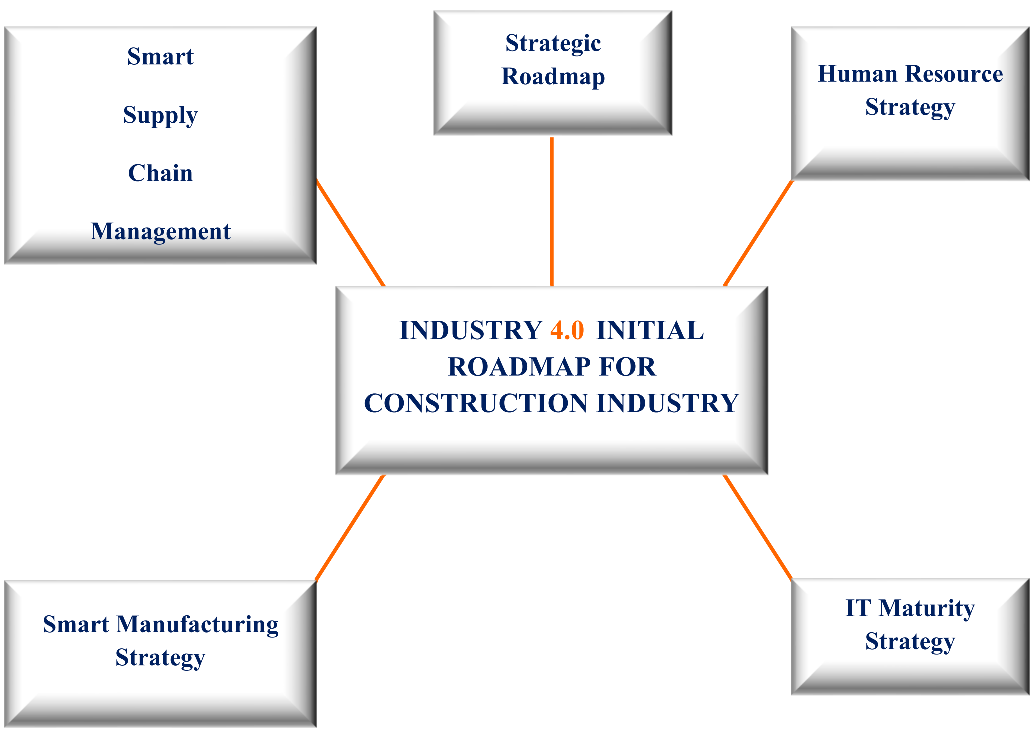
Source: (Alaloul et al., 2020).

The PESTEL system was developed using the PEST analysis to perform market research and develop a deeper understanding of the various macro-environmental variables that must be addressed. After analyzing literature from a variety of outlets, (Alaloul et al., 2020) concludes that security considerations remain a primary contributor that must be taken into consideration. Almost all of the elements in PESTEL have security problems. The technological aspect, for example, consists of IT protection problems, which pose a danger to construction firms due to the possibility of data manipulation and leaked data. The legal aspect, on the other hand, is security questions regarding privacy and data safety. This complexity should be eliminated to guarantee that the variables only apply to one issue. As a result, security factor should be included in the PESTEL system, making it PESTELS: Political (P), Economical (E), Social (S), Technological (T), Environmental (E), Legal (L), and Security (S). The overview of the collected difficulties and prospects of applying IR 4.0 in the construction industry is illustrated in Tables based on the results gathered by a literature review (3 and 4). The Social (S) factor has been found to have the highest impact, while the Political (P) factor has the lowest impact of all the aspects involved. Economical (E) and technical (T) principles continue to be one of the most important influences. Security (S) came in fourth place, led by Legal (L) in fifth place, and Environmental (E) in sixth place. In conclusion, all the factors contribute greatly towards successful implementations.

Strategic Roadmap for Implementing Industry 4.0 in Construction Companies

To promote the transition to Industry 4.0, companies should establish a strategic roadmap to take every step and decision more transparent and understandable.

To state the highlighted challenges, a simple roadmap is presented as guidance for the digital transformation of construction companies. This roadmap paves the road for companies to determine their particular Industry 4.0 aims and develop a set of actions to reach them. Construction industry players need to envision (company-specific understanding of Industry 4.0 vision), enable (develop a roadmap and identify success factors), and enact for this transformation (Erol et al., 2016). A comprehensive roadmap should have a specific framework for each phase of strategic management, marketing, human resource, IT maturity, smart manufacturing, and smart supply chain management.



Source: (Ebrahimi, 2019).

Figure 2: Figure industry 4.0 initial roadmap phases

Strategic Roadmap

The key process of the industry 4.0 development roadmap is strategic management. The overall state of an organization (where it is, where it can go, and how to get there) and a time-dependent (short-term, medium-term, and long-term) plan would be defined based on Industry 4.0 concept and proposed benefits (Erol et al., 2016). It is critical to appoint a team to oversee the introduction of Industry 4.0 and a company's digital transition, as well as the integration of traditional technology with emerging systems and technologies (Ghobakhloo, 2018). Mergers and acquisitions (M&A) are daunting for businesses because not all firms are capable enough to hold horizontal manufacturing convergence, and they still lack the necessary facilities, capital, and IT sophistication to embrace Industry 4.0. (Ghobakhloo, 2018). It shows the value of M&A factors for both major firms and small enterprises. The industry 4.0 development team should create a transition plan and decipher the steps, then define the characteristics of each transformation stage and perform a broad cost-benefit analysis for each stage. Furthermore, for each step of the industry 4.0 deployment roadmap, internal and external performance drivers, technical requirements, and priorities must be understood (Kagermann, 2015).

IT Maturity Strategies' RoadMap

Information and communication technologies (ICTs) are used in the value chain of Industry 4.0. Industry 4.0 architecture blocks (vertical and horizontal integration), as well as types of innovations such as CPS, IoT, BIM, and others, demonstrate that ICT technology plays a significant role in the transition to Industry 4.0. (Leyh et al., 2016). To take the first step toward ICT maturity, businesses must conduct a thorough investigation into their IT infrastructure, including hardware, applications, IoT devices, and qualified personnel, and then assess their company's IT development level and the appropriate IT level for Industry 4.0 implementation.

The IT team should define which phases of the market need ICT implementation, and if the existing IT infrastructure is inadequate, they should use Industry 4.0-created ICT principles in the process segments (Savtschenko et al., 2017). The major elements in the progress of the industry 4.0 transition are communication and coordination within the process. Industry 4.0 technology and principles empower the whole supply chain (equipment, elements, and machinery) to interact in real-time and also at the ground level by collecting, evaluating, and recommending data to management (Gilchrist, 2016). However, in a digitalized factory, all equipment and components do not speak the same technical language, have the same characteristics, or obey the same protocol. As a result, the IT team needs to ensure that recently adopted ICTs are completely integrated and aligned with previous elements, as well as that the whole mechanism is fully compatible (Chen et al., 2018).

Smart Manufacturing Strategies' Roadmap

Smart manufacturing is characterized by transparency, connectivity, and convergence (smart construction site). Smart construction sites, like other manufacturing environments, are attempting to transition from a conventional manufacturing environment to one that is completely scalable, complex, and interconnected, relying on data collection sources from multiple manufacturing operations (Kang et al., 2016). Implementation of IoT and RFID devices is needed for creating smart communications in the manufacturing process, as is strategic integration of materials, databases, equipment, procedures, and personnel to establish a smart construction site (Da Xu et al., 2014; Gilchrist, 2016). To obtain process-level data, taking advantage of various procedure controllers (such as SCADA) and automatic mobile elements are necessary. The manufacturing execution system (MES) will be developed due to connected control systems with the central control system. Further, the integration of MES with enterprise resource planning (ERP) enables the required transparency and connection within the process to produce real-time data. A combination of smart ERP and data mining processes will facilitate the creation of a digital twin, which provides the system lifecycle information of projects and any single component of it for the whole production system. The digital twin has a noticeable impact on the expansion of the smart manufacturing site because it provides (Ghobakhloo, 2018).

Smart Supply chain Strategies' Roadmap

Because of the massive digitalization of operations and the advancement of data creation tools, the industry 4.0 transition has had a huge effect on supply chain relations (Wu et al., 2016; Zhong et al., 2016). Partners must merge and align their procedure's digital twins in ways to construct an intelligent and digital supply chain. This implementation is primarily focused on ICT configuration in the supply chain, resulting in real-time data and data access. Using blockchain technology will help the supply chain maintain data consistency and confidentiality, which is a key problem in this transformation since it protects different stakeholders' intellectual property. As a result, if the value chain can fully integrate the flow of data, operations, finances, materials, and both manufacturing and managerial skills, it would be easier to create a smart value chain that plays a key role in digital transformation. Smart value chain and smart production convergence allow for the gathering of real-time data from different partners, customers, and operations processes, resulting in increased supply chain value (Ghobakhloo, 2018).

Human Resource Management Strategies

The establishment of a human resource plan is the final step of the development strategy. According to reports, one of the most significant considerations for an effective digital transition is getting competent workers. Industry 4.0 can establish a shared interaction between the real and virtual worlds by using ICT trends such as CPS, RFID, IoT, IoS, modelling systems, cloud networking, BIM, and cybersecurity. This requires strong technical expertise and related training from employees (Gilchrist, 2016). Companies should better assess their employees' technological skills and recognize their existing capability gap, according to experts, to meet the industry 4.0 transformation criteria (Hecklau et al., 2016). While the present staff lacks sufficient experience and expertise, they are also professionals and aware of the company's procedures and norms. Current workers have a significant advantage with the new upcoming supply chain, so training and preparing them to implement the innovative innovations and principles proposed by Industry 4.0 is the best choice. As a result, businesses must perform a rigorous cost-benefit study of business 4.0 programs in the human capital and value chain. They should also strive to hire a multi-skilled workforce who is eager to learn new techniques and ideas (Shamim et al., 2016).

DISCUSSION

Preparing for the future is always something to keep in mind, but COVID-19 has undoubtedly brought more urgency to this task. It's high time to prepare the workforce for the future, and doing that requires to level up in terms of technology, adaptability, efficiency, and safety. It's time to start building a strong construction workforce today, and for the advancement of construction's future (digital building, 2020). The potential to transform so many facets of construction is up for grabs. Unlocking this potential will become critical for contractors over the coming years. But we'll also see a new competitive landscape emerge, as democratic access to such disruptive technologies makes it easier for firms to innovate. A competitive landscape where traditional barriers to entry—capital, knowledge, efficiencies, relationships—might be swept away. The rewards are significant: Improved levels of productivity, reduced risk, greater resilience, and better margins. While Construction 4.0 is predominantly discussed in terms of technology, successful implementation will depend on the critical issues surrounding people, practices, and the environment.

CONCLUSION

Industry 4.0 is a relatively new research field led by Germany and pursued mostly by developed western countries. While numerous disciplines are represented, the field of construction management is conspicuously under-represented, knowing that construction is a globally significant industry that employs millions of people and contributes massively to the GDP of individual nations and the global economy. The adoption of Industry 4.0 technologies has far-reaching implications for the whole construction industry, the involved companies, the environment, and employees. Besides the economic benefits for improving productivity, efficiency, quality, and collaboration, their adoption can help to enhance safety, sustainability, decision making and thus to improve the poor image of the construction industry in the long run. Despite the advantages, several challenges must be addressed by all involved parties to ensure a successful implementation. To promote the transition to Industry 4.0, and fully reap these benefits, manifold political, economic, social, technological, environmental, and legal challenges have to be embraced, Companies should put industry 4.0 at the core of their strategic plan to gain national and international competitive advantage, The digital transition necessitates the use of a company's innovative ability, as well as new business models, tactics, organizational improvements in human resources, production processes, and management practices, technology styles, and physical infrastructures (Gilchrist, 2016).companies, should establish a strategic roadmap to take every step and decision more transparent and understandable. Construction industry players need to envision (company-specific view of industry 4.0 vision), enable (develop a roadmap and define success factors), and implement (Erol et al., 2016). Each phase of strategic management, marketing, human resources, IT maturity, smart manufacturing, and smart supply chain management should have its framework in a comprehensive development plan. In short, despite the challenges, the implementation of IR 4.0 within the Construction Industry would drive the industry's performance to match with their industry counterparts such as the manufacturing, and automotive industry. Industry 4.0 is indeed the way of the future and must be embraced. There is no alternative to digitization, even on the building site Construction needs to catch up.

RECOMMENDATIONS

As discussed, many times, the construction industry resist for implementing Industry 4.0 technologies and undergo digital transition, the result is the shortage of theory knowledge. Therefore, Extra efforts among academicians and industry players are required to implement the innovative concept of Industry 4.0 in the complicated environment of the construction industry and push its traditional borders.

ABBREVIATIONS

AEC	**A**rchitecture, **E**ngineering & **C**onstruction
AI	Artificial Intelligent
AR	Augmented Reality
DIHK	Association of German Chambers of Commerce and Industry
CPS	Cyber-Physical System
GDP	Gross Domestic Product
ICT	Information Communication Technology
IoT	Internet of Things
IR4.0	Industry revaluation 4.0
VR	Virtual Reality
BIM	Building Information Modeling
DT	Digital Transformation
R&D	Research and development
PESTEL	P - Political, E - Economic, S - Social, T - Technological, E - Environmental, L – Legal
M & A	Mergers and Acquisitions

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