The Built Environment and Industry/Construction 4.0 Technologies towards achieving SDG 9.

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INTRODUCTION

Industry 4.0 represents a new concept of automation and digitalization of manufacturing processes. However, the aim is not only to optimize the product itself, but also to consider the organization as a whole, with a focus on a digital business model that integrates information technology (IT) infrastructure, manufacturing aspects, service providers, and the importance of the data collected from several sources, implementing analysis methods to produce information that endorses collaborative spaces to advance the value chain. Industry 4.0 aims to implement automated working environments, connected widely, systematized, and robotized at an elevated level (De Assis Dornelles et al., 2022). This alteration from conventional industry will require employee competencies and new skills (Hanna, et al., 2022). For example, engineering professionals with extensive digital skills, problem-solving, teamwork, agile learning, effective communication, and innovation will be required. Therefore, individuals should know how to respond to new production plant operations' integrated digital and automatic work dynamics (Peres, et al., 2020).

Industry 4.0 includes a range of technologies to develop a digital and automated manufacturing environment and digitize the value chain. The term was developed by the German federal government and can be described as the trend toward digitalization and automation of manufacturing environments. In other words, Industry 4.0 is a new manufacturing paradigm that mainly focuses on the creation of smart products and processes by using smart machines and the transformation of conventional manufacturing systems into smart factories. As a result, the term "smart" is a keyword for the Industry 4.0 framework (Alaloul et al., 2020). This raises the following questions: One has to do with the main contribution of Industry 4.0. Two is the distinguishing feature from the other industrial revolutions. Comparing the 4 revolutions, it would be discovered that the impact of the first three industrial revolutions was on the industrial processes by allowing productivity and efficiency to increase using disruptive technological developments, such as electricity, steam engine, or digital technology. In contrast, the impact of Industry 4.0 will completely and profoundly change the manufacturing and industry sectors and create new opportunities regarding production technology, business models, and new jobs and work organization (Hussien, 2017)

The construction sector sits at a junction, affecting our everyday lives, and is economically crucial to the success of a country. The sector is a massive technical collection that adds value by supporting small-scale construction businesses and associated industries, including SMEs, in their different configurations and capacities. Several authors have described the sector as wide-ranging where the value-adding company, consisting of a large, medium, and small-scale construction business, is the strength of economies (Gunduz & Yahya, 2018; Babalola et al., 2019). According to several research studies (Baghalzadeh Shishehgarkhaneh et al., 2022; Sadeghi et al., 2022), the construction sector considered the background knowledge of various innovative ideas introduced in the form of cutting-edge technologies. Also, it has been constantly at the top of innovative technology becoming the central point of attraction worldwide. For instance, the implementation of Building information modeling (BIM), Artificial

Intelligent (AI), the Internet of Things (IoT), Virtual Reality (VR), and Augmented Reality (AR) in the construction sector has massively increased, with the most popular combination of BIM, IoT, and AI to improve organizational performance. Therefore, IoT and BIM could be considered among the most impactful and practical attempts to achieve smart construction 4.0. This includes a robust combination of knowledge, processes, data, and stakeholders. Lekan et al. (2021) suggested that innovation made by industry 4.0 had shaped the construction sector by applying conventional tools and introducing the enhancement of productivity to achieve a sustainable built environment.

BIM establishment has significantly impacted the construction sector. Zhao et al. (2022) argued that innovations have considerably affected construction and building work via the enhancement in productivity and motivation within the design and construction of buildings. Similarly, Olanrewaju et al. (2022) agreed with the view that more results have been noted in the aspect of building design, and general construction works. Also, it was discovered that implementing new technologies within the sector have improved the administration and the current practices and performance of previous tools. For example, establishing lean concepts, BIM, and building informatics has considerably affected the infrastructure design, management, and construction (Hussien, 2017). Several researchers have also considered the Internet of People (IoP) as a new theory that identifies people as an active part of the internet rather than being deemed as end-users only (Sun & Scanlon, 2019).

According to Van Tulder et al. (2021), the United Nations perspective of the 21st century (Agenda 21), coupled with a reaction to the global sustainability within different industries and economies, have formed a series of agreements aligning international development policies in a common framework called the Sustainable Development Goals (SDGs). The SDGs adopted 17 goals within a universal agreement addressing the scientific and practical evidence required for a further sustainable attempt at its development actions (Dawes, 2022). This perspective emphasizes the significance of innovation in responding successfully to the challenges of Industry 4.0 professionals, in line with the responsibilities of sustainable development goals. Innovative and dynamic professionals empower the integration of efficiency of human interaction, production systems, and automatic systems as solutions to new challenges along with these production systems (Wieser et al., 2021).

To this end, this chapter explored the place of Industry 4.0 innovations in achieving sustainable development goals within the construction sector using the industrial revolution as the primary point to achieve sustainable development goal 9. This chapter centered on achieving the development goal (9), which states that investments in infrastructure are crucial in achieving sustainable development. The goal specified introducing cutting-edge technologies and achieving sustainable global development via innovations and industry 4.0.

Sustainable Development Goal 9 (SDG 9)

SDG 9 is one of the 17 goals adopted by the United Nations. Therefore, building resilient infrastructure, advancing sustainable industry, and encouraging innovation are the three main purposes requiring achievement integration. However, it provides a roadmap for achieving the industrial digital revolution, industrial automation for increased productivity, process and procedure innovation, and resilient infrastructure development. The SDG 9 (industry, innovation, and infrastructure) targets is illustrated in figure 22.1.

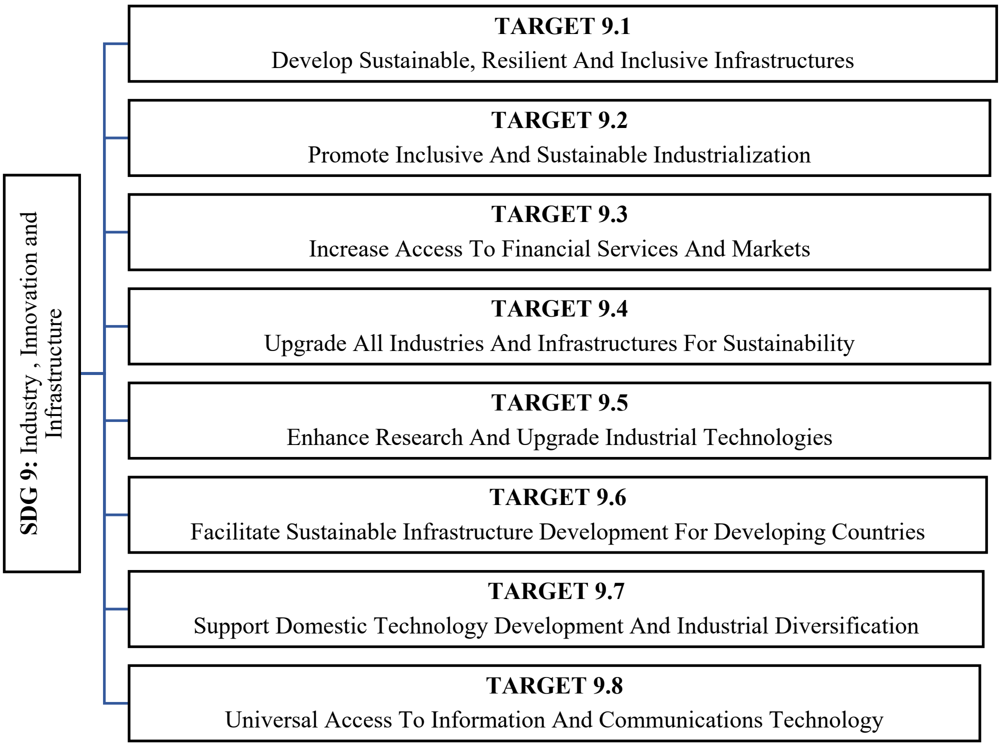

Figure 22.1 SDG 9 and key targets

SDG 9 includes a road map for achieving industrial digitalization, automation to enhance innovation, productivity, procedure and process, and building resilient infrastructure and facility. Empowering innovation is needed to help bridge the gap between the masses and infrastructures.

Therefore, achieving SDG 9 opens the way to digital industrialization, which aligns with the need of the present generation. The aim is to include the industrial revolution, technologies, and infrastructural development (Sadeghi et al., 2022). Technology innovations are processes or items through which new methods of achieving results developed. Furthermore, the impact of SDG 9 could be achieved through conventional techniques by combining contemporary technologies with skills. Thefore, the concept of combining the fourth industrial revolution and SDG 9 was proposed for the construction sector to create a route for industrial development whilst also needed in the provision of good and services for economic development. The impact of SDG9 is to be considered in some areas, such as balanced environmental conditions and affordable housing.

INDUSTRY 4.0/ CONSTRUCTION 4.0 TECHNOLOGIES

The European construction industry federation defined Construction 4.0 as a branch of Industry 4.0 which relates to the digitalization of the construction industry (Lubanski, 2000). The concept seeks to digitalize the construction industry by implementing new technologies that would positively and significantly impact the construction process. On the other hand, construction 4.0 has been defined as the use of ubiquitous connectivity technologies for real-time decision-making. It has been argued to mean a more extensive approach that goes beyond the simple technologies framework to address the industry current challenges..Even though it has attracted several definition, theconcept works around one central point which is to find a connection between physical space and cyberspace through ubiquitous connectivity. Looking deeply, this connection already exists in the BIM. However, the weak point is that the presence of a human is necessary for this model to manage and maintain this connection which the new technologies would gradually replace (Chen et al., 2022). Several types of technologies have been used within the sector. This chapter will discuss each of them and the overlap amongst them with their massive benefit to the construction sector.

Researchers observed that various factors must be implemented within Construction 4.0 in the construction sector, and four main questions arose:

- What are the technologies included in Construction 4.0?
- Where are these technologies used?
- Do the technologies incorporate each another?
- What obligations should construction organizations take into consideration when implementing Construction 4.0?

Identifying Construction 4.0 Technologies and their usage

It is essential to identify the technologies facilitating this transformation of construction 4.0. However, there are several technologies involved within the construction sector. This chapter concentrates on eight technologies often cited in lietrature. These technologies have significantly affected an industry traditionally considered unproductive, inefficient, and hesitant to use technology.

Table 22.1 Construction 4.0 Technologies and their usage

Technologies	**Definition, Benefit, and sustainable impact**
Building Information Modelling BIM	BIM is a management process developed resulting in an intelligent model linking the architecture, engineering, and construction (AEC) sector, enabling data exchange efficiently throughout a project’s life cycle (Chen et al., 2022). Incorporating BIM into the construction processes associated with building design, construction, and operation is the sustainability characteristic in the built environment. The higher level of traditional Building Information Modelling (BIM) is Integrated Building Information Modelling (IBIM) which contains three elements (Hussien et al., 2020): • The architectural integration specifies significant (IBIM) layers and how they are interlinked. • Defines the object’s behaviour function and content via the product model • The mechanism and interaction scheme between model objects via the process model. Resulting in smart and energy-efficient buildings, which will monitor the continuous improvements in SDG9

Augmented Reality AR	Augmented reality has been a research focus for decades since Ivan Sutherland first coined it in 1968 (Borgmann, 2010). The properties of augmented reality are: • Combines real and virtual objects in a natural environment. • Runs interactively and in real-time. • Registers (aligns) real and virtual objects with each other. Until recently, the cost of the devices was the main barrier to implementing AR applications. The common implementation of mobile devices has eliminated this limitation, as tablets and smartphones contain all the processing units and sensors required to develop and use AR applications. In the building sector, monitoring operations, AR intuitively highlights any error or variation in a facility.
Virtual Reality VR	Virtual reality is the technology in which the user is engaged in a virtual world" (Jimeno & Puerta, 2006). Implementing VR technology in the built environment creates a new paradigm of design and communicating design in architecture via monitors of the construction process (Kim et al, 2013). The VR technology creates a virtual construction environment for subcontractors' coordination, site layout, safety assessment, construction scheduling, and safety training of workers. This could also help and promote interactive educational session where knowledge could become more comprehensive. However, within engineering discipline, as Walker et al. (2020) stated, the adoption of VR technology in education is on the rise. Still, the specific educational approach employed in such virtual environments is often unclear or unarticulated. This endeavor leverages ongoing discussions about VR education and investigates the creation of a VR setting with an explicit pedagogical framework.
3D printing	3D printing makes the processes of construction projects more effective by simultaneously allowing the moving of value-adding activities back to the construction site and moving only the manufacture of complex components off-site, mainly for small and medium-sized applications at the time (Olsson et al., 2021).
Artificial intelligence AI	Artificial intelligence (AI) represents a replication of humans by machines. One of the primary elements of AI is machine learning, where a machine learns from a set of data and predicts results, e.g., the prediction of the performance and strength of structural elements (Forcael et al., 2020).
Drones	Drones, also known as Unmanned Aerial Vehicles (UAVs) have been increasingly used in recent years within the construction sector. E.g., health and safety quality control, materials tracking, structural damage assessment, data collection, land surveying, human performance monitoring, and evaluation of the equipment damage (Aiyetan & Das, 2022) .
Internet of Things IoT	The construction sector will benefit from implementing IoT e.g., better monitoring execution, efficient controlling, improved quality, timesaving, and cost-saving. In addition to the improvement of decision-making due to the availability of real-time data (Gamil et al., 2020).
Big Data BD	Big Data is when large amounts of data are processed and valuable insights are extracted. Five characteristics are used in describing Big Data: variety, volume, value, velocity, and veracity. Several research such as Mehmood et al. (2019) argued that Big Data is important to the

	construction sector and showcased that the proper implementation of Big Data is feasible throughout the whole lifecycle of a construction project. The benefits include enabling improving decision-making, stakeholder-driven analysis, boosting transparency and information exchange, and project performance improvement (Yousif et al., 2021)

Construction 4.0 incorporation of technologies

Construction 4.0 incorporates technology that maintains smart construction sites, virtualization, and simulation to encourage maximum project performance. 3D printing, prefabrication, mixed reality (AR and VR), drones, and big data are utilized to improve real-time and enhance decision-making processes. Construction 4.0 allows the construction sector to improve productivity, lower project costs and time delays, manage complexity, safety improvement, and improve quality and resource economy (De Assis Dornelles et al., 2022). This fits with SDG 9, which results in the construction sector becoming increasingly energy-efficient, affordable, comfortable, safe, and sustainable as advanced technologies and materials are developed. Innovative technologies and digital transformation within the construction sector provide an inclusive overview of the materials developments, cutting-edge technologies, and approaches in designing smart buildings, operations, and construction.

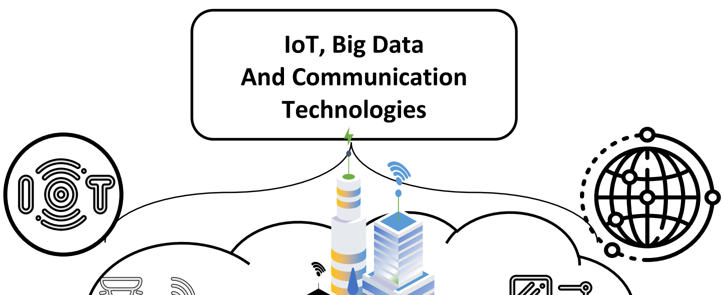

Figure 22.2 Construction 4.0 Technologies Incorporation

The interactions of construction 4.0 technologies are presented in Figure 22.2. The figure highlighted multiple applications, such as integrating AR objects with drone live feed. The implementation of AR in inspection and safety training, combining the use of drones in surveying with AR/VR simulations, leads to real-time virtual tours through cameras installed on drones. The construction sector is a critical partner in the global effort to achieve sustainable development by 2030 by delivering sustainable projects. This study identifies the important characteristics of Industry 4.0/Construction 4.0, correlated with automation, efficient production, digitalization, and connectivity through networking and digital communication. They concentrate on the characteristics that influence construction professionals. These characteristics are outlined within the challenges of Sustainable Development Goals (SDGs), providing the foundation for classifying new abilities and characteristics that engineers and construction professionals would require.

THE IMPACT OF CONSTRUCTION 4.0 TECHNOLOGIES ON DIFFERENT PROFESSIONS

This section presents how Construction 4.0 technologies have influenced the practice of some of the key professions in the built environment (Figure 22.2). Specifically, the choice of these professions is because of their key roles in the decision-making process of physical development.

- **Architecture**

The architectural practices have been impacted greatly by the uptake of the BIM paradigm from the pre-design through the design process and the building completion. This has been demonstrated in developed countries and the developing country context, delivering global success in achieving SDG9 in the built environment. Building Information Modelling as a concept helps architects to create a digital 3-dimensional (3D) model of a proposed development, enabling them to appreciate what it would like. Besides, it also helps to generate appreciable data, which according to HMC Architects (2019) can be useful for establishing parametric relationships and model element dependency. In addition, the data could help in computational design; space planning; energy analysis; light and daylight analysis; display of complex spatial relationships.

However, one of the greatest impacts of BIM is the seamless collaboration it enables between the design team and the developer. For instance, any change in design by the architect can easily be noticed by the other consortium members, indirectly enabling better communication. Notably, this form of efficient communication and update is not only amongst the design team at large but also within architects because all the architects on a project can see the latest design changes. Architectural practices have also benefited from BIM by coming as a handy modeling tool to deliver more detailed visualizations. Before BIM, architects could only appreciate the 3 dimensions (3D) height, width, and depth. However, BIM introduced two additional dimensions to traditional 3D modeling: the fourth dimension of time, which accounts for the project's duration, and the fifth dimension of cost.
BIM is a process that involves the creation and management of digital representations of the physical and functional characteristics of a building or structure. BIM encompasses all aspects of a building, including its physical and functional properties and its construction and operational life cycle. It involves the creation of a digital model that can be used throughout the building's life cycle to facilitate communication, collaboration, and decision-making (Hussien, 2017). On the other hand, 3D Information Modeling is a narrower concept that refers specifically to creating 3D digital models. While 3D modeling can be a component of BIM, BIM includes many other aspects beyond just 3D modeling, such as scheduling, cost estimating, sustainability analysis, and more.
In summary, 3D Information Modeling refers to the creation of 3D digital models, while BIM is a broader concept encompassing the creation and management of digital models throughout a building's life cycle.

Furthermore, BIM packages such as Revit Architecture enable architects to depict a building in its sixth dimension by providing comprehensive data about its environmental impact, including detailed analyses of its annual energy consumption, heating and cooling loads, and other relevant factors. These analyses help the architect in recommending suitable energy-efficient materials. This is not to mention such packages as IESVE, which can be useful to help architects meet certain standards such as CISE, LEED, ASHRAE in their design decisions. Agreeing with Hossein (2019), the above submission suggests that the capabilities of the BIM methodology in architecture can be demonstrated at the seven stages of design; representation; documentation and information management; inbuilt intelligence; analysis; simulation tool; and collaboration and integration.

Furthermore, three-dimensional (3D) printing has been enormous in architectural practice allowing designs to be created and printed in detail, influencing creativity. In the view of Nasir (2022), ideas can easily be appreciated inside the design creation process without embarking on a lengthy design process. The use of 3D printing technology in architecture has progressed from scale modeling to a full-sized finished product (Selcuk and Sorguc, 2015). Before the invention of 3D printing, architectural models were made of cardboard, wood, and other materials, which is time-consuming and resource-demanding. However, the following benefits have been made available by 3D printing. One is that building and construction components manufacturing on-site and off-site is now possible (Tay et al., 2017). Two is that construction 3D printing technology has helped fabricate houses and construction components such as columns, cladding and structural panels. Three is that 3D printing technology has been quite helpful in building under challenging situations where human labor appears impossible, especially in areas with peculiar conditions (Camacho et al.,2018). More recently, this technology has been applied in interior architecture with no limit to creativity. Also, architects are no longer restricted to delivering imaginations with technical limitations due to the greater design flexibility provided by 3D printing. Besides these advantages, this additive manufacturing technique has helped save time as what would take days or weeks as characterized by the typical methods is now possible within hours. Architects do not necessarily have to be restricted by the materials or resources available in the market because material selection is gradually but steadily becoming a key part of the interior design process.

In summary, in the architecture industry, the technologies' impact has proven to be valuable for several reasons. Firstly, it enables architects to showcase complicated designs in greater detail, allowing clients to visualize and better understand their proposed project. Additionally, architects can experiment with different materials and colors to test their design's visual and functional properties. Furthermore, 3D printing technology can help with time management by allowing architects to quickly produce and modify prototypes before moving on to the final project. This can save time and money by reducing errors and minimizing the need for rework. Lastly, 3D printing technology allows for duplicating finished 3D models, making it easier for architects to communicate their designs to stakeholders and collaborate with other professionals. This can lead to better decision-making and more efficient project management.

- **Civil engineering**

The civil engineering profession has witnessed great impact of construction 4.0 technologies. Similarly to architectural practices, civil engineers have maximized the use of BIM applications in preparing and documenting structural drawings. The huge data generated by these applications have been very useful in presenting finished work to clients. Also, usually time consuming calculations are now carried out by these BIM applications. These various technologies have also been useful for civil engineering works on site, delivering quality and value within the minimal possible time. Also, it is important to note that these technologies have not only been applicable in new development but have also been widely used in existing infrastructures. However, the digital twin is one of the major technologies that has continued to gain prominence with potential impact in the civil engineering profession (Pregnolato et al., 2022). In 2019, the global market was valued at USD $3.8bn which is expected to go up to about USD $35.8bn by 2025 (Evans et al., 2020). Future projection suggests that at least 60 per cent of large industrial companies will be deploying at least one digital twin in the next decade (Costello and Omale, 2019). This is despite the inadequacy in terms established protocols and standards that could result in a common narrative and guidance (Enzer et al., 2019)- a situation which is responsible for continued conversation between the industry and academia to arrive at a common definition for the technology especially for existing infrastructure with less digital attributes than newly built (Arup, 2020). According to Centre for Digital Built Britain, CDBB (2020) and Pregnolato et al (2022), it is a process whereby assets, systems, and processes are digitally represented realistically with a defining characteristic of a data connection between the real world and its digital representation. Conceptually according to Jones et al. (2020), the digital twin comprises three corresponding parts: the physical entity (the real-world object) set in the physical environment; the virtual entity set in the virtual environment; and a two-way link that connects the two entities.

Though still at its prototype stage in terms of application, digital twin, which provides access to both as-built and as-designed models, could begin to have impact using individual assets as an example in the following ways. One is preventing catastrophic occurrences by tackling chronic stresses of aging infrastructure and unexpected acute shocks (CDBB, 2020). Two is improved monitoring and whole-life management of bridges and dams. According to Ye et al. (2019), such applications for bridges could result in efficient data queries, integrated data processing capabilities, and a single collaborative platform through the lifecycle. There is the potential of digital twin to enhance the maintenance system of a typical bridge structure as noted by Dang et al. (2018), Shim et al. (2019) and Shim et al. (2019) using a high-level framework. Ye et al. (2019) supported this possibility, who provided an overview of the necessary capabilities needed for a digital twin of two railway bridges to conduct an early-age behavior assessment for structural health monitoring purposes. Four is the digital twin-enabled anomaly detection for built asset monitoring in operation and maintenance (Lu et al., 2019; Lu et al., 2020) which was demonstrated by developing a process flow and a pilot for circulating pumps in the HVAC system of a building.

Other potential areas of digital twin in civil engineering as documented by Pregnolato et al (2022) include: energy performance and carbon emission reduction (Alonso et al., 2019; Francisco et al., 2020); management of drinking water distribution networks (43); sustainability assessment of infrastructure (Kaewunruen and Xu, 2018); ground resistance model for liquefaction risk assessment (Song and Jang, 2018). In civil engineering, a digital twin is a virtual replica of a physical infrastructure asset, such as a bridge, road, or building. It is created by combining data from various sources, such as sensors, geographical information systems (GIS), and building information modeling (BIM).

Digital twins in civil engineering can simulate various scenarios and conditions, including environmental factors, structural performance, and maintenance needs. This can help engineers and construction teams to identify potential issues early on in the planning and design phases, and to make more informed decisions about the design, construction, and maintenance of infrastructure assets. For example, digital twins can be used to monitor a bridge's structural health, using data from sensors to identify signs of wear and tear or potential failures. This information can be used to plan maintenance and repair activities, and to reduce the risk of accidents or disruptions to traffic.

Digital twins can also be used to simulate the performance of a building in different weather conditions or under different loads. This can help to optimize the design of the building for energy efficiency, comfort, and safety.

Overall, digital twins in civil engineering have the potential to revolutionize the industry by improving the design, construction, and maintenance of infrastructure assets, and by enhancing safety and efficiency.

- **Quantity surveying**

Construction 4.0 through BIM has found a variety of applications in the quantity surveying profession as documented by various scholars (Kulasekara et al., 2016) with interconnected impacts in accuracy, cost efficiency, time, and quality of construction projects. This has not only been tested in developed countries but also in developing countries (Ismail et al., 2017). In fact, what distinguishes the uptake of BIM from the traditional approach is how it enables visualization of spatial information and the possibility of further analysis due to the huge database it provides. BIM helps to enhance the accuracy and reliability of output at the conceptual stage of work and supports the documentation of project performance over the project life cycle (Alhasan et al., 2019). Also, budgets can now be more reliable with fewer errors in the measurement of quantities due to the level of detail that has been made available by BIM technology. This has further led to more reliable working practices among Quantity Surveyors (Ismail et al., 2019).

The data generated by BIM has been useful in cost analysis and construction project estimation. According to Forgues et al. (2012), this enhances the delivery of high-quality project because the effectiveness of the BIM decreases the risk factors associated with inaccuracies typical of the traditional quantity take-off methods. It is noteworthy that this is also done within the shortest possible time, besides the accuracy that it brings. BIM has also been quite useful in assisting Quantity Surveyors by providing information about the building lifecycle alongside completed design documents which can easily be shared and accessible by team members working on the project. In summary, the impact of BIM in Quantity Surveying at both pre- and post-construction stages is illustrated in Figure 22.3 adapted after Wong (2014).

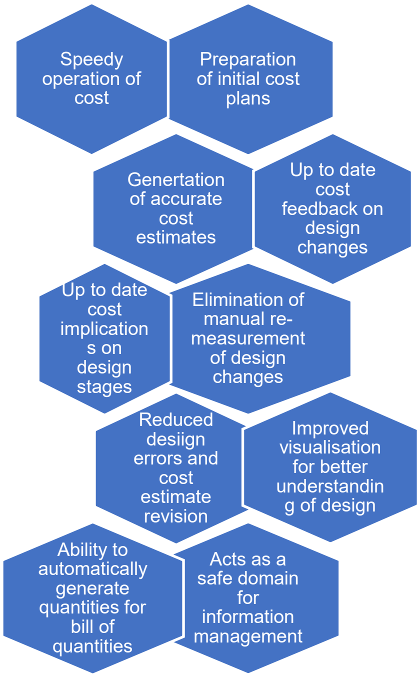

Figure 22.3 Implications of BIM in Quantity Surveying Profession

- **Real estate**

Although the Industry 4.0 technologies such as BIM has been widely applied and developed by the architecture, engineering, and construction (AEC) sector to help in design management and construction data, other professions such as real estate have benefited immensely from the used data within, or that is linked to BIM models (Wilkinson and Jupp, 2016). It is important to note that the data can be useful when assessing the sustainability potential of a property and its overall rating when evaluated against the standard of assessment frameworks such as BREEAM, LEED, or Green Star. According to El-Gohary (2010), this has the potential to add value to the property. With the data as well, clients and residents can better be informed about the social, environmental, and economic costs and benefits of the property which could guide in their decision-making when considering various options.

With BIM methodology, it is now easier and more efficient to have an overview of the lifecycle management of a building. It provides the anticipated operating costs of the building from the cradle to the grave. According to HM Architects (2019), this information enables estate and facility managers to make decisions that would contribute to cost savings while ensuring simpler future building maintenance.

The real estate industry is no exception and is already experiencing the benefits of Industry 4.0 technologies. Here are some ways in which Industry 4.0 technologies are transforming the real estate industry:

- Smart buildings: Smart buildings use IoT seBIM’s easy communications usage, temperature, and other metrics to optimize energy consumption, improve comfort levels, and reduce operating costs.
- Virtual and augmented reality: Virtual and augmented reality technology allows real estate developers to create immersive, realistic experiences for prospective buyers and tenants, enabling them to visualize the space before construction even begins.
- Building information modeling (BIM): BIM is a digital representation of a building that includes detailed information on every aspect of its design and construction. BIM can be rove collaboration between architects, engineers, contractors, and other stakeholders, reduce errors and rework, and optimize building performance.
- Drones: Drones are increasingly being used in the real estate industry for site surveys, inspections, and to capture aerial footage for marketing purposes.
- Blockchain: Blockchain technology can facilitate real estate transactions, track property ownership, and streamline the buying and selling process.

Overall, Industry 4.0 technologies are transforming the real estate industry by improving efficiency, reducing costs, and enhancing the customer experience. As these technologies continue to evolve, we can expect to see even more innovations in the real estate sector in the years to come.

- **Construction management**

BIM leads to faster project completion because it now takes less time to deliver the design which allows construction process to start earlier than when there was no such provision. The construction managers also benefit from BIM’s easy communication with the design team, developers, and clients.

Also, BIM contributes to the overall quality of the design delivery. This is because, from the project's inception, building contractors can identify the position and placement of every element such as windows, floors, doors, and insulation, that would enhance the building to perform most efficiently. Additionally, contactors can now spot mistakes which would be helpful to reduce the risk of repair cost later in the project phase.

In addition to the BIM methodology, which is very useful at the pre-construction stage, the evolution of smart construction site is one of the key elements of construction 4.0. This has been widely applied in construction management. A construction site can be considered smart when equipment and workers can be continuously tracked near real time (Hammad et al., 2012). Beyond this, it also encompasses the adoption of automated machines connected to cloud data whereby these machines (or robots) would be able to carry out task with less human intervention or support (Osunsanmi et al., 2020). This, on its own, can address the challenge of staff shortage being witnessed in the construction industry, ensuring timely delivery of projects. Recently, the use of drones has been introduced to construction site, whilst other aspects that contributes to a smart construction site such as prefabrication, internet of things, radio frequency identification (RFID), automation and product lifecycle management, have continued to aid the construction process (Akanmu et al., 2013). Besides timely delivery of projects and resource management, RFID, which is the most popular, has resulted in reduced hazards on site because the activities of construction workers can now be easily monitored. As a key aspects of a smart construction site, it also contributes to management of construction quality information, material supply information and promoting collaborative working (Zhou et al., 2018). Smart construction sites rely on several key aspects to optimize the construction process and improve outcomes. One of these aspects is managing construction quality information and material supply information. By implementing smart technologies such as sensors, drones, and other Internet of Things (IoT) devices, construction teams can gather real-time data on various aspects of the project, including quality control measures and material inventory levels.

This information can then be shared with stakeholders and team members in a collaborative working environment, helping to improve communication and decision-making throughout the construction process. For example, if a quality issue is detected, the team can quickly identify the source of the problem and take corrective action to ensure that the project stays on track. Smart technologies can also facilitate the tracking and managing material supply information, including orders, deliveries, and inventory levels. This can help construction teams ensure they have the right materials at hand at the right time, reducing delays and other issues that can arise when material supply needs to be managed effectively.

By leveraging smart technologies to manage construction quality and material supply information, construction teams can improve efficiency, reduce waste, and ultimately deliver higher-quality projects on time and budget.

SUMMARY

To achieve building resilient infrastructure, advancing sustainable industry, and encouraging innovation requires people, process and technology in the construction section to be integrated. Building Information Modeling paradigm was an initiative that through Lean Management show the capacity of elaborating Lean and BIM from a more conceptual and sophisticated perspective. Hence, to achieve targets such as: development of sustainable resilient and inclusive infrastructures; promoting inclusive and sustainable industrialization; increasing access to financial services and markets; upgrading all industries and infrastructures for sustainability; enhancing research and upgrading industrial technologies; facilitate sustainable infrastructure development for developing countries; support for domestic technology development and industrial diversification; universal access to information and communications technology, it requires the architecture engineering construction and operation (AECO) sector to be ready on how technology integration within projects and enterprises could be linked and the aassociated benefits.

According to Hill (2010), the uptake of new technology is heavily influenced by the three factors of perceived benefits, external forces, and internal readiness. Undoubtedly, these need to be addressed to ensure the uptake of BIM and other construction 4.0 technologies in both developed and developing countries context. Internal readiness is driven by technology know-how and support from the top management team. On the other hand, the key external forces are the government political will and the push from the market (software developers) for BIM. Both organizations and government have a great role to play in driving the adoption of construction 4.0 components not only to achieve SDG9 but to deliver on resource efficiency and carbon reduction. Organizations need more organization support by providing the enabling environment for this to thrive in their operations. In addition, top management team members need to be more receptive to change and seek knowledge of construction 4.0 where necessary. For instance, Parida et al. (2010) showed that managers' awareness and understanding of the BIM methodology greatly influence its uptake in their organizations. The quantity surveying profession appears to be the most affected in this aspect as argued by Gilchrist (2021) who noted that Quantity Surveyors are reluctant to adopt the BIM methodology but would prefer to follow the traditional method which appears to be because of inadequate understanding of the potential uses and benefits that BIM offers. This does not only affect BIM but also extends to other digital technologies such as Aritifical Intelligence, Virtual and Augument Reality and the use of drone amomgst others.

Whilst the construction 4.0 market has continued to grow with companies like Autodesk facing healthy competition from other software developers such Glodon prominent in China used for engineering quantity claculation, what appears to be a critical challenge in the global drive for SDG9 is the cost of the BIM packages in most developing countries where it is still being sold in foreign currencies suggesting a need for indigenous software companies in those countries. Additionally, New areas such as the digital twin that are currently being explored in civil engineering also have some key barriers that need to be addressed. Besides, the high level of complexity, there appears not to be a definition of a unified process (Pregnolato et al., 2022).

This chapter has attempted to explore how the uptake of construction 4.0 technologies could be a suitable platform for achieving SDG9 in both developed and developing countries. Whilst some of the impacts and benefits that construction 4.0 technologies brings are already appreciated in the industry, there are potentials which have only been explored theoretically especially in digital twin. With continued knowledge sharing, awareness, willingness to change, learning from demonstration projects, there is more that can be expected from construction 4.0 in delivering SDG9.

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