A Study of Smart Construction Based on the Digital Twins

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Abstract. Nowadays, with the rapid development of technology in the world, the debate over the concept of metaverse has exploded, while various new technologies, concepts and scenarios geared towards metaverse have emerged and various industries are making their presence felt. The digital twin has also become one of the core technologies for building metaverse. The digital twin, it can be argued, is the closest technology to comprehending the metaverse, and it provides the best technical support for the digitisation of architecture and cities. Originating from digital design, virtual simulation and the industrial internet, the digital twin as a concept that transcends reality is essentially a simulation process that brings together multiple dimensions and disciplines by playing with data from multiple aspects, including physical models and sensors, to map reality in virtual space, thus corresponding to the full lifecycle of an entity. This paper examines the application of the digital twin in smart construction and its advantages and disadvantages, and analyses the research topic through a case study approach, thus illustrating the significance of the digital twin for smart construction. The paper also concludes that the digital twin has the advantages of accurate mapping, interaction between reality and reality, and intelligent intervention in the construction industry, but also has certain shortcomings in terms of data awareness and software.

Keywords: Digital twins · construction engineering · building systems · smart construction

1 Introduction

With the development of technology and the economy in recent years, concepts such as the Internet of Things and meta-universe have become big hits. And in the field of engineering and construction, the concept of the digital twin has gradually come into the limelight as the theory develops and matures. The digital twin is a concept within the Internet of Things that refers to the creation of a digital simulation within an information technology platform by integrating physical feedback data and supplementing it with artificial intelligence, machine learning, and software analysis. This simulation will automatically change accordingly to the physical entity based on the feedback. Ideally, the digital mapping could learn itself based on multiple feedback sources of data, thus rendering the real state of the physical entity in the digital world in almost real time.

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This paper analyses the use of digital twins in smart construction through a case study approach, thus illustrating the role of digital twins in smart construction. The application of the digital twin in smart construction will facilitate the transformation and upgrading of the construction industry at home and abroad and will be beneficial for practitioners in the construction industry to efficiently and comprehensively simulate and control the whole life cycle of a building, from design and construction to use.

2 Construction Engineering with Digital Twins

2.1 History of Construction Engineering

The construction industry was the first to use manual drawing and construction of houses after the advent of civilisation. It was not until 1959 that the first computerised drafting system was created in the USA that computer-aided design technology with some simple drafting functions began to emerge, the earliest concept of computer aided design. By the mid-1980s, with the introduction of microprocessors and storage devices, CAD technology was gradually becoming more widespread and developing towards standardisation, succession talk and intelligence. The concept of building information modeling was first introduced by Dr. Chuck Eastman in 1975. BIM technology is a data-based tool applied to engineering design, construction, and management. Through the integration of data-based and information-based models of buildings, it is shared and delivered throughout the entire life cycle of project planning, operation and maintenance, enabling engineers and technicians to make correct understanding and efficient responses to various building information. This provides a basis for design teams and all construction entities, including construction and operation units, to work collaboratively and play an important role in improving productivity, saving costs, and shortening schedules. But it was not until 2002 that the concept and technology was officially introduced by Autodesk, and has been in rapid development since 2011.

2.2 The Concept of Digital Twins

The concept of digital twins (as shown in Fig. 1) can be traced back to a presentation given to industry by Professor Michael W. Grieves at the University of Michigan PLM Centre in 2002, but from the written evidence, the digital twin was explicitly proposed by the US Air Force Research Laboratory in March 2011, and the concept was first introduced by the US Air Force Research The labs pinned their hopes on solving the maintenance problem of fighter airframes [1].

The digital twin, also known as the "digital twin", is the mapping of the structure, state, behaviour, function and performance of complex physical systems such as industrial products, manufacturing systems and cities into a digital virtual world, and the portrayal, prediction and control of physical systems through real-time sensing, connection mapping, accurate analysis and immersive interaction, realising the fusion of reality and reality in complex systems and maximising the closed-loop optimisation of the whole system element, process and value chain. The theoretical system can be applied in numerous fields, including product design, product manufacturing, medical analysis and engineering construction.

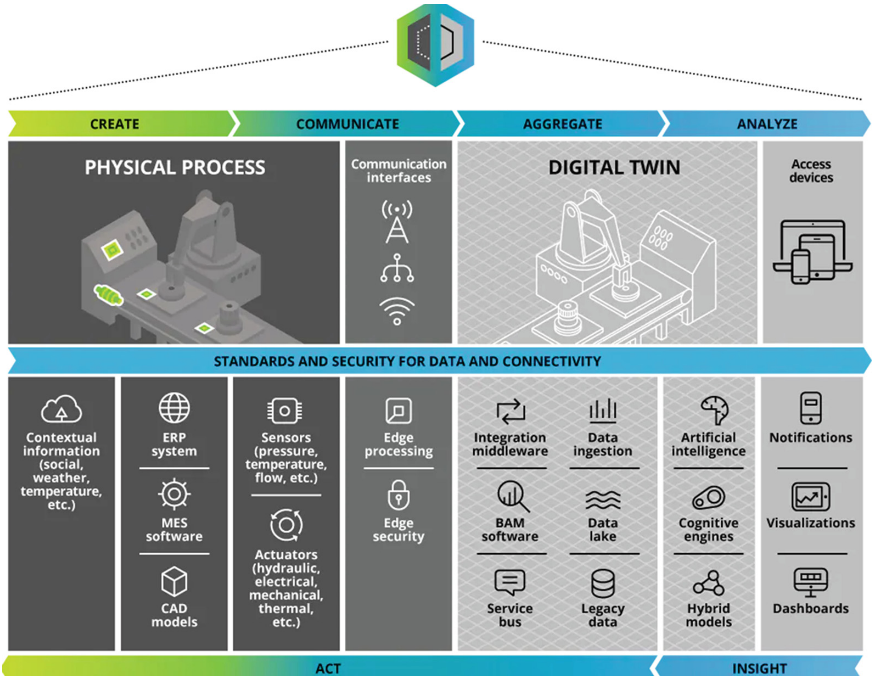

Fig. 1. Digital twin concept architecture [1] (Aaron, P., and Lane, W. Industry 4.0 and the digital twin, 2017, Licensed by the author)

As early as the Eastern Han Dynasty, the first digital twins (or sandboxes) were already on the scene and were widely used in military strategies for warfare and the construction of cities. Even today, engineers often use sandboxes to simulate construction projects as a way to achieve a dynamic simulation of the physical project. This approach not only avoids the impact on the real thing, but also saves costs and increases efficiency and reduces the probability of many errors.

In short, the digital twin is a whole process that involves transferring everything that happens in the actual world into digital space for purposes such as product design, production layout, process simulation, yield optimization, and so on [2].

3 Development Trends and Industry Pain Points

3.1 Industry Development Trend

The construction industry has always been a pillar industry of a country. The data shows that since 2010, the added value of the construction industry in China and the United States has basically shown a steady growth trend, while at the same time, the growth of the construction industry in other countries has not been significant, and even declined to varying degrees in some periods. Condition. In some developed countries such as the United States, France, Germany, and Japan, the average urbanization rate is about 80%. In the process of its development, the construction industry has shown a steady growth trend in the process of increasing urbanization from 60 to 80%. In the process of gradually becoming saturated, the construction industry of these countries gradually began to optimize and upgrade the structure within the industry, and the investment remained stable and conservative [3].

3.2 Low Carbon Requirements

At present, no matter which country or industry in the world, all are committed to implementing the environmental protection goal of low-carbon energy-saving, so that all fields can further enter the low-carbon model, so as to achieve higher quality development. As a project with a long cycle, high cost and large carbon emissions, construction projects have always faced unprecedented challenges in the transformation of energy conservation and carbon reduction [4]. As far as China is concerned, data show that its current annual carbon emissions from new construction projects once reached nearly 20% of the total emissions, which involves a series of processes such as the production of steel, glass, cement and other building materials.

3.3 Impact of the Epidemic

Since the outbreak of the new crown virus in late 2019, economic markets around the world have suffered unprecedented setbacks. The construction industry, as an old-fashioned secondary industry, has gone through unprecedented hardships. For example, it is difficult for construction workers to arrive at their posts, a substantial increase in project costs; delays in project progress; and difficulties in epidemic prevention and control [5].

3.4 Digital Development

Today's world is in the midst of a major transformation from an industrial economy to a digital economy. Informatization, digitization, and the Internet of Things have become important boosters for global economic and social development. As can be seen from the McKinsey Global Institutional Industry Digitization Index, the digitalization of the construction industry ranks at the bottom (Fig. 2) [6]. However, with the rapid growth of the construction industry and the large-scale and complex construction projects, good and effective data and communication channels have become more important than ever.

4 The Application of the Digital Twins

Whether it is low-carbon energy efficiency, the impact of the epidemic or the general direction of digital development, these forms of development are forcing the construction industry to make the right decisions and transformations when the time comes. In some regions, however, there are already many practical examples of how to address these issues. The following are a few examples that address the above-mentioned issues in the construction industry.

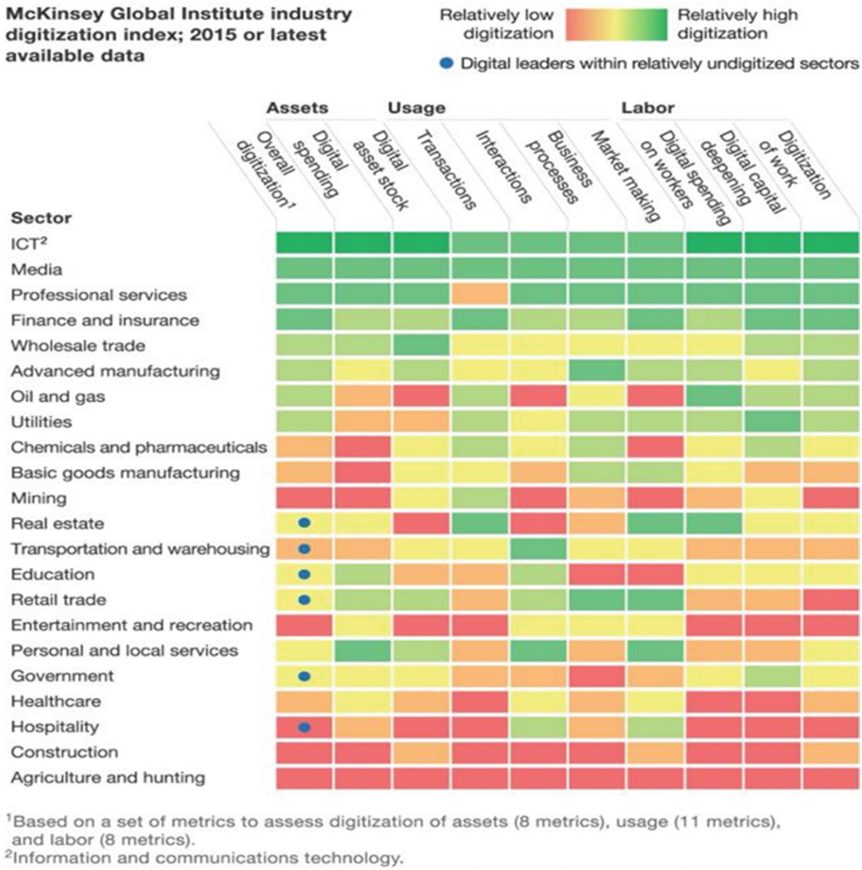

Fig. 2. McKinsey Global Institutional Industry Digitization Index [6] (Rajat, A., and Shankar C., and Mukund. Imagining construction's digital future, 2016, Licensed by the author)

4.1 Stadium Smarts

The 2022 Winter Olympics in Beijing will not only be a world-renowned sporting event, but the venues and technologies of the Winter Games will also be in the spotlight. Among them, the low-carbon and smart sports buildings are a real eye-opener. Firstly, the China National Speed Skating Stadium, known as the "Ice Ribbon". The stadium not only brings together the best technological achievements from various countries at the most basic level of building materials to significantly reduce carbon emissions, but also uses digital twin technology to transform the stadium itself into an intelligent platform that can feel, breathe and think [7]. This means that not only are there various IoT sensors in the building, but also a built-in super brain to monitor and collect data such as air quality and light levels. There is also a digital simulation of the arena on the cloud, which can accurately and quickly make judgments based on different situations and requirements, and take appropriate measures to adjust the ice system, dehumidification system of the

Table 1. Olympic profits over the years (Original)

Year held	Host country	Host city	Earnings($ million)
1988	South Korea	Seoul	49,700
1992	Spain	Barcelona	4000
1996	United States	Atlanta	1000
2000	Australia	Sydney	36,750
2004	Greece	Athens	−100,000
2008	China	Beijing	1600
2012	United Kingdom	London	Total output £28–41 billion
2016	Brazil	Rio de Janeiro	−130,000

venue, etc. to ensure a good experience for all events. The use of these technologies has gone some way to reducing the stadium's huge carbon footprint.

The operation of the stadiums during the games is only part of the equation; it is the disposal of the stadiums after the event is over that really needs to be considered. After all, the buildings typically last for decades. The profitability of the Olympic Games has varied over the years (see Table 1), and the 'Montreal trap' of stadiums after the Games is a worldwide problem that is difficult to solve at this profit hurdle.

The city of Montreal, Canada, which hosted the 21st Olympic Games in 1976, overspent its budget by US$124 million to US$1.5 billion, with the venues accounting for 70% of the cost, creating a financial burden for Montrealers that lasted for over 20 years, resulting in the city's poor and dilapidated municipal facilities and its inability to improve them, and hence the "post-games wasteland" of Olympic venues. This has led to the city's crumbling municipal facilities and its inability to improve them. However, the 2022 Beijing Olympic Winter Games will use some of the land and urban infrastructure from the 2008 Games while using six Olympic venues from the 2008 Games, a move to reuse resources that will significantly reduce the total carbon emissions of this sporting event. In addition, on the post-operational aspects of the 2022 Beijing Winter Olympics, the authorities said they will continue to use digital twin technology to keep the venues running with low energy consumption. The venues will be put into operation after the facilities and other issues have been arranged to ensure maximum use of the venues and maximum energy efficiency, with the technology being put into operation for first-class events, visitor leisure and entertainment.

4.2 Facing up to the Challenges of the Epidemic

The second example is for the digital twin in terms of mitigating the impact of the epidemic. With the new challenges of transformation and upgrading in the construction industry, many large buildings are inefficient to operate and maintain, requiring huge labour and other costs. The collision between the transformation and the epidemic has not only made manual operations and maintenance less convenient, but has also forced the construction industry to look to digital twins to try to overcome this challenge [8].

From an urban management perspective, the digital twin of a building or an entire city can effectively assist in urban planning as well as the operation and maintenance of physical assets. The digital twin breaks the current state of fragmented and siloed information among the building's various business systems by deploying multi-functional IoT devices, smart gateways and edge computing nodes to collect information collected by the building's IoT and support integrated management after unified aggregation and processing to achieve dynamic data integration and sharing in the building. For example, the identification and preventive maintenance of physical assets or city networks can save time for subsequent corrective maintenance and minimise service interruption time due to any problems; the risk to the city due to adverse weather conditions can be reduced by simulating sunlight conditions. In 2018 Shanghai Pudong Lingang Smart City Development Centre started cooperation with a group of leading companies, including the Chinese Academy of Sciences, to build the Smart Lingang City Brain project. The project achieves data interoperability from government departments to enterprises to the internet in Lingang by building up Lingang's digital twin and building on the BIM big data platform [9]. Convergence of data resources from macro to micro across the city and analysis and processing. In terms of visual energy, thousands of roads in the main city of Lingang are connected to cameras, using the ability of the digital twin to monitor in real time, providing strong support in the city plagued by epidemics from the governance of traffic roads, security management, identification of social events and other issues, to a certain extent reducing the need for the urban building system in manual operation and maintenance, and facilitating the prevention and control of epidemics. In addition, the project is extremely powerful in terms of computing capacity. The project's digital twin city deploys massive heterogeneous computing resources such as CPUs and GPUs, and supports algorithm deployment of 1010 points.

4.3 The Digital Rise of the Xiongan New Area

The last example is for the case of digital twin promoting digitalization and informatization in the construction industry. From the approval of its planning outline in 2018 to its construction to date, the Xiong'an New Area has embraced the innovative concept of using digital twin technology smartly to create a smart city [10]. From the initial construction of the underlying database, the Xiongan New Area has been built with an intelligent platform that combines IoT, big data and AI. This is what gives the Xiongan New Area sufficient power for the digitalisation of its buildings. The superb data collection capacity, the huge data storage capacity and the flexible data processing capacity all make the construction of the Xiong'an New Area efficient and fast. Not only in terms of data processing, but also in terms of information control, the Xiongan New Area has created "one centre and four platforms" (the "one centre" refers to the Xiongan Urban Computing Centre, and the "four platforms" include a block data platform, an IoT platform, a video platform, and a CIM platform). This is the basic urban architecture of the core intelligent building. This allows the Xiongan New Area to have not only a physical building entity, but also a digital virtual city on the cloud through digital twin technology. The construction of the Xiongan New Area truly starts from a digital twin perspective, completely solving the problems of incomplete, inefficient and error-prone traditional data collection in the construction sector. It also creates a new way of integrating, digitising and platforming building construction and operations.

4.4 Discussion

From the three case studies above, we can see that the digital twin has been of great benefit in mitigating and even addressing the construction industry in terms of energy efficiency, low carbon, epidemic and digital development. At a time when the construction industry is facing the challenges of transformation and upgrading, the digital twin brings promise to the construction industry.

But overall, digital twin technology is still in its early stages. Digital twin technology requires full domain awareness, operational monitoring, and the integration of historical accumulated data for computing, as well as fast and timely output of information, which is highly dependent on the data and information collected by sensors in the first place.

In terms of data perception, accurate full-domain perception of machines in factories, not to mention other areas, is still difficult at the current state of the art. Data from physical entities is not detailed enough, so digital copies can be missing, which can lead to biased predictions and judgments obtained from digital copies. The solution to this problem requires technological advances such as chips, sensors, and the Internet of Things.

Secondly, in terms of software, more advanced algorithms are needed, as well as the integration of various types of software, such as the use of artificial intelligence, edge computing and other technologies to analyse and process data more quickly and to visualise and present it.

The current bottleneck of digital life technology comes from various aspects, and it is still difficult to apply it on a large scale, but it can bring unlimited possibilities for industrial manufacturing and future life. However, it can bring unlimited possibilities for industrial manufacturing and future life. Along with the development of other technologies, the digital twin will have even more scope for imagination.

5 Conclusion

The digital twin, a future star of the construction industry, may eventually become a common tool for operating and managing an office or apartment building. But there is no doubt that many more countries and universities will be involved in this direction. Digital twins can be used for building operations and optimising efficiency, but more importantly, they can create value through predictive analysis of building data. However, as far as research is concerned, digital twins are not yet ready for use, not least because the built environment is changing rapidly and engineers are now addressing this issue.

The author's lack of breadth of vision in writing this paper may have missed some of the pain points in the construction industry that digital twins can address.

In short, the digital twin is the future of facilities management. As this technology becomes more prevalent and is integrated early in the building process, more and more facility managers will be able to proactively interact with building data. By integrating data, facilities managers will find their role shifting from being reactive to being more of a curator of management optimisation and implementation. At the same time, the buildings that facilities managers oversee will become healthier, safer and smarter. Ultimately, people's living environments and quality of life will change, and ultimately, cities and countries and regions will become smarter, more scientific and more pleasant thanks to digital twin technology.

Acknowledgments. I hate to use the book, but I regret that I am late in reading. Writing a thesis is an arduous and challenging process. Looking back on the past writing process, I am grateful that I was able to persevere through the pain and that all the hardships were worth it.

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