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Digital Design and Fabrication: Transforming Civil Engineering Excellence

10 April 2024 | Technical Topic Webinar

Presented by:

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EIT Lecturer & Civil Engineer

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Introduction - Presenter

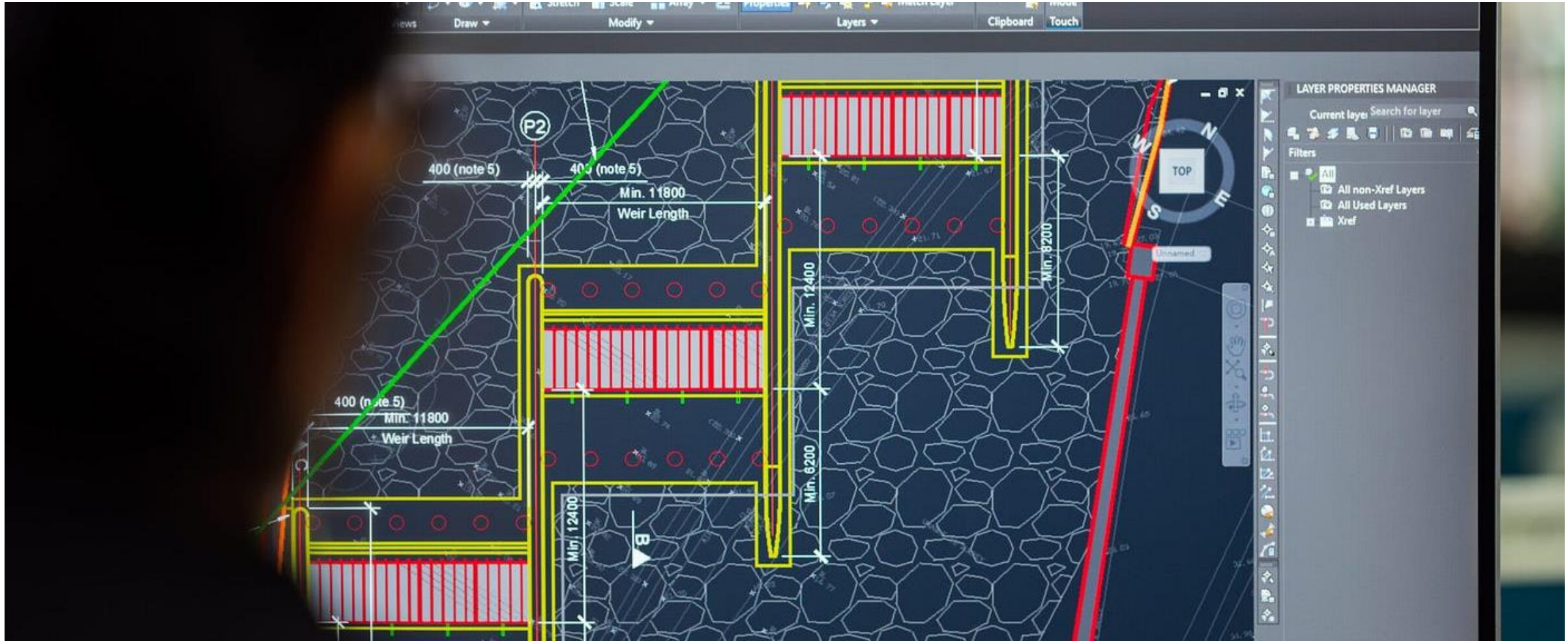
Dr Karoline Figueiredo is a dedicated professional with a robust background in sustainable construction and environmental engineering. She holds a bachelor's degree in Civil Engineering and a Master's in Environmental Engineering from the Federal University of Rio de Janeiro (UFRJ), Brazil. Besides, her Ph.D. focused on leveraging Digital Twin and Blockchain technologies to drive sustainability in the built environment.

Throughout her academic journey, Karoline served as a Visiting Researcher and Visiting Lecturer at renowned institutions globally. Her international experience includes conducting research at Universitat Rovira i Virgili in Spain and Western Sydney University in Australia, contributing significantly to the field of life cycle assessment of construction materials. Specializing in Building Information Modeling (BIM) and Life Cycle Sustainability Assessment (LCSA) methodologies, Karoline develops innovative solutions, utilizing her comprehensive understanding of these tools to navigate complex projects and implement sustainable practices effectively. Beyond her research achievements, Karoline works as a lecturer at the Federal University of Rio de Janeiro (UFRJ), Brazil, and at the Engineering Institute of Technology (EIT), Australia, where she conducts lectures and tutorials for Higher Education (HE) and Vocational Education and Training (VET) Programs.

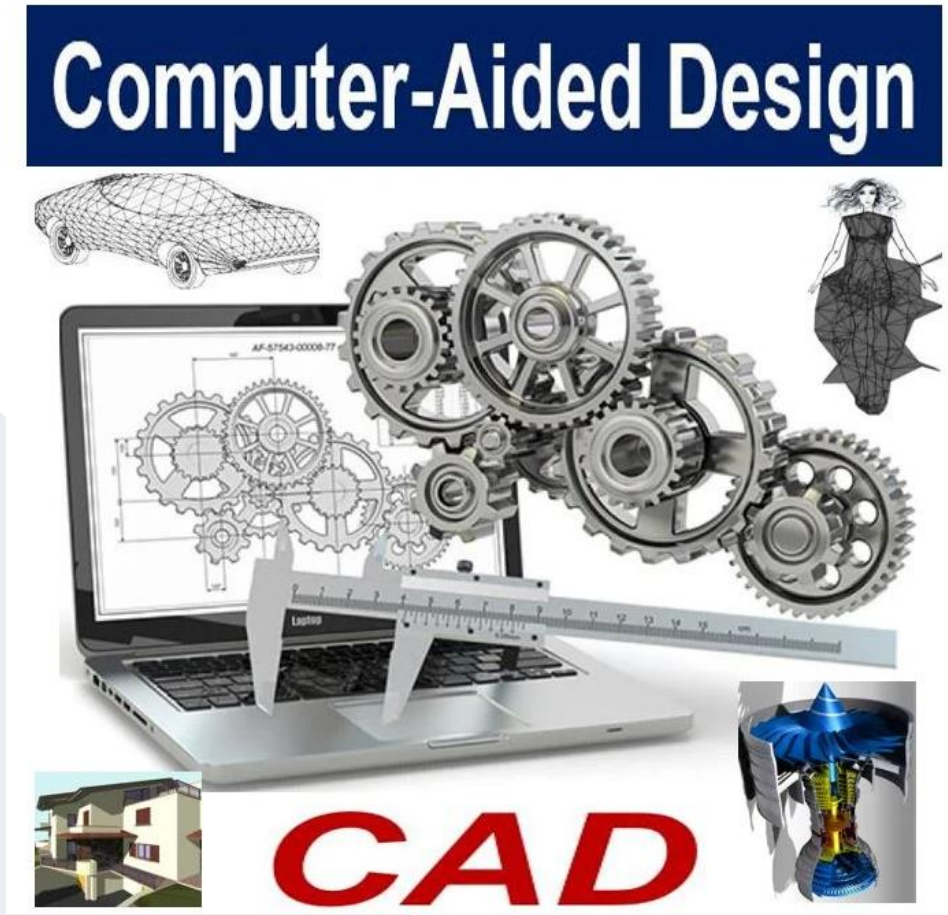
Agenda

1	Welcome and Introduction
2	Digital Design Tools in Civil Engineering
3	Advanced Fabrication Techniques
4	Digital Twins in Civil Engineering
5	Blockchain Technology in Civil Engineering
6	Strategic Implementation
7	Conclusion and Q&A

Digital Design Tools



Digital Design Tools



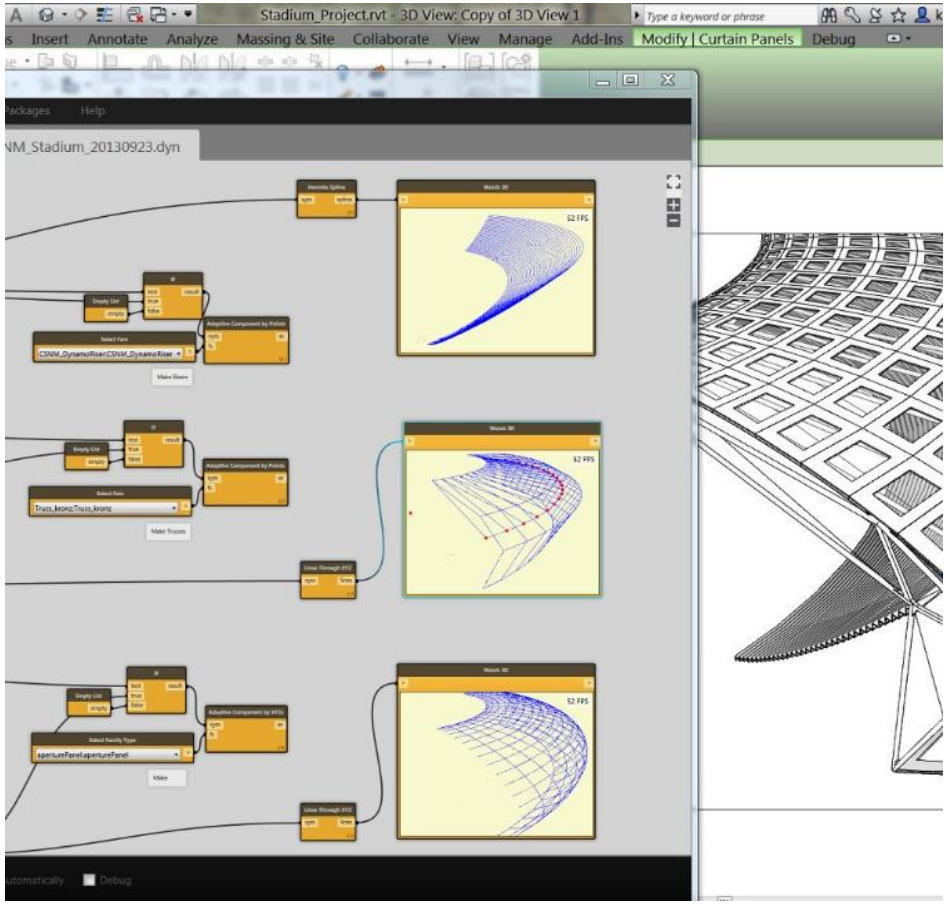
Digital Design Tools

Importance in Enhancing Design Efficiency and Precision

Digital design tools play a pivotal role in enhancing design efficiency and precision in civil engineering projects through various mechanisms:

1. Iterative Design Process;
2. Visualisation and Simulation;
3. Collaboration and Communication;
4. Integration with Construction and Fabrication Processes.

Digital Design Tools



Material-based computational design

Over the last decade, information technologies have had a significant impact on the Architecture, Engineering, and Construction (AEC) industry, leading to a new relationship between construction materials and architectural design.

In this way, the **material-based computational design** concept emerges. Computation Design (CD) involves the use of computation to develop designs, which is not exactly the same as **Digital Design** (*i.e., the use of computer tools in the design process*).

For instance, using a computer-aided design (CAD) application as a drafting tool without explicitly using computation is an example of Digital Design that is not CD.

Advanced Fabrication Techniques

- Advanced fabrication techniques leverage digital technologies to revolutionise the way structures and components are manufactured in the field of civil engineering.
- These techniques offer unprecedented levels of precision, customisation, and efficiency, allowing engineers to realise complex geometries and optimise material usage.
- Digital technologies play a crucial role in driving innovation across various fabrication processes, enabling the adoption of novel manufacturing methodologies and materials.
- Key advancements in this domain include **additive manufacturing** (e.g., 3D printing), **computer numerical control (CNC) machining**, and **robotic fabrication**.

Advanced Fabrication Techniques

Additive Manufacturing

A new topic that has been discussed worldwide is the use of **3D printing materials**, also known as **additive manufacturing (AM)**. This emerging technology has the potential to revolutionise the construction industry and represents the creation of components in a layer-by-layer manner from a digital file.

This technology can significantly reduce **construction costs**, **labor expenses**, **time consumption**, and **on-site injury rates**. Besides, by decreasing the amount of construction waste, additive manufacturing takes a significant step towards combating the threat of **global warming**, positively impacting society and the environment.

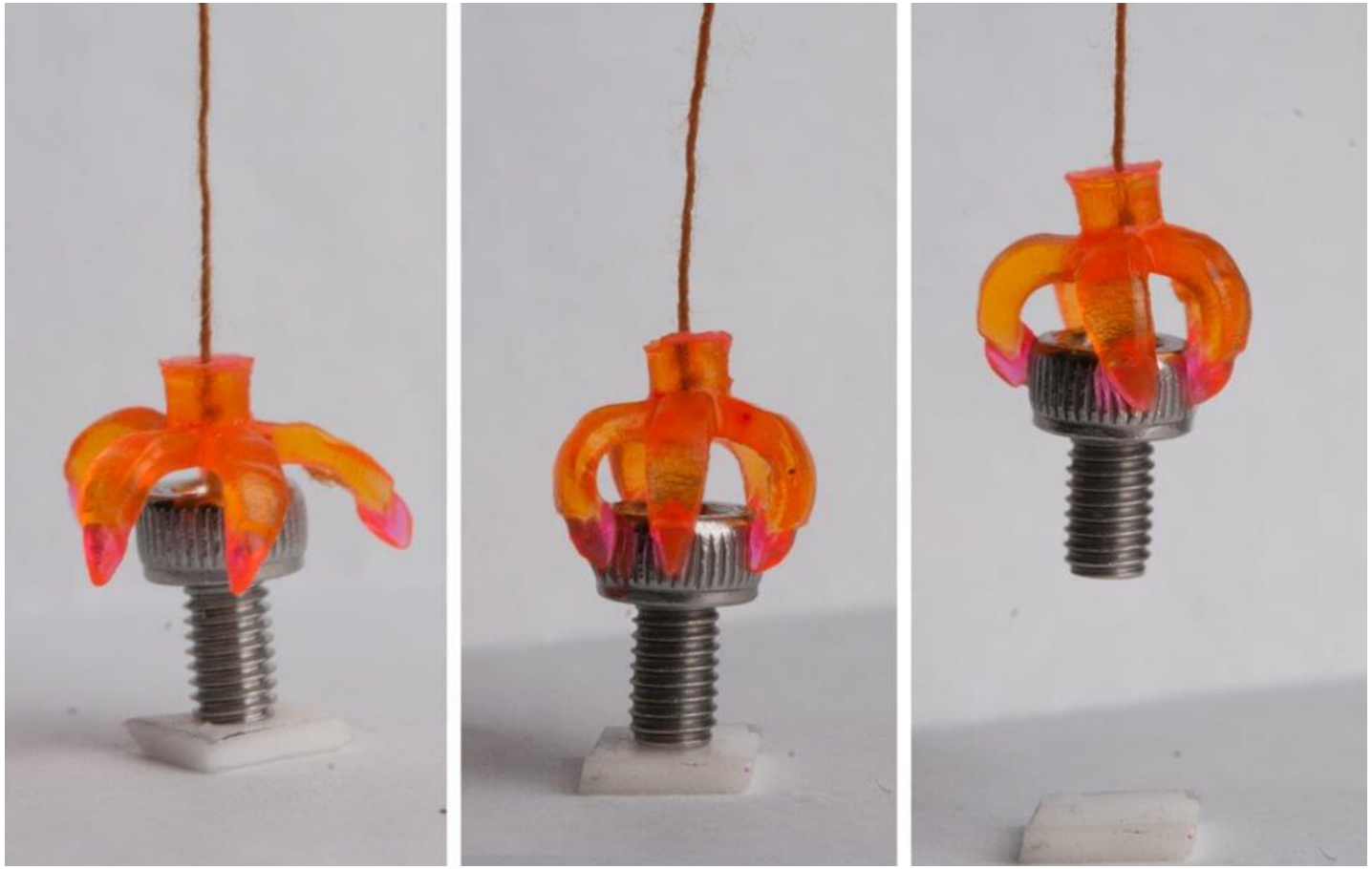
Advanced Fabrication Techniques

Multi-material 4D printing

The field of 4D printing is seen as a game-changing manufacturing technology that allows the creation of cutting-edge devices that can **adapt to their surroundings**.

This is achieved by combining additive manufacturing techniques with **active and passive materials** that can be influenced by an energy stimulus, resulting in components that can transform their properties, shapes, or functions.

By carefully programming the behaviour of those materials, designers can create structures that can self-assemble, change shape, or even repair themselves over time.



Prefabricated Construction

Prefabricated Modular Construction

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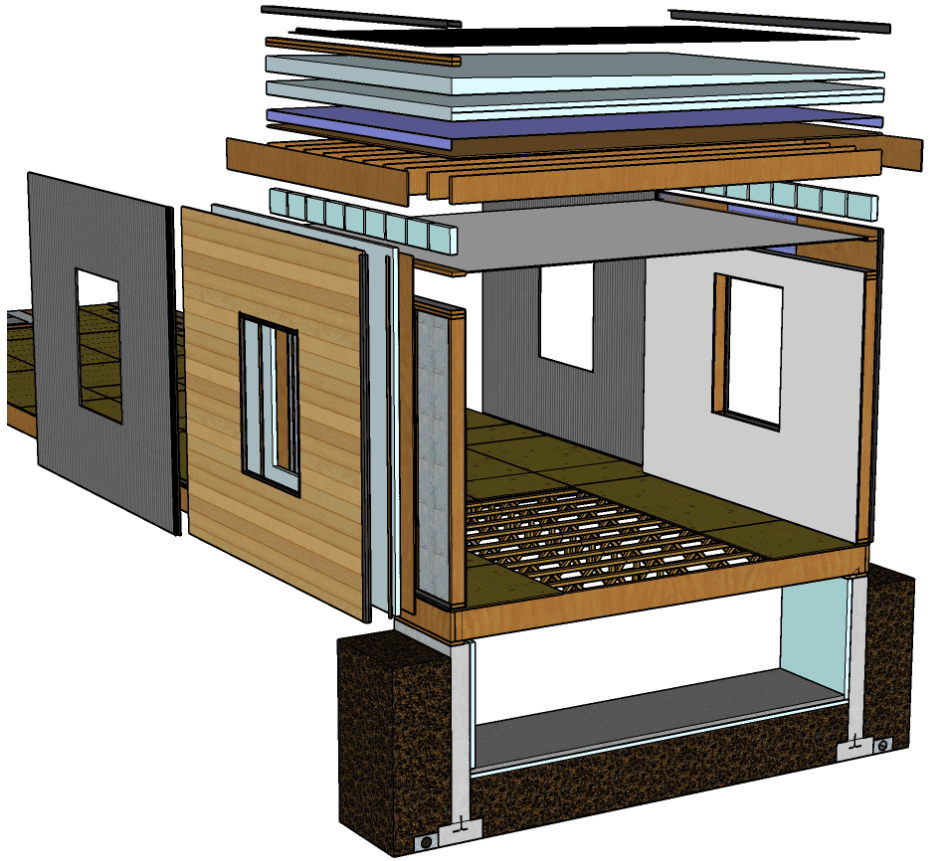
Prefabricated Modular Construction

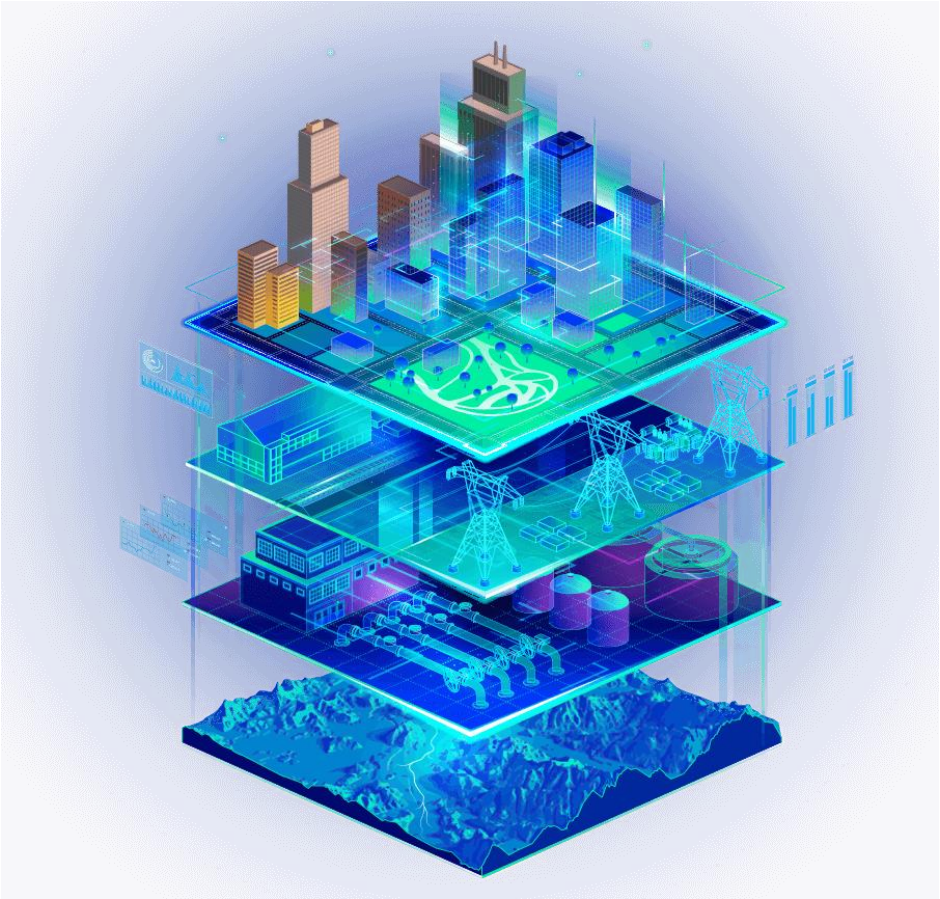


- Prefabricated modular construction reduces **construction time** and the **generation of environmental impacts** during the construction phase.
- Prefabricated modular construction has been considered an **economical construction approach**.
- Prefabricated modular construction enhances **safety on construction sites** by reducing **on-site labor** and **associated risks**.
- However, for this method to effectively achieve these outcomes, it is necessary to carefully optimise building material choice and improve **design, manufacturing, logistics, and assembly processes**.

Integrative Solutions

Advancing Data Integration in Construction

- Advanced design and fabrication techniques represent significant advancements in construction methodologies, offering efficiency, sustainability, and safety benefits.
- However, as construction projects become increasingly complex, there arises a critical need for **advanced data management** and **integrative solutions** to optimise decision-making, enhance performance, and ensure long-term sustainability.



Integrative Solutions

- A commonly utilised methodology in the construction scenario is **Building Information Modeling (BIM)**.
- It refers to a working methodology based on a digital representation and information exchange, incorporating all stakeholders and facilitating data access along the project's life cycle.
- BIM models provide crucial insights into project planning, design coordination, and clash detection, enhancing collaboration and efficiency.
- However, the current state of BIM primarily offers **static data of the built environment** and lacks compatibility with **real-time updates** and **Internet of Things (IoT) integration**.

Digital Twins in Civil Engineering

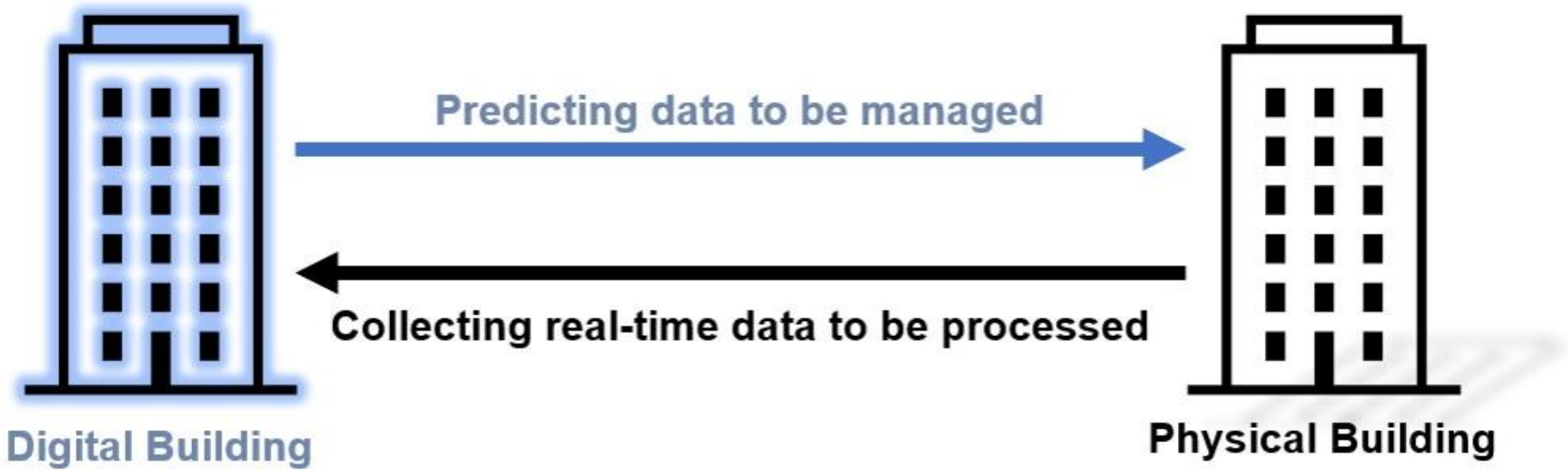
Derived from product engineering, the Digital Twin concept has swiftly expanded into diverse domains.

Recognised by the technology sector as a promising tool for enhancing efficiency and optimisation, a Digital Twin is a virtual representation of an object or a system, serving as the real-time digital counterpart of the physical asset during its lifecycle.

By dynamically integrating data and information, a Digital Twin can improve the design of new assets and the understanding of existing asset conditions.

Digital Twins in Civil Engineering

BIM-based Digital Twin



Source: Created by Karoline Figueiredo.

Benefits and Advantages

- Efficiency Improvement:
    - Real-time insights streamline decision-making and resource allocation.
    - Bottlenecks are identified and processes are optimised, reducing delays and rework.
- Cost Reduction:
    - Precise resource tracking and waste minimisation.
    - Predictive maintenance reduces downtime and avoids unforeseen breakdowns.
- Quality Enhancement:
    - Ongoing monitoring ensures compliance with design requirements.
    - Swift identification and correction of deviations lead to higher-quality deliverables.
- Collaboration Enhancement:
    - Shared platform for multidisciplinary teams fosters effective communication.
    - Streamlined collaboration leads to faster decision-making and improved project outcomes.

Challenges and Limitations

- Data Privacy and Security:
    - Ensuring privacy and security of data within the digital twin ecosystem is crucial.
- Integration Complexities:
    - Integration of various hardware, software, and data sources can be challenging and time-consuming.
- Skill Gap:
    - Knowledgeable staff with expertise in data analytics, IoT, simulation modeling, and cybersecurity is required.
- Initial Investment:
    - Initial expenditure required for sensors, IoT devices, data analytics software, and simulation models.

Digital Twins in Civil Engineering

- The aggregation of data across multiple parties and sources in BIM-based DTs presents security challenges.
- Professionals traditionally raised concerns about the absence of systematic records of inspection and operations during the fabrication stage. Utilising a digital fabrication drawing production with the synchronization of data records would enable higher transparency and better collaboration opportunities.
- Besides, using information from the factory, it is possible to develop a digital fabrication model in real-time, improving the digital building model.

Blockchain in Civil Engineering

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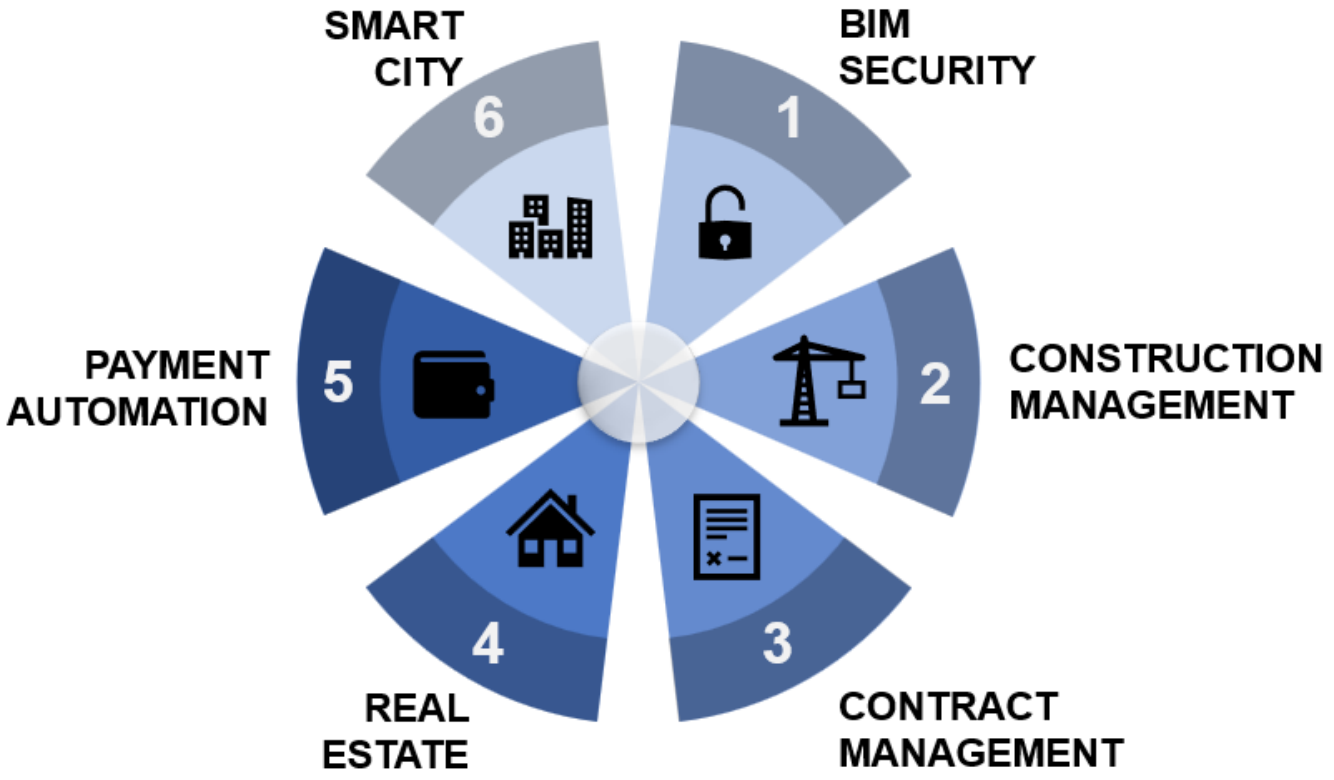
Blockchain refers to the technological infrastructure and protocols that allow the information transaction between peers in a decentralised way.

This technology consists of a digital ledger and a distributed peer-to-peer network that forms a shared database, and it differs from other information systems due to four characteristics occurring in its application:

- Decentralisation
- Security
- Auditability
- Smart Execution

Blockchain in Civil Engineering

Authors	Document Type	Source *IF: Impact Factor *CS: CiteScore	Description of the study
1 - Blockchain application for BIM Security			
(Turk and Klinc, 2017)	Journal paper	Procedia Engineering (IF: 1.880; CS: 4.0)	The authors discuss blockchain potential to address some issues found in BIM applications, such as confidentiality, change tracing, and data ownership, and use generic business solutions to manage BIM files using blockchain.
(Xue and Lu, 2020)	Journal paper	Automation in Construction (IF: 7.700; CS: 12)	The authors propose a novel semantic differential transaction (SDT) approach to integrate BIM and blockchain technologies and test this proposal into two different pilot cases, adopting modern data structures to allow the bi-directional operations between these two technologies.
(Das et al., 2021)	Journal paper	Automation in Construction (IF: 7.700; CS: 12)	The study presents a framework to facilitate secure storage and distribution of BIM and a second framework based on blockchain to record BIM changes in a tamper-proof ledger for the non-trusting environment of construction projects.
(Nawari, 2021)	Conference paper	Proceedings of the 18th International Conference on Computing in Civil and Building Engineering, Brazil	The author presents a case study for automated code compliance verification mechanisms to prove how blockchain can address some of the current BIM workflow shortcomings.
(Ye et al., 2018)	Conference paper	Proceedings of the 35th International Symposium on Automation and Robotics in Construction, Germany	The authors conduct a literature review to analyse the possible applications of BIM, the internet of things, and blockchain throughout the life cycle of a building to generate a decentralised common data environment.



Source: Figueiredo, Karoline, et al. "Assessing the usability of blockchain for sustainability: Extending key themes to the construction industry." Journal of Cleaner Production 343 (2022): 131047.

Blockchain in Civil Engineering

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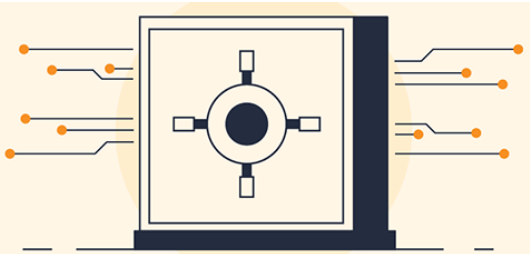
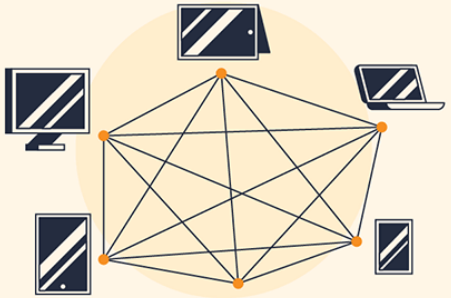
SECURE

Multilayer encryption protects data from unauthorized changes





DECENTRALIZED

Lack of a central server lessens the possibility of a system failure

SCALABLE

Interconnected architecture adapts to small and large projects

PREDICTIVE MAINTENANCE

A detailed ledger of a building's assets **simplifies long-term repair and upkeep**

24/7 COLLABORATION

With instant access to project files, **any party can give input for all to see**

PROACTIVE OVERSIGHT

Adhering to regulations is simple for third parties responsible for oversight

Source: https://www.bigrentz.com/blog/blockchain-in-construction

Blockchain in Civil Engineering

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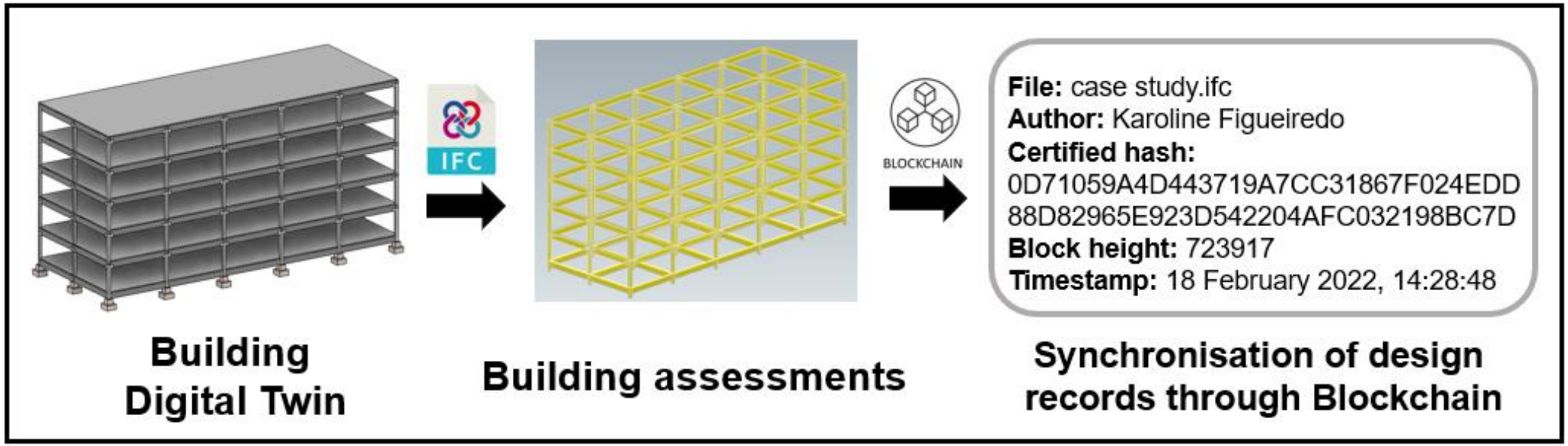
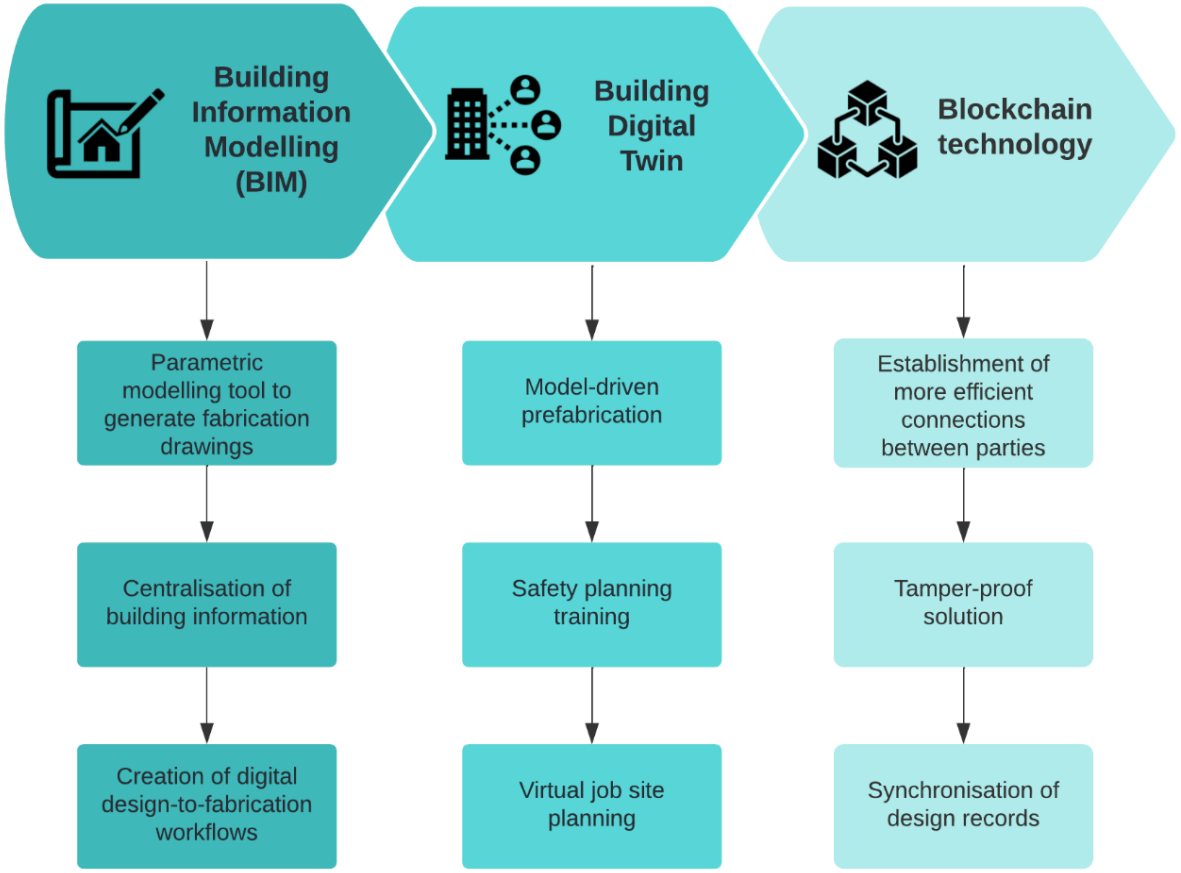
First steps to integrate Digital Twin and Blockchain



Source: Figueiredo, Karoline et al. "Improving sustainability in the built environment through a BIM-based integration of digital twin and blockchain: An analysis of prefabricated modular construction." CRC Press, 2023. 101-122.

Blockchain in Civil Engineering



Source: Figueiredo, Karoline et al. "Improving sustainability in the built environment through a BIM-based integration of digital twin and blockchain: An analysis of prefabricated modular construction." CRC Press, 2023. 101-122.

Strategic Implementation

The Shard, a prominent skyscraper in London: From Design to Maintenance

- The Shard, standing at over 300 meters tall, is an iconic skyscraper located in the heart of London. It incorporates a sophisticated digital twin system to monitor and manage various aspects of the building's operations in real-time.
- Detailed architectural designs and structural simulations were integrated into the building’s digital twin during the design phase.
- After the building was finished, the digital twin became a vital tool for tracking its performance, especially in terms of energy efficiency and structural integrity.

Strategic Implementation

Heathrow Terminal 5: Enhancing Efficiency and Collaboration

- Another effective illustration of how digital twin technology in construction simplifies challenging construction projects is Heathrow Terminal 5.
- The development of the terminal required a large number of stakeholders, complex designs, and an aggressive timeframe. The project team was able to get a complete picture of the construction progress by using a digital twin.

Conclusion

- **Integration of Digital Technologies:** Digital design tools, advanced fabrication techniques, and emerging technologies like digital twin and blockchain are revolutionising the construction industry. The seamless integration of these technologies enhances efficiency, precision, and sustainability across the construction lifecycle.

- **Empowering Innovation:** The adoption of digital technologies empowers engineers, architects, and construction professionals to innovate and push the boundaries of what is possible in civil engineering. From conceptualisation to fabrication and beyond, these tools provide the foundation for innovative solutions and transformative projects.

- **Collaborative Future:** Digital tools facilitate seamless communication and collaboration among multidisciplinary teams, fostering creativity, problem-solving, and collective achievement.

Conclusion

- **Sustainable Progress:** By harnessing the power of digital design tools, advanced fabrication techniques, and emerging technologies, it is possible to shape a sustainable future. From reducing environmental impacts to enhancing safety and quality, these collective efforts are driving positive change and leaving a legacy for generations to come.

- **Continued Progress:** The construction industry is continually evolving, driven by technological advancements, changing needs, and global challenges. By staying informed, adaptable, and forward-thinking, we can navigate the dynamic landscape of construction with confidence and purpose.

- **Call to Action:** Whether you're an industry veteran or a student, there's always room to learn, innovate, and contribute to the collective advancement of our field.

Conclusion

Conclusion

What courses cover this topic?

- *Graduate Certificate in Civil Engineering: Structural*
- *Online – Bachelor of Science (Civil & Structural Engineering)*
- *On-Campus – Bachelor of Science (Civil & Structural Engineering)*
- *Online – Master of Engineering (Civil: Structural)*
- *On-Campus – Master of Engineering (Civil: Structural)*
- *Graduate Certificate in Civil Engineering (Structural Analysis and Design)*

Upcoming Courses

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We have a range of courses in Civil Engineering.

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Graduate Diploma of Engineering (Civil: Structural)	24 June 2024
Graduate Certificate in Civil Engineering: Structural	24 June 2024
Online – Master of Engineering (Civil: Structural)	24 June 2024
52873WA Advanced Diploma of Civil and Structural Engineering	2 July 2024
Undergraduate Certificate in Engineering Foundations	22 July 2024
Undergraduate Certificate in Civil Engineering	22 July 2024
Online – Bachelor of Science (Civil & Structural Engineering)	22 July 2024
Doctor of Engineering	22 July 2024
52896WA Advanced Diploma of Civil and Structural Engineering (Materials Testing)	3 September 2024
Professional Certificate of Competency in Structural Design for Non-Structural Engineers	1 October 2024

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Q&A

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